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Evaluation of the Mechanical Properties and Color Stainability of Different Pressed Lithium-X-Silicate Ceramics

Preslenen Farklı Lityum-X-Silikat Seramiklerin Mekanik Özelliklerinin ve Renk Değişikliklerinin İncelenmesi

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ABSTRACT

Lithium-X-silicate glass ceramics are widely used in prosthetic dentistry for their esthetic and mechanical properties, yet surface treatments during clinical procedures may alter these characteristics and affect restoration longevity. This study evaluated the effects of different surface treatments on the optical (color stability) and mechanical (flexural strength and surface hardness) properties of three pressed lithium-X-silicate ceramics: IPS e.max Press, Celtra Press, and HS10PC. A total of 132 specimens were prepared (22 bars and 22 discs per material) and divided into glazed and ground–polished subgroups (n=11). Color was measured with a spectrophotometer before and after 14-day coffee immersion, and color change (ΔE2000) was calculated. Vickers hardness and flexural strength were assessed, and surface morphology was examined with SEM. The results showed that surface treatment significantly affected color change and hardness ($p<0.05$), whereas ceramic type had no effect on these parameters. Flexural strength was significantly influenced by ceramic type ($p<0.001$) but not by surface treatment, with IPS e.max Press showing relatively higher strength compared with the other ceramics. SEM observations revealed smoother surfaces in glazed specimens. In summary, surface treatments improve superficial properties such as color stability and surface hardness, while ceramic type plays a greater role in determining flexural strength. These findings highlight the importance of considering both material selection and surface finishing in restorative planning to support the esthetic quality and durability of lithium-silicate restorations.

Keywords: Color Stability, Lithium Silicate, Mechanical Properties.

ÖZ

Lityum-X-silikat cam seramikler, estetik ve mekanik özellikleri nedeniyle protetik diş hekimliğinde yaygın olarak kullanılmaktadır; ancak klinik işlemler sırasında uygulanan yüzey işlemleri bu özellikleri değiştirebilir ve restorasyonların ömrünü etkileyebilir. Bu çalışmada, üç farklı preslenmiş lityum-X-silikat seramiğin (IPS e.max Press, Celtra Press ve HS10PC) optik (renk stabilitesi) ve mekanik (eğme dayanımı ve yüzey sertliği) özellikleri üzerine farklı yüzey işlemlerinin etkileri araştırılmıştır. Toplam 132 örnek hazırlanmış (her biri için 22 çubuk ve 22 disk) ve tüm gruplara glaze uygulandıktan sonra örneklerin yarısı aşındırılmış ve sonrasında polisaj uygulanmış, diğer gruba ise ek bir işlem uygulanmamıştır. (n=11) Renk, 14 günlük kahvede bekletme öncesi ve sonrası spektrofotometre ile ölçülmüş ve renk değişimi (ΔE2000) hesaplanmıştır. Vickers sertliği ve eğilme dayanımı test edilmiş, yüzey morfolojisi SEM ile incelenmiştir. Bulgular, yüzey işlemlerinin renk değişimi ve yüzey sertliği üzerinde anlamlı bir etkisi olduğunu ($p<0.05$), ancak seramik tipinin bu parametreler üzerinde etkili olmadığını göstermiştir. Buna karşılık, eğilme dayanımı seramik tipine bağlı olarak anlamlı farklılık göstermiştir ($p<0.001$), ancak yüzey işleminden etkilenmemiştir; IPS e.max Press diğer seramiklere kıyasla görece daha yüksek eğme dayanım sergilemiştir. SEM incelemelerinde glaze uygulanmış örneklerde daha pürüzsüz yüzeyler gözlenmiştir. Sonuç olarak, yüzey işlemleri renk stabilitesi ve sertlik gibi özellikleri geliştirirken, seramik tipi eğme dayanımı etkilemiştir. Bulgular, restoratif planlamada hem materyal seçiminin hem de yüzey bitiminin göz önünde bulundurulmasının estetik kalite ve dayanıklılığın sağlanması açısından önem taşıdığını göstermektedir.

Anahtar Kelimeler: Renk Stabilitesi, Lityum Silikat, Mekanik Özellikler,

Highlights

*Surface finishing was found to improve optical stability.
*Glazed specimens were found to present smoother and harder surfaces.
*Flexural strength was found to vary according to ceramic type.
*IPS e.max Press was found to show relatively higher strength values.

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INTRODUCTION

Over time, there has been an increased interest in all-ceramic restorations due to improved socioeconomic status and the growing importance of aesthetics. All-ceramic restorations offer favorable optical and mechanical properties, as well as biocompatibility, which helps meet the expectations of most patients(1). Among the various all-ceramic options available today, lithium-X-silicate ceramics—encompassing different lithium silicate–based crystalline phases—have gained popularity. Lithium-X-silicate ceramics comprise a group of materials that include lithium silicate, lithium disilicate, lithium metasilicate, lithium orthophosphate, and lithium aluminosilicate(2).These ceramics exhibit a microstructure composed of lithium-X-silicate crystals embedded in a glassy matrix containing SiO_2, K_2O, MgO, Al_2O_3, P_2O_5 and other oxides. The presence of this unique crystalline phase in lithium-X-silicate ceramics results in natural light reflection on the ceramic surface, enhancing their esthetic properties(3). Additionally, the interpenetrating structure found in glass ceramics enhances the mechanical properties of these ceramics(4). Technological advancements in the manufacturing process have contributed to a reduction in complications such as chipping and fracture(5). Today, studies on the development of glass ceramics continue and new products are being launched on the market. Pressable glass ceramics have many advantages, including ease of fabrication (lost wax technique), optimal optical properties, improved mechanical properties, and reduced porosity(5). Indeed, the manufacturing process of pressed ceramics, which involves the use of the lost wax technique, offers advantages in terms of occlusal accuracy and marginal adaptability(6,7).

In the final session of prosthetic treatment or after cementation, when occlusal or marginal adjustments are necessary, clinical grinding of the materials may be required. After grinding, glazing or polishing procedures are necessary to prevent surface roughness, avoid porosities, and maintain color stability(8,9). Although there are studies on various surface treatments applied to glass-ceramics, conditions commonly encountered chairside, such as polishing following grinding, have not been thoroughly investigated. Flexural strength (FS) refers to the material's ability to resist bending without fracturing, which is essential for dental restorations as it ensures they can endure the forces exerted during chewing(10,11). Another significant mechanical property is surface hardness (VH), which indicates the material's resistance to permanent surface indentations or penetrations(12–14). Surface treatments contribute to increasing the wear resistance of ceramics and reducing abrasion on the opposing tooth. Additionally, glazing and polishing procedures are necessary to improve the FS(15). The surface roughness that occurs after occlusal adjustment affects the long-term success of the restoration(16).

Although glass ceramics are frequently used in modern dentistry, a comprehensive analysis of the properties of pressable lithium-X-silicate ceramics reinforced with different molecules is lacking in the literature. The purpose of this study is to comparatively evaluate the FS, VH and color stainability of three different lithium-X-silicate ceramics subjected to glazing (GL), and to glazing followed by grinding and polishing (GP) to simulate possible clinical adjustments after glazing. The null hypothesis of this study is that material type and surface treatment will not have a significant effect on the FS, VH, and color stainability of lithium-X-silicate ceramic materials.

MATERIALS AND METHODS

Ethical approval for this study was obtained from the Ataturk university Dentistry Faculty ethics committee No.94 (02.12.2022). The materials used and the

production of the samples in this study were supported by a Ataturk University scientific research project grant (Project No. TDH-2021-9708).

In this study, three different lithium-X-silicate reinforced pressable glass ceramics were utilized: HS10PC (Estetic Ceram Ag, Liechtenstein), IPS e.max Press (Ivoclar Vivadent, Schaan, Liechtenstein), and Celtra Press (Dentsply Sirona, Hanau, Germany). Initially, all specimens were subjected to a glazing procedure. Thereafter, while half of the specimens retained their glazed surfaces, the remaining half underwent surface grinding followed by a polishing protocol designed to simulate common clinical adjustments, such as occlusal or proximal corrections, performed after restoration delivery.(8) This resulted in a total of six subgroups: IPS e.max Press glaze (IEG), IPS e.max Press polishing (IEP), Celtra Press glaze (CG), Celtra Press polishing (CP), HS10PC glaze (HSG), and HS10PC polishing (HSP). The composition of the ceramics used in the study is presented in Table 1.

Table 1. The Descriptions and Composition of the Materials Used in the Study (2,24)

Press Ceramic	Lithium-X-silicate ceramic	Composition	wt%
IPS e.max Press	Lithium Disilicate Ceramic	SiO_2	57-80%
		Li_2O	11-19%
		K_2O	0-13%
		P_2O_5	0-11%
		ZrO_2	0-8%
		ZnO	0-8%
		Other oxides and pigments	0-10%
Celtra Press	Lithium Silicate Ceramic	SiO_2	59,3%
		Al_2O_3	3%
		Li_2O	14,5%
		K_2O	1,2%
		Na_2O	0,2%
		P_2O_5	4,9%
		B_2O_3	2%
		MgO	0,01%
		ZrO_2	9,3%
		SrO	0,0003%
		CeO_2	0,83%
		V_2O_5	0,61%
		Tb_20_3	3,3%
		Er_2O_3	0,73%
		HfO_2	0,21%
+HS10PC	Lithium Disilicate Ceramic	SiO_2	65-80%
		Al_2O_3	0-11%
		Li_2O	11-19%
		K_2O	0-7%
		Na_2O	0-5%
		CaO	0-10%
		P_2O_5	1,5-7%
		ZnO	0-7%
		Other oxides and pigments	0-15%

From each ceramic group, 22 bar-shaped (18 × 3 × 3 mm) and 22 disc-shaped (10 × 1.2 ± 0.02 mm) samples (ISO 6872:2015) were obtained. (17)

The sample dimensions were verified by measuring with a digital caliper. The samples were prepared using the lost wax method, following the manufacturer's instructions. CAD/CAM wax blanks (Bilkim Medical) were milled into fully flammable templates using a CAD/CAM milling machine (VHF K5 scraper, Çatak Dent. Lab.). The milled wax samples were threaded, with three samples placed in each cuff.

The investment material (SheraFina2000/Sheraliquid; Werkstoff Technologie, Lemförde, Germany) was prepared and poured into the cuffs according

to the manufacturer's instructions. The samples were allowed to harden and were preheated in a furnace (Mikrotek Dental) at 940°C for 10 minutes. After removing the wax, the specimens were pressed in a ceramic press furnace (Programat EP 5000, Ivoclar Vivadent AG, Schaan, Liechtenstein) following the manufacturers' instructions (Table 2).

Table 2. Press Parameters for Lithium-X-Ceramics Depending on the Pressing Furnace

	Initial Temperature (°C)	Heating Rate (°C/Min)	Final Temperature (°C)	Holding Time (Min)	Pressure (Mpa)
IPS e.max Press	700	60	920	15	0,5
Celtra Press	700	40	860	30	0,5
HS10PC	700	60	910	20	0,5

After cooling down to room temperature, all specimens were cleaned by air-particle abrasion (sandmaster FG3-92, Sandmaster, Zofingen, Switzerland) using 125 µm/0.4 MPa and 50 µm/0.2 MPa alumina powder (Orbis Dental, Orbis Dental Handelsgesellschaft, Münster, Germany). The samples were then polished with P4000 grit, silicon carbide grinding paper using a water-cooled polishing machine at 150 rpm (Abramin, Struers, Ballerup, Denmark).

Once the samples were ready for the glazing process, glaze powder and liquid were mixed according to the manufacturer's instructions, and a homogeneous and creamy paste was obtained. The mixture was applied homogeneously to the ceramic surface in a thin layer by the same person with a brush. IPS Ivoclar Glaze (Ivoclar Vivadent AG, Shaan, Liechtenstein) was used for glazing IPS e.max Press, High Flu (Dentsply Sirona, Bensheim, Germany) for glazing Celtra Press, and Glaze LFU (Estetic Ceram Ag, Liechtenstein) for glazing HS10PC. The samples were then fired in a porcelain furnace (Programat P300, Ivoclar Vivadent AG, Shaan, Liechtenstein) using the glaze firing cycle specified in Table 3.

Table 3. Glaze Firing Parameters For Tested Glass-Ceramics

	Predrying Temperature (^{O}C)	Time (Minutes)	Heating Rate (^{O}C/Min)	Firing Temperature (C^{o})	Holding Time (Minute)
IPS e.max Press	403	6	60	710	1
Celtra Press	400	2	55	750	2
HS10PC	400	4	45	710	1

Glaze firing was applied to one surface of all the samples.

Half of the samples from each group were randomly selected and treated with an 11.5x3 inverted conical grinding stone DIASYNT® PLUS RA (EVE Diapro, EVA Ernst Vetter GmbH, Pforzheim, Germany) containing diamond particles. Grinding was performed by a single researcher at 10,000 rpm for 20 s under water cooling. The ground samples were washed with distilled water and dried. After this process, mechanical polishing was applied. A 2-stage mechanical polishing was applied to the samples whose glaze layer was removed by grinding with DIASYNT® PLUS RA. Mechanical polishing was performed with Eve Technik Diapro RA 361 (EVA Ernst Vetter GmbH, Pforzheim, Germany) polishing kit on the samples fixed with double-sided tape on a surface under constant load (2±0.25 kg). The ceramic surfaces were initially pre-polished with a 6x7.5 mm medium-grain cone-shaped polisher at 10,000 rpm for 1 minute, following the manufacturer's instructions. Subsequently, a 6x7.5 mm fine-grain cone-shaped polisher was used to complete the polishing process. The samples were rinsed with distilled water for 30 seconds and then air-dried for 10 seconds using an oil-free air syringe from a distance of approximately 10 cm.

To maintain standardization, color measurements were conducted by the same investigator, at the same time of day, in a consistent environment. A digital spectrophotometer (Vita Easyshade V, Vita Zahnfabrik, Germany) was used for the color measurements, with a gray background employed for accuracy (18).

In the study, all samples were stored in a solution using a Binder ED 23 Etuv Classic. Before storage,the untreated (intaglio) surfaces of the samples were coated with nail polish (Flormar, Groupe Rocher, France) prior to storage. This application served two purposes: to protect the identification numbers marked on these surfaces from being erased during immersion in the staining solution, and to simulate the clinical scenario in which the internal surface of a restoration is not exposed to oral pigments after cementation, thereby preventing unwanted color absorption. Bar-shaped samples were stored in distilled water at 37°C for 2 days, while disc-shaped samples were stored in a coffee solution made from Jacobs Monarch Gold (Czech Republic) at 37°C for 14 days. The coffee solution was prepared according to the manufacturer's instructions, dissolving 2 g of 100% soluble coffee in 200 ml of water at 96°C. The coffee solution was renewed daily by the same investigator (19,20). After the storage period, the nail polish was removed from the surfaces. The samples stored in the coffee solution were brushed circumferentially ten times under running water using a toothbrush from Difaş (Turkey) coated with Sensodyn toothpaste (GSK, UK)(21,22). Following brushing, the samples were dried with a napkin.

To ensure standardization, color measurements were conducted by the same investigator, at the same time of day, in a same environment. A digital spectrophotometer (Vita Easyshade V, Vita Zahnfabrik, Germany) was used for the color measurements. In this study, the color differences in the samples, measured using the gray background, were calculated using the CIEDE 2000 color change formula. The following formula was utilized to calculate the color change:

$$\Delta E00=[(\Delta L'/(kLSL))2+(\Delta C'/(kCSC))2+(\Delta H'/(kHSH))2+RT(\Delta C'/(kCSC))(\Delta H'/(kHSH))]$$

ΔL': lightnessdifference,ΔC': chroma difference,ΔH': hue difference, S_L, S_C, S_H: weighting functions for lightness, chroma, and hue, respectively, K_L, K_C, K_H: parametric correction factors (typically set to 1), RT: rotation term accounting for the interaction between chroma and hue differences

The 18x3x3 bar-shaped samples, which were stored in distilled water for 2 days, underwent a uniaxial 3-point flexural test to determine their FS. The flexural strength test was conducted following the ISO 6872:2015(17) standards. A universal testing machine (Instron 5566A; Instron Co, Norwood, Massachusetts) was used for the 3-point flexural test. For the test, each sample was positioned on a metal fixture with treated surfaces facing upwards, and the supports were set at a distance of 15 mm, with the sample centered under the loading bar. The test was carried out at a speed of 1 mm/min, controlled by software (BlueHill 3; Instron Co). The flexural strength (σf) was calculated according to the formula specified in the ISO 6872:2015(17) standards.

$$\delta_f = \frac{3Fl}{2wh2}$$

f: Fracture resistance (Newton), l: span distance (mm), w: sample width (mm), h: sample height (mm)

Vickers hardness tests were conducted on the treated surface of the disc-shaped specimens. The Vickers hardness measurements were performed using a light microscope (FM-800e, Future Tech, Japan). Each sample was placed on the table of the light microscope, and the area where the Vickers tip would be applied was determined at a magnification of x40. The force applied by the Vickers hardness tester was set to 1000 gf, which is equivalent to 9.8 Newtons. The penetration time of the Vickers tip was marked as 20 seconds on the microscope. Measurements were carried out by applying a pyramid-shaped Vickers diamond tip with a 135° apex angle and a load of 9.8 N for 20 seconds. The length of the diagonals of the impression created by the Vickers tip was observed at a magnification of x40 and measured by placing horizontal lines on the

screen at the two ends of the diagonals. Surface hardness values were automatically calculated by the instrument using the length data of the diagonals.

For qualitative surface analysis of the samples, was performed with scanning electron microscopy (SEM) (Zeiss Sigma 300VP, Austria). The SEM examination parameters were as follows; 10 kV acceleration voltage, 10 mm sample detector distance. Micrograps were recorded at 20000 x magnification.

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) for Windows version 23.0 (IBM SPSS Inc., Chicago, IL). The normal distribution of the variables was assessed through visual tests (histogram and probability plots) as well as the Shapiro-Wilk test. The Kruskal-Wallis test was employed for independent numerical variables with more than two groups, while the Mann-Whitney U test was used for independent numerical variables between two groups. Following the Kruskal-Wallis test, pairwise comparisons within groups were conducted using the Bonferroni-adjusted post hoc analysis. Statistical significance was considered as $p < 0.05$.

RESULTS

The Shapiro-Wilk test revealed that the variables of FS, VH, and color change did not follow a normal distribution, indicating a non-parametric data structure. Descriptive statistics were therefore presented as median values, minimum–maximum values, frequencies, and percentages. The median values of FS, VH and color change (ΔE_{00}) for each group are shown in Table 4, while additional descriptive analyses are presented in Tables 5 and 6.

Table 4. FS, VH and ΔE_{00} Median Values of the Groups

	IEG	IEP	CPG	CPP	HSG	HSP
FS (MPa)	265,58	287,25	245,16	221,25	219,75	206,30
VH (N/mm²)	4113	4346	4217	5200	4461	4190
ΔE_{00}	0,46	0,80	0,51	1,30	0,93	1,5

(VH values were expressed as N/mm² according to calculations based on the applied load in Newtons.)

Table 5. Descriptive Statistics of FS, VH and ΔE_{00} Based on Surface Treatment

	Glaze	Grinding+polishing
FS (MPa)	245,8[a]	235[a]
VH (N/mm²)	4217[a]	4346[b]
ΔE_{00}	0,53[a]	1,22[b]

Values with different superscript letters within the same row indicate statistically significant differences ($p < 0.05$, Mann–Whitney U test).

Table 6. Descriptive Statistics of FS, VH and ΔE_{00} Based on Material Type

	IPS emax Press	Celtra Press	HS10PC
FS (MPa)	285,20[a]	232,41[b]	216,25[b]
VH(N/mm²)	4304[a]	4496[b]	4203[a]
ΔE_{00}	0,62[a]	0,69[a]	1,08[a]

Values with different superscript letters within the same row indicate statistically significant differences ($p < 0.05$).

A statistically significant difference was observed among the groups in terms of FS, VH and color change ($p < 0.001$). The highest median ΔE_{00} value was observed in the CP group (ΔE_{00} = 1.30), while the lowest was recorded in the IEG group (ΔE_{00} = 0.46). The color change was minimal in the GL group (ΔE_{00} = 0.53), whereas the GP group exhibited a significantly higher value (ΔE_{00} = 1.22), which was statistically significant ($p < 0.001$).

In terms of FS, the highest median value was recorded in the IEP group, whereas the

lowest was found in the HSP group. Material type significantly affected flexural strength. Following the Kruskal-Wallis test, pairwise comparisons were conducted using the Bonferroni-adjusted post hoc test ($p < 0.017$, Kruskal-Wallis with Bonferroni correction; significance level adjusted from 0.05/3). IPS e.max Press showed significantly higher FS than both Celtra Press and HS10PC ($p < 0.001$), whereas no significant difference was found between Celtra Press and HS10PC ($p > 0.017$). The applied surface treatments did not significantly affect FS ($p > 0.05$).

Regarding VH, the highest median value was observed in the CP group. VH was significantly higher in the GP group compared to the GL group ($p < 0.05$). However, material type did not have a statistically significant effect on VH ($p > 0.05$).

Fig 1 presents SEM images of the surfaces of the ceramics, revealing that the surface topography of the glazed surfaces appeared to be more regular compared to the polished surfaces. Additionally, it was observed that the surface of CG exhibited more indentations and protrusions compared to the other groups. For all the groups, the biggest gaps were observed in the surface of HSP. IEG and HSG exhibited a smooth homogeneous surfaces.

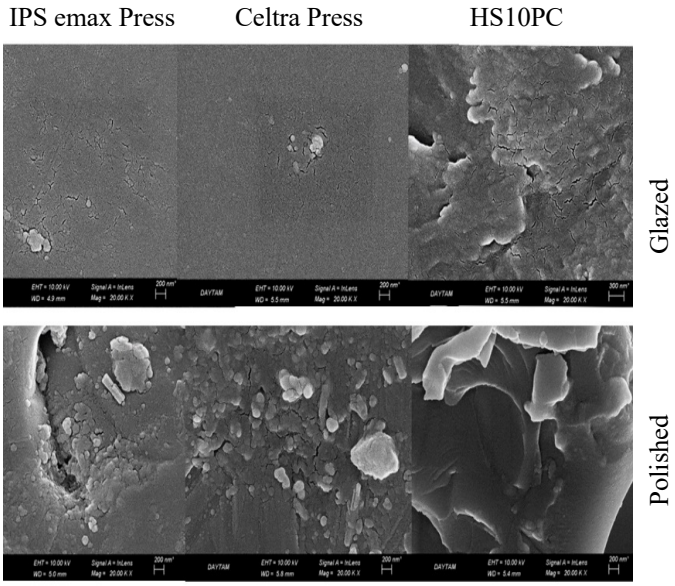

Figure 1. SEM images (×20,000 10 kV, 10 mm working distance)

The SEM findings supported the quantitative results of the present study. Smoother and more homogeneous surfaces observed in glazed groups may explain their lower ΔE_{00} values, whereas the irregularities and gaps detected in polished groups may have increased susceptibility to discoloration. In addition, removal of the glaze layer may have contributed to the tendency toward higher VH values in polished specimens.

DISCUSSION

The present study investigated the mechanical properties and color stainability of three different lithium-X-silicate ceramics: IPS e.max Press, Celtra Press, and HS10PC. The null hypothesis, which proposed that material type and surface treatment would not significantly affect color stainability, FS and VH was rejected.The selection of materials and methods for this study was driven by a gap identified in the existing literature, particularly regarding the limited research on the color properties of Celtra Press and HS10PC ceramics. Mayinger et al. emphasized the need for further investigation into the optical properties of HS10PC for a more comprehensive evaluation of this material (24). These ceramics are widely used in clinical practice, and with the continuous

introduction of new products to the market, there is a growing need for comparative studies that assess both the mechanical and aesthetic properties of lithium-X-silicate ceramics.

Since the first glass-ceramics were introduced in 1984, ongoing efforts to enhance their strength through chemical composition modifications and optimization of the production process have persisted. In this context, lithium-X-silicate ceramics, classified as synthetic ceramics under the glass-matrix category according to Gracis' updated ceramic classification(25), represent a significant advancement in glass-ceramic materials.

The optical properties of dental restorations are critical in determining patient satisfaction and the overall success of treatment. Paravina et al.(26) reported perceptibility and acceptability thresholds of 0.8 and 1.8 units, respectively, based on the CIEDE2000 color change formula, which were adopted as the criteria for perceptibility and acceptability in this study. In the present study, the ΔE_{00} value in the GL group was below the perceptible threshold, while the GP group exceeded the perceptible level but remained within an acceptable range. These findings align with prior research indicating that also observed the effect of surface treatments on color changes(27,28). Similar results have been reported in studies involving CAD/CAM materials, further supporting this effect(29). Several researchers have noted that glazing has been shown to result in less discoloration compared to polishing, likely due to the smoother surface it produces(30–33). The similar results observed in our study and in similar studies can be attributed to the smoother surfaces and higher light reflectivity provided by glazing, while polishing or the removal of the glaze layer tends to create rougher surfaces, which contribute to greater discoloration. It has been widely reported that glazing results in smoother surfaces compared to other finishing techniques, which may help explain the reduced color change observed with GL group (29,31). The SEM images of the GL groups in our study revealed less porosity, which may be correlated with reduced color change. In contrast to our study, Alp et al.(34), in their investigation involving both lithium silicate (LS) and lithium disilicate (LS_2) ceramics, reported that glazing led to greater color changes, particularly in LS_2 materials. Therefore, they suggested that glazing should be avoided in the case of LS_2 ceramics. Conversely, the findings of our study indicate that glazing is beneficial for both LS and LS_2 ceramics in terms of enhancing color stability.

In the context of prosthetic dentistry, FS is a critical indicator of the mechanical performance of lithium-X-silicate ceramics, which are frequently used in clinical practice. This parameter, which reflects a material's resistance to stress before fracture, plays a critical role in interpreting the findings of the present study (35). The observed differences in flexural strength among the tested ceramics may be attributed to variations in their compositional and microstructural characteristics. It has been shown in the literature that there is a linear correlation between three-point and four-point flexural tests, with the three-point flexural test being both repeatable and reliable(36). In our study, the three-point flexural test was used to assess the FS of the ceramics. In the present study, IPS e.max Press exhibited higher FS compared to Celtra Press and HS10PC, with no significant difference observed between the latter two. Previous studies have suggested that crystalline-reinforced glass-ceramics generally show enhanced FS due to the presence of the crystalline phase(34,37,38). Additionally, the role of crystal size in enhancing mechanical properties has been highlighted in the literature, with larger crystals often associated with improved FS and overall mechanical performance (39,40). IPS e.max Press is characterized by a high volume fraction of elongated lithium disilicate crystals embedded within a glassy matrix, forming an interlocking microstructure that enhances resistance to crack initiation and propagation. These needle-like lithium disilicate crystals promote crack deflection, crack bridging, and crack branching mechanisms, which effectively dissipate

applied stresses and delay catastrophic fracture under flexural loading. In this context, the smaller crystal size of Celtra Press, compared to other lithium disilicate ceramics like IPS e.max Press, may explain the observed difference in flexural strength in our study. The present finding corroborates the results of Alghazzawi et al.(41) and Mayinger et al.(42), both of whom reported superior FS of IPS e.max Press compared to other lithium-X-silicate based ceramics. In contrast, a separate study found no significant difference between IPS e.max Press and Celtra Press(2), which may be attributed to variations in surface conditioning protocols and pressing parameters known to influence mechanical properties.

VH is an essential mechanical property that reflects a material's resistance to indentation and penetration, which directly impacts the long-term performance of dental restorations(13,14). Among the various microhardness tests used in dentistry, the Knoop and Vickers tests are most commonly employed, with the Vickers test being the preferred method in dental material studies due to its greater precision and broader applicability(43). In this study, VH was evaluated using the Vickers hardness test. A trend toward higher VH values was observed in the GP group compared to the GL group; however, no statistically significant differences were detected among the different ceramic materials. This finding suggests that surface treatment techniques, rather than material composition alone, may be more influential in determining the VH of dental ceramics under functional conditions. A similar outcome was observed in a previous study(41), where comparable materials were used. In contrast, another investigation identified Celtra Press as exhibiting the highest VH among lithium-X-silicate ceramics. The discrepancies between these findings could be attributed to variations in surface treatment methodologies and differences in pressing furnace parameters. Consistent with our findings, other research(44,45) also reported that polished ceramic groups exhibited significantly higher surface hardness compared to their glazed counterparts.The influence of glaze and polishing processes on surface hardness has been widely discussed in the literature (45). This effect may be linked to the dissolution of silica molecules (Si-O-Si) by H_3O+ and OH- ions and H_2O molecules, which can cause the loss of elements like Si, Al, Na, K, and Zr from the surface(46,47). Glazing has been associated with decreased surface hardness, which may reduce wear on opposing teeth(48,49).

This comprehensive study, which evaluates the mechanical properties and color changes of recently introduced ceramics, provides valuable insights for their clinical application. However, certain limitations must be acknowledged. The mechanical tests were conducted on samples prepared in standardized geometric shapes, which may not accurately reflect the natural morphology of teeth. In addition, all specimens were initially glazed, and one group subsequently underwent glaze removal followed by polishing. Although this sequential protocol was intentionally selected to simulate routine clinical practice, it may partially limit the direct comparability of isolated surface treatment effects. Additionally, color measurements were performed in vitro, and color alterations in restorations may differ when natural tissues are present in the oral environment. In addition, although appropriate non-parametric statistical methods were applied according to the data distribution, effect size measures were not reported. Therefore, the magnitude and clinical relevance of the observed differences should be interpreted with caution. Furthermore, the polishing kits utilized in clinical practice may exert varying effects on both the mechanical properties and color stainability of the materials. The study utilized a coffee solution as a coloring agent, and the effects of coffee on color change were assessed. Future investigations could benefit from exploring the impact of different coloring agents on the color change of dental materials. Therefore, in vivo studies conducted under clinical conditions, alongside more extensive experiments, are recommended for further exploration.

CONCLUSION AND RECOMMENDATIONS

This study provides a comparative evaluation of three lithium-X-silicate ceramics—IPS e.max Press, Celtra Press, and HS10PC—in terms of FS, VH, and color stability following different surface treatments. IPS e.max Press demonstrated significantly higher FS, indicating its potential for use in high-load bearing restorations within fixed prosthodontics. Although no significant differences in VH and color change were observed among the materials, surface treatment had a notable influence. Polishing after glazing increased VH but also resulted in greater color change, emphasizing the need to balance mechanical durability with esthetic outcomes during clinical adjustments. These findings underline the importance of both material selection and surface treatment protocol in optimizing the performance and longevity of all-ceramic restorations in prosthodontic applications. The results support evidence-based clinical decision-making in fixed prosthodontics.

Author Contributions

B.B.S: Conceptualization, methodology, data collection, formal analysis, investigation, writing – original draft, visualization, review & editing. E.K.: Conceptualization, supervision, methodology

All authors read and approved the final version of the manuscript.

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Conflict of Interest Statement

The authors declare no competing interests

REFERENCES

1. Tang X, Tang C, Su H, Luo H, Nakamura T, Yatani H. The effects of repeated heat-pressing on the mechanical properties and microstructure of IPS e. max Press. Journal of the Mechanical Behavior of Biomedical Materials. 2014;40:390-6.
2. Stawarczyk B, Dinse L, Eichberger M, Jungbauer R, Liebermann A. Flexural strength, fracture toughness, three-body wear, and Martens parameters of pressable lithium-X-silicate ceramics. Dental Materials. 2020;36(3):420-30.
3. Ozturk O, Uludag B, Usumez A, Sahin V, Celik G. The effect of ceramic thickness and number of firings on the color of two all-ceramic systems. The Journal of Prosthetic Dentistry. 2008;100(2):99-106.
4. Hallmann L, Ulmer P, Gerngross MD, Jetter J, Mintrone M, Lehmann F, vd. Properties of hot-pressed lithium silicate glass-ceramics. Dental Materials. 2019;35(5):713-29.
5. Fabbri G, Zarone F, Dellificorelli G, Cannistraro G, De Lorenzi M, Mosca A, vd. Clinical evaluation of 860 anterior and posterior lithium disilicate restorations: retrospective study with a mean follow-up of 3 years and a maximum observational period of 6 years. International Journal of Periodontics & Restorative Dentistry. 2014;34(2).
6. Gorman CM, McDevitt WE, Hill RG. Comparison of two heat-pressed all-ceramic dental materials. Dental materials. 2000;16(6):389-95.
7. Fahmy NZ, Salah E. An in vitro assessment of a ceramic-pressed-to-metal system as an alternative to conventional metal ceramic systems. J Prosthodont. 2011;20(8):621-7.
8. Asai T, Kazama R, Fukushima M, Okiji T. Effect of overglazed and polished surface finishes on the compressive fracture strength of machinable ceramic materials. Dental materials journal. 2010;29(6):661-7.
9. Motro PFK, Kursoglu P, Kazazoglu E. Effects of different surface treatments on stainability of ceramics. The Journal of prosthetic dentistry. 2012;108(4):231-7.
10. Saini RS, Gurumurthy V, Quadri SA, Bavabeedu SS, Abdelaziz KM, Okshah A, vd. The flexural strength of 3D-printed provisional restorations fabricated with different resins: a systematic review and meta-analysis. BMC Oral Health. 10 Ocak 2024;24(1):66.
11. Ilie N, Hilton TJ, Heintze SD, Hickel R, Watts DC, Silikas N, vd. Academy of dental materials guidance—Resin composites: Part I—Mechanical properties. Dental materials. 2017;33(8):880-94.
12. Kang SH, Chang J, Son HH. Flexural strength and microstructure of two lithium disilicate glass ceramics for CAD/CAM restoration in the dental clinic. Restorative Dentistry & Endodontics. 2013;38(3):134-40.
13. Mohsen C. Corrosion effect on the flexural strength & micro-hardness of ips e-max ceramics. Open Journal of Stomatology. 2011;1(2):29-35.
14. Quinn JB, Sundar V, Lloyd IK. Influence of microstructure and chemistry on the fracture toughness of dental ceramics. Dental Materials. 2003;19(7):603-11.
15. Silva A, Soares E, Abuna G, Vitti R, Sinhoreti M. Finishing and Polishing Procedures and Glaze Application on Physical Properties of a Fine-Structure Feldspathic Ceramic. Eur J Prosthodont Restor Dent. 2023;31(3):248-53.
16. Nakamura Y, Hojo S, Sato H. The effect of surface roughness on the Weibull distribution of porcelain strength. Dental materials journal. 2010;29(1):30-4.
17. 14:00-17:00. ISO. [a.yer 12 October 2022]. ISO 6872:2015. https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/05/99/59936.html

18. CIE. Commission Internationale de l'Éclairage, Colorimetry. Bureau Central de la CIE Vienna, Austria; 1976.

19. Guler AU, Kurt S, Kulunk T. Effects of various finishing procedures on the staining of provisional restorative materials. The Journal of Prosthetic Dentistry. 2005;93(5):453-8.

20. Sarikaya I, Güler AU. Effects of different surface treatments on the color stability of various dental porcelains. Journal of Dental Sciences. 2011;6(2):65-71.

21. Arif R, Yilmaz B, Johnston WM. In vitro color stainability and relative translucency of CAD-CAM restorative materials used for laminate veneers and complete crowns. The Journal of Prosthetic Dentistry. 2019;122(2):160-6.

22. Demirel M, Diken Türksayar AA, Donmez MB. Translucency, color stability, and biaxial flexural strength of advanced lithium disilicate ceramic after coffee thermocycling. 2022,Journal of Esthetic and Restorative Dentistry

23. Sharma G, Wu W, Dalal EN. The CIEDE2000 color-difference formula: Implementation notes, supplementary test data, and mathematical observations. Color Research & Application: Endorsed by Inter-Society Color Council, The Colour Group (Great Britain), Canadian Society for Color, Color Science Association of Japan, Dutch Society for the Study of Color, The Swedish Colour Centre Foundation, Colour Society of Australia, Centre Français de la Couleur. 2005;30(1):21-30.

24. Mayinger F, Lümkemann N, Musik M, Eichberger M, Stawarczyk B. Comparison of mechanical properties of different reinforced glass-ceramics. The Journal of Prosthetic Dentistry. 2022; 127(1):146-153.

25. Gracis S, Thompson VP, Ferencz JL, Silva NR, Bonfante EA. A new classification system for all-ceramic and ceramic-like restorative materials. International Journal of prosthodontics. 2015;28(3).

26. Paravina RD, Ghinea R, Herrera LJ, Bona AD, Igiel C, Linninger M, vd. Color difference thresholds in dentistry. Journal of Esthetic and Restorative Dentistry. 2015;27:S1-9.

27. Palla ES, Kontonasaki E, Kantiranis N, Papadopoulou L, Zorba T, Paraskevopoulos KM, vd. Color stability of lithium disilicate ceramics after aging and immersion in common beverages. The Journal of Prosthetic Dentistry. 2018;119(4):632-42.

28. Tabatabaian F, Vali S, Namdari M. Effect of surface treatment and surface region on the color stainability of a cemented high-translucency monolithic zirconia ceramic after coffee thermocycling. Journal of Prosthetic Dentistry. 2022;127(5):767.e1-767.e7.

29. Adawi HA, Al Moaleem MM, Al Ahmari NM, Shariff M, Qahhar MA, Muharraq SM, vd. Assessment of Color Stainability of Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) Ceramic Materials After Hot and Cold Coffee Immersion at Different Time Intervals. Medical Science Monitor: International Medical Journal of Experimental and Clinical Research. 2021;27:e932745-1.

30. Seyidaliyeva A, Rues S, Evagorou Z, Hassel AJ, Rammelsberg P, Zenthöfer A. Color stability of polymer-infiltrated-ceramics compared with lithium disilicate ceramics and composite. Journal of Esthetic and Restorative Dentistry. 2020;32(1):43-50.

31. ALGhazali N, Laukner J, Burnside G, Jarad FD, Smith PW, Preston AJ. An investigation into the effect of try-in pastes, uncured and cured resin cements on the overall color of ceramic veneer restorations: an in vitro study. Journal of dentistry. 2010;38:e78-86.

32. Stawarczyk B, Sener B, Trottmann A, Roos M, Oezcan M, Haemmerle CH. Discoloration of manually fabricated resins and industrially fabricated CAD/CAM blocks versus glass-ceramic: effect of storage media, duration, and subsequent polishing. Dental materials journal. 2012;31(3):377-83.

33. Quek SHQ, Yap AUJ, Rosa V, Tan KBC, Teoh KH. Effect of staining beverages on color and translucency of CAD/CAM composites. Journal of Esthetic and Restorative Dentistry. 2018;30(2):E9-17.

34. Alp G, Subasi MG, Johnston WM, Yilmaz B. Effect of surface treatments and coffee thermocycling on the color and translucency of CAD-CAM monolithic glass-ceramic. The Journal of Prosthetic Dentistry. 2018;120(2):263-8.

35. Alshali S, Basunbul G, Basunbul A, Giordano II R. Comparison of the flexural strength of printed and milled denture base materials. BMC Oral Health. 2024;24(1):929.

36. Chung SM, Yap AUJ, Chandra SP, Lim CT. Flexural strength of dental composite restoratives: Comparison of biaxial and three-point bending test. Journal of Biomedical Materials Research Part B: Applied Biomaterials: An Official Journal of The Society for Biomaterials, The Japanese Society for Biomaterials, and The Australian Society for Biomaterials and the Korean Society for Biomaterials. 2004;71(2):278-83.

37. van den Breemer CR, Vinkenborg C, van Pelt H, Edelhoff D, Cune MS, van den Breemer CR. The Clinical Performance of Monolithic Lithium Disilicate Posterior Restorations After 5, 10, and 15 Years: A Retrospective Case Series. International Journal of Prosthodontics. 2017;30(1).

38. Alkadi L, Ruse ND. Fracture toughness of two lithium disilicate dental glass ceramics. The Journal of prosthetic dentistry. 2016;116(4):591-6.

39. Lubauer J, Belli R, Peterlik H, Hurle K, Lohbauer U. Grasping the Lithium hype: Insights into modern dental Lithium Silicate glass-ceramics. Dent Mater. 2022;38(2):318-32.

40. Wang F, Yu T, Chen J. Biaxial flexural strength and translucent characteristics of dental lithium disilicate glass ceramics with different translucencies. Journal of Prosthodontic Research. 2020;64(1):71-7.

41. Alghazzawi TF. Flexural strengths, failure load, and hardness of glass-ceramics for dental applications. Journal of Prosthetic Dentistry. 2022;128(3):512.e1-512.e9.

42. Elsaka SE, Elnaghy AM. Mechanical properties of zirconia reinforced lithium silicate glass-ceramic. J Mech Behav Biomed Mater. 2016;53:343-349

43. Kakaboura A, Rahiotis C, Zinelis S, Al-Dhamadi YA, Silikas N, Watts DC. In vitro characterization of two laboratory-processed resin composites. Dental Materials. 2003;19(5):393-8.

44. Fouda AM, Bourauel C, Samran A, Kassem AS, Alhotan A. Effect of glazing and thermocycling on the fracture toughness and hardness of a New fully crystallized aluminosilicate CAD/CAM ceramic material. BMC Oral Health. 2024;24(1):620.

45. Alencar-Silva FJ, Barreto JO, Negreiros WA, Silva PGB, Pinto-Fiamengui LMS, Regis RR. Effect of beverage solutions and toothbrushing on the surface roughness, microhardness, and color stainability of a vitreous CAD-CAM lithium disilicate ceramic. J Prosthet Dent. 2019;121(4):711.e1-711.e6.

46. Esquivel-Upshaw JF, Dieng FY, Clark AE, Neal D, Anusavice KJ. Surface Degradation of Dental Ceramics as a Function of Environmental pH. J Dent Res. 2013;92(5):467-71.

47. Kukiattrakoon B, Junpoom P, Hengtrakool C. Vicker's microhardness and energy dispersive x-ray analysis of fluorapatite-leucite and fluorapatite ceramics cyclically immersed in acidic agents. Journal of Oral Science. 2009;51(3):443-50.

48. Sarac D, Sarac YS, Yuzbasioglu E, Bal S. The effects of porcelain polishing systems on the color and surface texture of feldspathic porcelain. The Journal of prosthetic dentistry. 2006;96(2):122-8.

49. Ludovichetti FS, Trindade FZ, Werner A, Kleverlaan CJ, Fonseca RG. Wear resistance and abrasiveness of CAD-CAM monolithic materials. The Journal of prosthetic dentistry. 2018;120(2):318-e1.