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COMPARATIVE STUDY OF COLOR STABILITY, TRANSLUCENCY, AND SURFACE ROUGHNESS OF ADVANCED, CONVENTIONAL LITHIUM DISILICATE AND HYBRID CAD/CAM CERAMICS. AN IN VITRO STUDY

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ABSTRACT

Aim: Compared the color stability, translucency, and surface roughness of CEREC Tessera, IPS e.max CAD, and VITA Enamic CAD/CAM ceramics before and after thermocycling.

Materials and Methods: A total of 72 ceramic samples were divided into three groups (n=24 each): Advanced lithium disilicate (CEREC Tessera), lithium disilicate (IPS e.max CAD), and hybrid ceramic (VITA Enamic). Each group was further subdivided by test type: color change (n=6), translucency (n=6), and surface roughness (n=12). Color and translucency were measured before and after thermocycling using a spectrophotometer and expressed as ΔE and TP values. Surface roughness samples were split into two classes: before (Class I) and after (Class II) thermocycling. Artificial aging was simulated by 5,000 thermocycles between 5°C and 55°C. Surface roughness (Ra) was measured using a contact profilometer.

Results: IPS e.max CAD showed the highest color stability ($\Delta E = 2.45$), falling well within the ideal esthetic range. **Tessera** ($\Delta E = 3.59$) and **Enamic** ($\Delta E = 3.02$) remained within the clinically acceptable limit of (3.7). E.max also exhibited the highest translucency ($TP = 16.53$) and the lowest surface roughness ($Ra < 0.2\ \mu m$), while Enamic recorded the lowest translucency ($TP = 11.70$) and the highest surface roughness ($Ra = 0.40\ \mu m$).

Conclusion: IPS e.max CAD showed superior optical and surface properties, making it more suitable for long-term esthetic restorations. Tessera had moderate performance; VITA Enamic showed the least favorable results.

KEYWORDS: Color stability, Translucency, Surface roughness, CAD/CAM ceramics, Thermocycling

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INTRODUCTION

The increasing demand for highly aesthetic dental restorations has driven substantial advancements in ceramic materials [1]. The integration of Computer-Aided Design and Manufacturing (CAD/CAM) has further enhanced the precision, efficiency, and reproducibility of ceramic restorations while reducing fabrication time and costs [2].

Glass ceramics are widely valued for their translucency and biocompatibility, yet their brittleness has prompted the development of reinforced systems like lithium disilicate ceramics (IPS e.max CAD; Ivoclar Vivadent) [3]. To enhance performance further, Advanced Lithium Disilicate (ALD) ceramics such as CEREC Tessera (Dentsply Sirona) were introduced. These incorporate virgilite crystals—formed during firing—within a zirconia-reinforced glass matrix, improving both strength and esthetics [4].

Alternatively, hybrid ceramics like VITA Enamic (VITA Zahnfabrik) offer a dual-network structure combining a feldspathic ceramic matrix with polymer infiltration (UDMA and TEGDMA)[5]. Introduced in 2013, this material bridges the gap between ceramics and composites, mimicking the mechanical behavior of natural teeth, with favorable wear resistance and fracture toughness [1].

Color stability, translucency, and surface roughness are key factors that influence the clinical longevity and esthetic performance of restorations. These properties affect not only visual integration but also plaque accumulation and wear resistance. In vitro thermocycling is a widely accepted method to simulate thermal stresses encountered intraorally, providing insights into material behavior over time.

Given the limited comparative data on CEREC Tessera, this study aims to evaluate and compare the color stability, translucency, and surface roughness of CEREC Tessera, IPS e.max CAD, and VITA Enamic before and after thermocycling.

The null hypothesis of this study stated that there would be **no statistically significant differences** in color stability, translucency, or surface roughness among **CEREC Tessera (ALD), IPS e.max CAD (LD), and VITA Enamic (VE)** before and after thermocycling.

MATERIALS AND METHODS

In the present study utilized three distinct CAD/CAM ceramic materials, advanced lithium disilicate ceramic (CEREC Tessera, shade A2HT) (Dentsply Sirona), a conventional lithium disilicate ceramic (IPS e.max CAD, shade A2HT) (Ivoclar Vivadent), and a hybrid ceramic (VITA Enamic, shade 2M2HT) (Vita Zahnfabrik).

Sample size calculation:

The required sample size was calculated using G*Power software (version 3.1.9.2). Based on the statistical parameters derived from similar previous study [6], a minimum of six samples per group was necessary to achieve 80% power at a significant level of 0.05 for one-way ANOVA testing.

A total of seventy-two (72) samples were fabricated, with 24 samples assigned to each of the three material groups. Each group was further subdivided according to the type of test conducted. For the assessment of color change, six samples were allocated per group. Another six samples per group were used for translucency measurement. The remaining twelve samples per group were reserved for surface roughness evaluation. These were further classified into two subgroups: Class I (before thermocycling, n = 6) and Class II (after thermocycling, n = 6).

Square-shaped samples for each material: advanced lithium disilicate (Cerec Tessera), Lithium Disilicate (IPS e.max) and Hybrid ceramic Vita Enamic with dimensions 10 × 14 mm in size, with a thickness of 1 mm [6]. were prepared by sectioning material blocks using the IsoMet 4000 precision

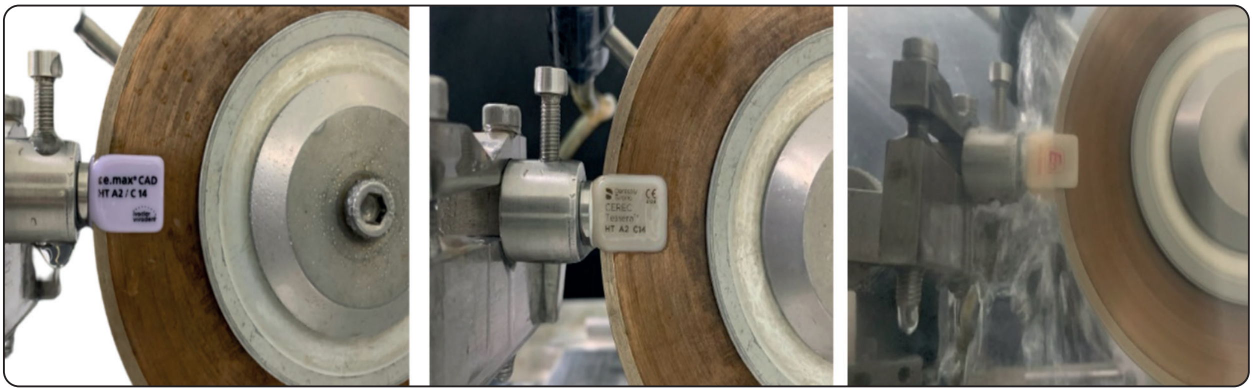

Fig. (1) Steps of cutting ceramics blocks by IsoMet Machine.

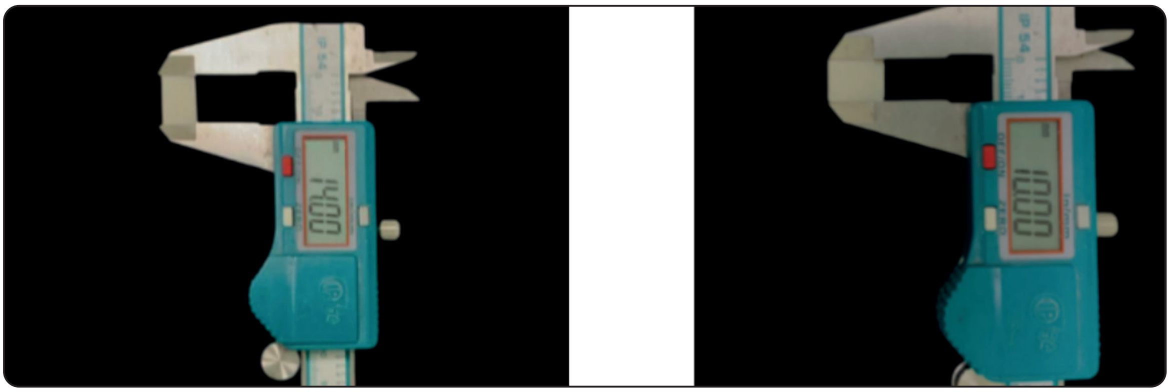

Fig. (2) Post-Cutting Calibration of Ceramic Samples

saw* Figure (1). A diamond blade with a thickness of 0.7 mm was utilized for cutting, operating at a speed of 2500 rpm. The cutting process was carried out under continuous water cooling, with a feed rate set to 5 mm/min

All samples were processed according to manufacturer guidelines. **IPS e.max CAD**** samples were crystallized in a ceramic furnace*** according to the manufacturer's guidelines, reaching 850 °C with controlled heating and holding times .Afterward, a universal glaze**** was applied, and the samples were glaze-fired starting at 403 °C, reaching 725 °C, held for 1–2 minutes under vacuum, then left to cool naturally. (Figure:3). **CEREC Tessera****** samples received a single-step matrix firing at 400 °C for 4 minutes, simultaneously with glazing application, without separate crystallization. **VITA Enamic******* samples did not undergo crystallization or glazing, as their resin-infiltrated surfaces are not compatible with conventional glaze bonding.

Polishing of all-ceramic CAD/CAM materials was performed using the EVE Universal Kit*******, **following the manufacturer's guidelines, . VITA Enamic** was polished with hybrid ceramic-specific grey and pink polishers at 6,000–15,000 rpm using light pressure and intermittent water cooling to prevent heat damage[7]. **CEREC Tessera** was polished with ceramic-specific tools at 8,000–12,000 rpm, taking care to minimize surface abrasion due to its zirconia-reinforced structure [8].

* IsoMet 4000 , Buehler , USA

** Ivoclar Vivadent. *IPS e.max CAD Instructions*, 2020.

*** Ivoclar Vivadent Liechtenstein Programt E P 310

**** Dentsply Sirona Universal Overglaze Paste – HIGH FLU

***** Dentsply Sirona. CEREC Tessera Instructions, 2020.

****** VITA Zahnfabrik. VITA ENAMIC Instructions, 2020.

******* Universal EVE finishing and polishing set, Germany

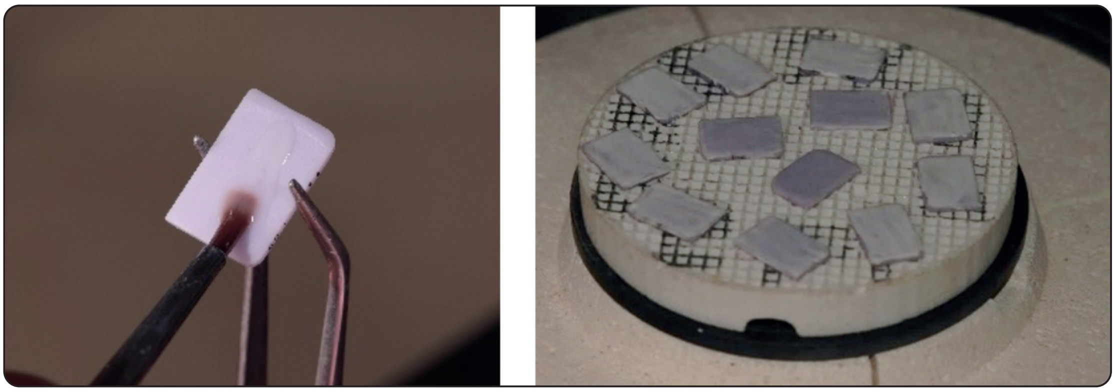

Fig. (3) Glazing of Ceramics with Universal Paste and Furnace

IPS e.max CAD underwent a complete polishing sequence from coarse to high-gloss polishers, reaching up to 15,000 rpm with intermittent water spray to control thermal effects [9]

Color Measurement Test Before Thermocycling

Color was measured for 18 ceramic samples (6 per material) using a spectrophotometer* with an integrating sphere. Three readings per sample were averaged. Measurements followed the CIE Lab* system: L* (lightness), a* (red green), and b* (yellow-blue), providing a precise 3D color profile.

Translucency Measurement Test Before Thermocycling

The same 18 samples were used for translucency evaluation. Each sample was measured over white and black backgrounds using a spectrophotometer. Three readings per background averaged. The translucency parameter (TP) was calculated from the color difference (ΔE) between both backgrounds using the CIE Lab* values, quantifying the material's light-transmitting ability. The equation used was:

$$TP = \sqrt{(L_w^* - L_b^*)^2 + (a_w^* - a_b^*)^2 + (b_w^* - b_b^*)^2}$$

Surface Roughness Measurement Test Before Thermocycling

Surface roughness was evaluated using a contact profilometer. Polished samples were fixed with the test surface facing upward. The device was calibrated with a 2 μm stylus, 0.75 mN force, 8 mm length, and 0.5 mm/s speed. Three Ra readings per sample were taken at 500 μm intervals and averaged. (figure4)

Thermocycling Procedure All samples underwent artificial thermocycling using an SD Mechatronic thermocycler. The process consisted of 5000 cycles, alternating between a cold-water bath (5°C) and a hot water bath (55°C), with each immersion lasting 30 seconds and a dwell time of 10 seconds between baths. The selected number of cycles corresponds to approximately 6 months of clinical aging

Post-Thermocycling Measurements:

Following thermocycling, color, translucency, and surface roughness were reassessed using the same methods. Post-aging values were statistically compared to baseline data to evaluate material changes.

RESULTS

The analysis of the data was carried out using the IBM SPSS version 25 statistical package software. The normality of the data was tested using the Shapiro-Wilk test. Data were expressed as mean ± SD and minimum and maximum range for normally distributed quantitative data. Analyses were performed between the three groups for parametric

* Carry 5000 UV-Vis-NIR, Agilent, USA

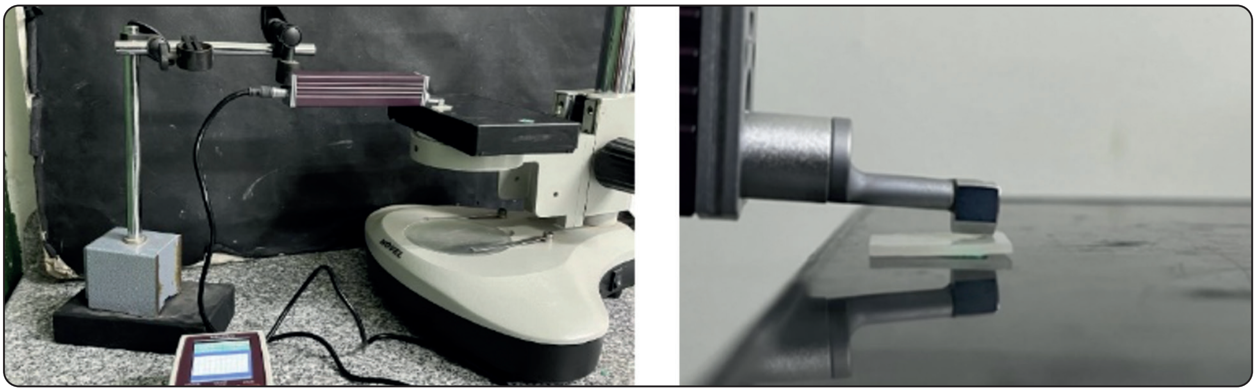

Fig. (4) Surface Roughness Profilometry

quantitative data using the One-Way ANOVA test, followed by post hoc analysis between each two groups. A p-value less than 0.05 was considered statistically significant.

Color change results

TABLE (1) The mean, standard deviation values and results of one-way ANOVA test for comparison between ΔE of the three ceramic types

	E-max	Vita Enamic	Tessera	P value
	N=6	N=6	N=6	
Δ E	2.45±0.22 [a]	3.02±0.12 [b]	3.59±0.19 [c]	*<0.001**

One-way ANOVA with post hoc test; different letters indicate significance (P < 0.05).

There was a statistically significant difference in color change (ΔE) among the tested groups after thermocycling, as shown in Table (1). IPS e.max CAD demonstrated the lowest mean ΔE value (2.45 ± 0.22), indicating the highest color stability, followed by VITA Enamic (3.02 ± 0.12), while CEREC Tessera exhibited the greatest color change (3.59 ± 0.19). As illustrated in Figure (5), one-way ANOVA confirmed a highly significant difference between the groups ($p < 0.001$), with post-hoc tests revealing significant pairwise differences, suggesting a strong influence of material composition on color stability. (figure 5)

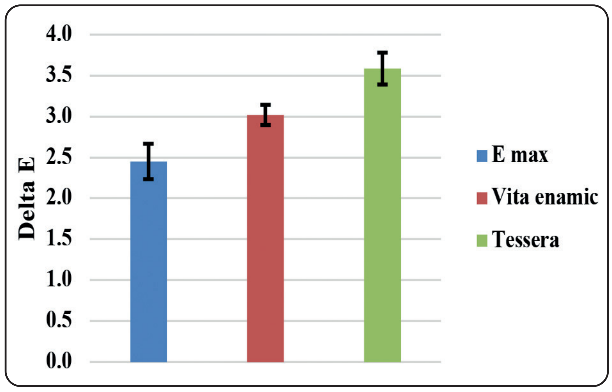

Fig. (5) Bar chart representing mean and standard deviation values for ΔE of the three ceramic types

Translucency parameters results (Tp)

TABLE (2) The mean, standard deviation values for comparison of Tp between the Three Materials before and after thermocycling

	E-max N=6	Vita enamic N=6	Tessera N=6	P value
TP before	15.69±0.21 [c]	10.51±0.16 [a]	13.26±0.13 [b]	*<0.001**
TP after	16.53±0.3 [c]	11.7±0.16 [a]	14.89±0.17 [b]	*<0.001**
P value	*<0.001**	*<0.001**	*<0.001**	

One-Way ANOVA was used for group comparisons, followed by post hoc analysis. Paired Samples T-test assessed time differences within groups. Superscripts with different letters indicate significant differences (P < 0.05).

Translucency parameters (TP) were measured before and after thermocycling for all three materials. Before thermocycling, E-max showed the highest translucency (15.69±0.21), followed by Tessera (13.26±0.13), and Vita enamic had the lowest (10.51±0.16). After thermocycling, all materials showed significant increases in translucency (p<0.001 for each material): E-max increased to 16.53±0.3, Tessera to 14.89±0.17, and Vita enamic to 11.7±0.16. The relative ordering of translucency remained consistent both before and after thermocycling (E-max > Tessera > Vita enamic).(Figure 6) .

Surface roughness results (Ra)

Surface roughness measurements revealed significant differences between materials both before and after thermocycling (p<0.001). Before thermocycling, Vita enamic showed significantly higher roughness (0.38±0.06) compared to both E-max (0.17±0.06) and Tessera (0.14±0.05), which were statistically similar to each other. After thermocycling, the pattern remained similar, with Vita enamic showing the highest roughness (0.4±0.07) compared to E-max (0.18±0.07) and Tessera (0.16±0.05). Notably, E-max, vita enamic and Tessera showed significant increases in roughness after thermocycling (p<0.001, p=0.003, and p= 0.006 respectively). (table 3, figure 7).

TABLE (3) The mean, standard deviation values for comparison of Ra between the Three Materials before and after Thermocycling

	E-max	Vita enamic	Tessera	P value
	N=6	**N=6**	**N=6**	
Roughness before thermocycling	0.17±0.06 [a]	0.38±0.06 [b]	0.14±0.05 [a]	***<0.001****
Roughness after thermocycling	0.18±0.07 [a]	0.4±0.07 [b]	0.16±0.05 [a]	***<0.001****
P value	***<0.001****	***0.003****	***0.006****	

Show significance at P < 0.05.

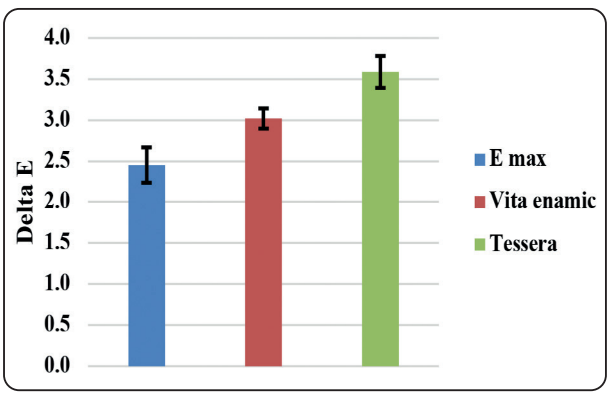

Fig. (6) Bar chart showing the mean and standard deviation of Tp values of the three ceramic materials after thermocycling

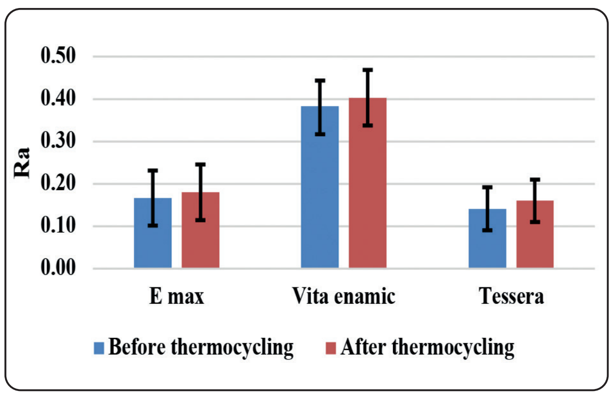

Fig. (7) Bar chart representing Ra values before and after thermocycling of the three ceramic types

DISCUSSION

The increasing demand for aesthetic restorations has led to the widespread adoption of advanced CAD/CAM ceramics. Patients and clinicians prioritize materials that combine strength, translucency, and color stability to ensure durable and lifelike restorations [(10),(11).] Lithium disilicate ceramics, including conventional LD, advanced LD (ALD), and IPS e.max CAD, are widely used due to their excellent mechanical and optical properties.

Conventional LD provides high strength and translucency, ideal for crowns, veneers, and onlays [(12),(13)]. ALD improves upon LD by offering higher flexural strength, enhanced translucency, and better resistance to aging effects such as thermocycling [(14),(15).] IPS e.max CAD, a widely used monolithic lithium disilicate, provides consistent performance and excellent aesthetics in CAD/CAM workflows[(16,17)].

Thermocycling, a common in vitro aging simulation, exposes materials to repeated temperature fluctuations, which can degrade their mechanical and optical properties [(18,19)]. Our study included LD, ALD, IPS e.max CAD, and the hybrid ceramic VITA Enamic (VE), to assess how each material responds to thermal aging in terms of color stability, translucency, and surface roughness.

Samples were standardized to 1 mm thickness using a precision saw to simulate common clinical applications and ensure reproducibility [(14).] Thermocycling (5000 cycles, 5°C–55°C) simulated six months of oral aging [(20,21)]. Shade and translucency were controlled across all materials to isolate the effect of aging on their intrinsic properties [(22,23)].

The study's findings indicate that there was a significant difference in **color stability** after thermocycling. IPS e.max CAD (LD) showed the lowest color change (ΔE = 2.45), confirming its superior resistance to aging, in line with Alsilani et al. (2022) [(24)]. Its dense crystalline microstructure and stable glass matrix are likely to contribute to this performance.

CEREC Tessera (ALD) showed a higher ΔE of 3.59, possibly due to microstructural changes in its virgilite-reinforced matrix. VITA Enamic (VE) also showed perceptible color change (ΔE = 3.02), likely resulting from polymer matrix degradation and water sorption (Paravina et al., 2023) [(25).]

Both ALD and VE exceeded the clinical perceptibility threshold of ΔE = 2.6 (Pop-Ciutrila et al., 2023) [(26)], suggesting that discoloration may be noticeable, especially in anterior restorations. However, some studies, such as Zhang et al. (2024) [(27),] report that ΔE values below 3.5 may remain imperceptible under clinical lighting conditions. Additionally, surface treatments like polishing or re-glazing have been shown to improve VE's color stability (Mühlemann et al., 2022) [(28)]. Acceptability thresholds for color differences in dentistry vary across studies. While values below 2.6 are preferred for high esthetic demand, Khashayar et al. (2014) [(29)] suggested that ΔE values up to 3.7 are acceptable to 50% of observers. More recently, Nayak et al. (2024)[(30)] reaffirmed that ΔE values above 3.7 are often considered clinically unacceptable, particularly when resulting from visual shade selection. These findings support the use of ΔE = 3.7 as a practical clinical threshold, especially for posterior or less esthetically demanding regions.

The results **of Translucency test showed that** IPS e.max CAD exhibited the highest translucency (TP), followed by CEREC Tessera and VE. All materials showed a slight but significant reduction in TP after thermocycling, consistent with findings by Al-Haj Husain et al. (2023) [(31)]. TP reduction may result from surface degradation and microstructural changes, which scatter light (Al-Thobity et al., 2022) [(32)]. Tessera's intermediate TP is attributed to zirconia particles, which enhance strength but reduce translucency. However, its dual-glass matrix and rapid-fire technology may preserve some optical performance (Potdukhe et al., 2024; Lee et al., 2022) [33,34].

VE showed the lowest TP values, due to mismatched refractive indices between polymer and ceramic phases (Kontonasaki et al., 2019) [33]. Still, all materials remained within acceptable clinical translucency ranges. Conflicting evidence suggests TP reductions may not always be perceptible or clinically relevant, especially in posterior restorations (Chen et al., 2024) [36].

Surface roughness (Ra) increased in all materials post-thermocycling. VE had the highest Ra both before and after aging, followed by Tessera and LD. These results are attributed to VE's resin content, which is more prone to hydrothermal degradation (Ziyad et al., 2021) [37].

LD showed the lowest Ra, reflecting the resistance of its dense glass-ceramic structure to wear and crack formation (Kim et al., 2021) [38]. Tessera's intermediate Ra is likely related to surface irregularities from its zirconia reinforcement (Stawarczyk et al., 2020) [39].

Surface deterioration may also result from glaze layer breakdown and microcrack formation (Osman et al., 2023) [40]. Although Ra values increased, all remained within clinically acceptable limits.

Importantly, finishing and polishing significantly impact long-term surface quality. Motevasselian et al. (2021) [41] and Celik et al. (2020) [42] showed that well-polished surfaces in VE and Tessera can resist aging effects. Menees et al. (2013) [43] emphasized that initial surface treatment is key to maintaining surface integrity.

From the above discussion, the hypothesis of this study stated that there would be **no statistically significant** differences in color stability, translucency, or surface roughness among CEREC Tessera (ALD), IPS e.max CAD (LD), and VITA Enamic (VE) before and after thermocycling. However, the results revealed statistically significant differences in all evaluated parameters among the tested materials, as well as between measurements taken before and after thermocycling. Therefore, the null hypothesis was rejected.

CONCLUSIONS

- **Lithium disilicate (IPS e.max CAD)** demonstrated the **greatest color stability** with minimal perceptible change and consistently exhibited the highest translucency among the tested materials.
- **Advanced lithium disilicate (CEREC Tessera) and hybrid ceramic (VITA Enamic)** showed more noticeable **color changes** after thermocycling, though still within clinically acceptable limits. In terms of **translucency**, CEREC Tessera showed moderate translucency, while VITA Enamic had the lowest among the tested materials.
- **Translucency** significantly increased in all materials after thermocycling
- **VITA Enamic** had the highest **surface roughness** before and after thermocycling
- IPS e.max CAD had the lowest values, while CEREC Tessera showed slightly higher roughness than e.max but remained comparable.
- All materials showed a statistically significant **increase** in roughness after thermocycling.

Limitations of the study

The study was conducted in vitro and may not fully replicate real intraoral conditions. Aging was simulated using only thermocycling, without applying mechanical loading to mimic chewing forces. Additionally, a single shade and thickness were tested, which limits the generalizability of the results to other clinical scenarios.

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