Received: 26 May 2022 | Revised: 12 August 2022 | Accepted: 13 August 2022

DOI: 10.1111/jerd.12960

RESEARCH ARTICLE

WILEY

Translucency, color stability, and biaxial flexural strength of advanced lithium disilicate ceramic after coffee thermocycling

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Abstract

Objective: To compare the color stability, translucency, and biaxial flexural strength (BFS) of differently glazed advanced lithium disilicate (ALDS) with those of lithium disilicate (LDS) and zirconia-reinforced lithium silicate (ZLS) after coffee thermocycling.

Materials and methods: Forty disk-shaped specimens were prepared from three lithium silicate based materials (CEREC Tessera, ALDS; IPS e.max CAD, LDS; Vita Suprinity, ZLS). ALDS specimens were divided into two subgroups according to glazing procedures (reduced glaze duration, ALDS-S and normal glaze duration, ALDS-N), while LDS and ZLS specimens were crystallized and glazed. Color coordinate measurements were performed before and after coffee thermocycling. Color differences (ΔE_{00}) and relative translucency parameters (RTP) were calculated. Specimens were then subjected to BFS test. Statistical analysis was performed by using 1- (ΔE_{00} and BFS) and 2-way (RTP) ANOVA tests ($\alpha = 0.05$).

Results: ΔE_{00} values of tested materials were similar (df = 3, F = 0.150, $p = 0.929$). Two-way ANOVA showed the significant effect of material type, coffee thermocycling, and the interaction between these parameters on RTP values ($p < 0.001$). Both before and after thermocycling, LDS had the highest ($p \leq 0.001$) and ZLS had the lowest ($p < 0.001$) RTP values, while ALDS-N had higher RTP than ALDS-S ($p \leq 0.001$). Among tested materials, only LDS had similar RTP values before and after thermocycling ($p = 0.865$) as the other materials had lower RTP values after thermocycling ($p < 0.001$). ALDS-N had higher BFS values than ALDS-S ($p = 0.005$), while LDS had similar values to ALDS specimens ($p \geq 0.201$). ZLS had the highest BFS ($p \leq 0.007$).

Conclusions: ALDS had comparable values to those of other materials. However, reduced glazing duration resulted in decreased translucency and BFS of ALDS.

Clinical significance: ALDS may be an appropriate restorative material for those patients with increased coffee consumption considering its color stability and ability to maintain translucency, particularly when glazed by using a conventional porcelain furnace.

KEYWORDS
CAD/CAM, color science, dental materials, prosthodontics

1 | INTRODUCTION

Computer aided design-computer aided manufacturing (CAD-CAM) technologies have diversified restorative materials,[1–4] including ceramics.[5] Among the available ceramic materials, glass-matrix ceramics have the advantages of translucency and biocompatibility. However, their brittle nature created the need for reinforcements for improved physical properties, which led to the introduction of millable lithium disilicate (LDS) glass ceramic (IPS e.max CAD; Ivoclar Vivadent) in the early 2000s.[2,6,7]

Even though lithium disilicate glass ceramic has increased its popularity significantly ever since and became the material of choice compared with other glass-matrix ceramics,[8] new materials are frequently marketed.[9–11] Zirconia-reinforced lithium silicate glass ceramic (ZLS) has been launched as a unique material that combines the advantages of lithium disilicate and zirconia[12–16] due to 10 wt% of zirconium dissolved in its glassy matrix.[17] Currently, ZLS is available either in crystallized (Celtra Duo; Dentsply Sirona) or pre-crystallized form (Vita Suprinity; Vita Zahnfabrik).[18,19] Even though both materials comprise a similar microstructure,[18,20] a previous study has reported that pre-crystallized ZLS had higher flexural strength values than crystallized ZLS.[21] One of the newest iteration of glass-matrix ceramics is called advanced lithium disilicate (ALDS) glass ceramic (CEREC Tessera; Dentsply Sirona), which also contains lithium aluminum silicate crystals called virgilite[22–24] in its glassy zirconia matrix.[2,8] The manufacturer claims that new virgilite crystals are formed through matrix firing process and virgilite gives the structure increased strength and esthetic properties. However, the reduced firing time of 4 min 30 s while using the appropriate induction chairside furnace (CEREC SpeedFire; Dentsply Sirona) is highlighted as the main advantage of ALDS. Nevertheless, it is still possible to fire the material by using a conventional furnace.[24]

Esthetic outcomes of a ceramic restoration depend on its translucency and optical properties.[25,26] In addition, color stability is an important parameter for a long-lasting restoration[27] as color change may affect the quality of a restoration.[28,29] However, along with optical properties, success of a restoration also depends on material's mechanical properties.[30] Considering that the reduced firing time of advanced lithium disilicate may contribute to chairside dentistry greatly, a study on how this feature affects the optical and mechanical behavior of ALDS would be beneficial for clinicians. To the authors' knowledge only three studies have investigated ALDS,[8,10,23] but those studies did not focus on its optical properties after coffee thermocycling. In addition, how reduced glaze firing duration affects these

TABLE 1 List of CAD-CAM lithium silicate ceramics used in this study

Material	Chemical Composition (wt%)	Manufacturer
CEREC Tessera (advanced lithium disilicate glass-ceramic, ALDS)	$Li_2Si_2O_5$: 90% Li_3PO_4: 5% $Li_{0.5}Al_{0.5}Si_{2.5}O_6$ (virgilite): 5%	Dentsply Sirona, York, PA, USA
IPS e.max CAD (lithium disilicate glass-ceramic, LDS)	SiO_2: 57–80% Li_2O: 11%–19% K_2O: 0%–13% P_2O_5: 0%–11% ZrO2: 0%–8% ZnO: 0%–8% Coloring oxides: 0%–8%	Ivoclar Vivadent, Schaan, Lichtenstein
Vita Suprinity (zirconia-reinforced lithium silicate glass ceramic, ZLS)	SiO_2: 56%–64% Li_2O: 15%–21% ZrO_2: 8%–12% P_2O_5: 3%–8% K_2O: 1%–4% Al_2O_3: 1%–4% CeO_2: 0%–4% Pigments: 0%–4%	Vita Zahnfabrick, Bad Säckingen, Germany

TABLE 2 Firing parameter of tested materials

Material	Crystallization	Glaze firing
ALDS-N	Not required	Stand by temperature: 400°C; pre-drying time: 2 min; closing time: 2 min; pre-heating time: 2 min; heating rate: 55°C/min; firing temperature: 760°C, holding time: 2 min
ALDS-S	Not required	Proprietary program of induction chairside furnace
ZLS	Stand by temperature: 400°C; closing time: 4 min; temperature increase rate: 55°C/min; holding temperature: 840°C; Vacuum on/off: 410/840°C; Long term cooling:680°C; Cooling temperature: 0 (the firing chamber must not be opened during long-term cooling)	Stand by temperature: 400°C; closing time: 4 min; temperature increase rate: 80°C/min; holding temperature: 800°C; holding time: 1 min
LDS	Stand by temperature: 403°C; closing time: 6 min; heating rate: 60°C/min; firing temperature: 770°C; holding time: 0:10 min; heating rate: 30°C/min; firing temperature: 850°C; holding time: 10:00; Long term cooling: 700°C; Vacuum on/off: 770/850	Stand by temperature: 403°C; closing time: 6 min; temperature increasing rate: 60°C/min; holding temperature: 725°C; holding time: 1 min; Vacuum on/off: 450/724°C

properties is unknown. Thus, the present study investigated color stability, translucency, and biaxial flexural strength (BFS) of differently glazed ALDS after coffee thermocycling and compared with those of LDS and pre-crystallized ZLS. The hypotheses were that (i) material type would affect color stability, (ii) material type and coffee thermocycling would affect translucency, and (iii) material type would affect BFS values after coffee thermocycling.

2 | MATERIAL AND METHODS

Chemical compositions and abbreviations of tested materials are given in Table 1. Number of specimens in each group was determined by a power analysis (effect size $f = 0.6$, $1 - \beta = 0.85$, $\alpha = 0.05$). A disk-shaped (ø: 12 mm, thickness: 1.2 mm) standard tessellation language (STL) file was designed (exocad DentalCAD; exocad GmbH). This STL file was used to fabricate a total of 40 specimens from three different CAD-CAM monolithic ceramics (ALDS, CEREC Tessera; Dentsply Sirona; LDS, IPS e.max CAD; Ivoclar Vivadent; ZLS, Vita Suprinity; Vita Zahnfabrik) with a milling unit (inLab MC XL; Dentsply Sirona). All CAD-CAM blocks were high translucent and in A2 shade. ALDS specimens were randomly divided into 2 subgroups (Excel; Microsoft Corp) according to the glazing performed (ALDS-N and ALDS-S) ($n = 10$). A uniform surface was achieved by using silicon carbide abrasive papers (#600, #800, and #1000) and thicknesses were checked with a digital caliper (Absolute Digimatic; Mitutoyo).

Table 2 lists the firing parameters of each group. Specimens of ALDS-N were glazed by using manufacturer's recommended porcelain furnace (Multimat Cube; Dentsply Sirona) after paste liquid glaze application (Universal Overglaze and Universal Stain and Glaze Liquid; Dentsply Sirona). For ALDS-S specimens, a spray glaze was applied (Universal Spray Glaze; Dentsply Sirona) evenly and fired in an induction chairside furnace (CEREC SpeedFire; Dentsply Sirona) furnace. LDS specimens were first crystallized in a porcelain furnace (Programat P300; Ivoclar Vivadent) and then coated with a powder liquid glaze (e.max Ceram Glaze Powder/Glaze and Stain Liquid; Ivoclar Vivadent). The recommended spray glaze (VITA AKZENT Plus Glaze LT Spray; VITA Zahnfabrik) was applied to ZLS specimens after crystallization and fired in the same porcelain furnace as LDS. A single experienced technician applied glazing on one surface of all specimens to achieve dry and uniform whitish glaze layer. Adequate glaze thickness (200 ± 12 μm)[3] was controlled with the same digital caliper. All specimens had a final thickness of 1.2 ± 0.2 mm, which is in line with the International Organization for Standardization (ISO) standard 6872:2015.[31] Specimens that do not meet this criterion were remade.

A digital spectrophotometer (CM-26d; Konica Minolta)[15] was used for color coordinate (L^*, which corresponds to lightness; a^*, which corresponds to redness; b^*, which corresponds to yellowness)[13,29,32] measurements. This spectrophotometer has a diffused illumination integrating sphere system (8° viewing) and two specular component modes (specular component included and excluded). It allows either medium (12 mm/8 mm illumination/measurement area) or small area view (6 mm/3 mm illumination/measurement area) and uses the CIE Standard 2° or 10° human observer characteristics along with a number of different illuminants in its color estimations. In the present study, the parameters of the spectrophotometer were set to small area view, 2° human observer characteristics, CIE D65 illumination, and the specular component was excluded. Same practitioner (M.D.) performed the measurement of each specimen on white (L^*: 91,90, a^*: −1,42, and b^*: 8,29), gray (L^*: 51,73, a*: −1,01, and b^*:−3,14), and black (L^*: 8,52, a^*: 0,32, and b^*: 0,65) backings (Figure 1) in a temperature- and humidity-controlled rom with daylight. Color coordinates of each specimen were measured three times on each background, which were then averaged. Spectrophotometer was calibrated before each measurement and a saturated sucrose solution was used for the optical contact between the specimens and the backing. Initial relative translucency parameter (RTP) values were calculated by using the coordinates measured on black and white backings. CIEDE2000 formula was used and the parametric factors (kL, kC, and kH) were set as 1[4,16,25,33]:

$$\mathrm{RTP} = \left[(\Delta L'/k_L S_L)^2 + (\Delta C'/k_C S_C)^2 + (\Delta H'/k_H S_H)^2 + R_T(\Delta C'/k_C S_C)(\Delta H'/k_H S_H)\right]^{1/2}.$$

After initial measurements, specimens were subjected to 5000 cycles of coffee thermocycling between 5 and 55°C and a dwell time of 30 s (THE 1100; SD Mechatronik) as described in previous studies.[16,25,28] A filter coffee machine was used to prepare the coffee

FIGURE 1 Schematic representation of color measurements

solution, which had a ratio of 177 ml of water for 1 tablespoon of coffee. Coffee solutions were changed in every 12 h.[16,25] Specimens were brushed with a toothpaste (Colgate Total Pro Breath Health; Colgate-Palmolive) 10 times, ultrasonically cleaned for 15 min, and dried with towel paper after coffee thermocycling. Once the specimens were completely dry, color measurements were repeated and RTP values were recalculated. The color difference (ΔE_{00}) caused by coffee thermocycling were calculated by using the coordinates measured on gray backing.

BFS test of the specimens was performed according to ISO standard 6872:2015.[31] Specimens were placed on 3 stainless steel balls (ø: 3.2 mm), which were positioned 120° apart from each other on a circle (ø: 10 mm). A piston (ø: 1.6 mm) attached to a universal tester (Lloyd LRX; Lloyd Instruments) was used to apply 1 mm/min force to the center of the specimens and the force at the moment of fracture was recorded (Figure 2).[19] BFS was calculated by using the following formula[11,13,19]:

$$\sigma = -0.2387\,P\,(X - Y)/d^2,$$

$$X = (1+v)\ln(r_2/r_3)^2 + [(1-v)/2]\,(r_2/r_3)^2,$$

$$Y = (1+v)\left[1+\ln(r_1/r_3)^2\right] + (1-v)\,(r_1/r_3)^2,$$

with σ = BFS (MPa), P = force at failure (N), d = thickness of the specimen (mm), v = Poisson's ratio (0.229 for ALDS, 0.216 for LDS, and 0.222 for ZLS),[8] r_1 = radius of the support circle (mm), r_2 = radius of the loaded area (mm), and r_3 = radius of the specimen (mm).

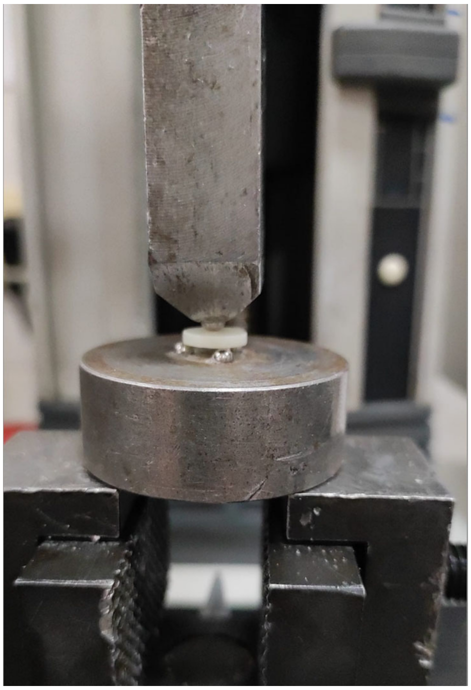

FIGURE 2 Representative image of biaxial flexural strength test

Data was assessed for normality by using Shapiro–Wilk test, which did not refute the normal distribution assumption of the data. Therefore, parametric tests were used for statistical analyses. One-way analysis of variance (ANOVA) was used to evaluate the ΔE_{00} and BFS values. Effect of material type and coffee thermocycling on RTP was analyzed by using 2-way ANOVA, while clinically relevant comparisons were resolved by using Bonferroni corrected *t* tests.[16] All analyses were performed by using an analysis software (SPSS v23; IBM Corp) at a significance level of $\alpha = 0.05$. ΔE_{00} and RTP values were further evaluated according to previously described clinical perceptibility (ΔE_{00}: 0.8 units and RTP: 0.62 units) and acceptability (ΔE_{00}: 1.8 units and RTP: 2.62 units) thresholds.[34,35]

3 | RESULTS

Figure 3 illustrates bar graph of ΔE_{00} values. ΔE_{00} values of tested materials were similar (df = 3, $F = 0.150$, $p = 0.929$). Table 3 summarizes the descriptive statistics of RTP values. Two-way ANOVA test revealed the significant effect of material type and coffee thermocycling and the interaction between these factors on RTP values ($p < 0.001$). Significant interactions of clinically relevant comparisons were resolved by using different materials in the same condition and the same material in different conditions. Regardless of coffee thermocycling, LDS had the highest RTP ($p \le 0.001$), whereas ZLS had the lowest ($p < 0.001$). In addition, ALDS-N had higher RTP than ALDS-S both before ($p = 0.001$) and after ($p < 0.001$) coffee thermocycling. All specimens had lower RTP after coffee thermocycling ($p < 0.001$), except for LDS ($p = 0.865$).

Material type had a significant effect on BFS values (df = 3, $F = 17.746$, $p < 0.001$). ZLS had the highest BFS ($p \le 0.007$). ALDS-N showed higher BFS than ALDS-S ($p = 0.005$). However, LDS had

TABLE 3 Descriptive statistics of relative translucency parameters values (95% confidence intervals) [min–max values]

Material	Before coffee thermocycling	After coffee thermocycling
LDS	27.82 ± 0.52^{dA}	27.89 ± 0.81^{dA}
	(27.45–28.19)	(27.31–28.47)
	[27.01–28.33]	[26.7–29.61]
ZLS	22.47 ± 0.8^{aA}	20.32 ± 0.89^{aB}
	(21.9–23.04)	(19.68–20.96)
	[20.82–23.74]	[18.78–21.87]
ALDS-N	26.37 ± 0.86^{cA}	24.79 ± 0.95^{cB}
	(25.75–26.98)	(24.11–25.46)
	[24.52–27.77]	[23.5–25.92]
ALDS-S	24.91 ± 0.86^{bA}	23.12 ± 0.54^{bB}
	(24.3–25.53)	(22.73–23.51)
	[23.5–25.99]	[22.19–23.8]

Note: Different superscript lowercase letters indicate significant differences in columns, while different superscript uppercase letters indicate significant differences in rows ($p < 0.05$).

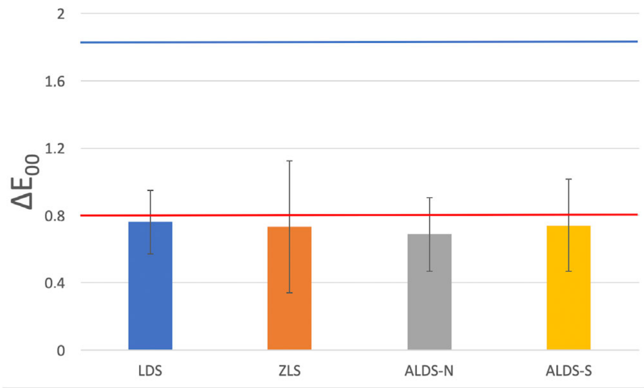

FIGURE 3 Color difference (ΔE_{00}) values of materials. Red line represents perceptibility threshold of 0.8 units, while blue line represents acceptability threshold of 1.8 units.[34] ALDS-N, advanced lithium disilicate-normal glaze duration; ALDS-S, advanced lithium disilicate-reduced glaze duration; LDS, lithium disilicate; ZLS, zirconia-reinforced lithium silicate

TABLE 4 Descriptive statistics of biaxial flexural strength (MPa) values (95% confidence intervals) [min–max values]

Material	Biaxial flexural strength
LDS	424.3 ± 52.26^{ab} (386.9–461.7) [318.3–514.2]
ZLS	549.4 ± 79.71^{c} (492.4–606.4) [438.4–679.3]
ALDS-N	463.22 ± 48.55^{b} (428.5–498) [368.1–548.7]
ALDS-S	374.22 ± 29.99^{a} (352.8–395.7) [335.2–430]

Note: Different lowercase letters indicate significant differences ($p < 0.05$).

similar BFS values to those of ALDS-N ($p = 0.41$) and ALDS-S ($p = 0.201$) (Table 4).

4 | DISCUSSION

ΔE_{00} values of tested materials were similar, which led to the rejection of first hypothesis. All materials had mean ΔE_{00} values that were below the clinically perceptible threshold,[34] which indicates that materials had imperceptible color changes. This result coincides with previous studies, which have shown that either LDS[4,25,28] or ZLS[4,16,25] are resistant to discoloration after coffee thermocycling. However, different clinical perceptibility and acceptability threshold values have also been reported.[4] In a recent study, the authors[4] concluded that ZLS had a perceivable color change after 6000 cycles of coffee thermocycling when prepared in 0.7 mm thickness. Even though material thickness and number of coffee thermal cycles applied were different from those of the present study, the authors[4] had accepted 1.24 units, which are greater than that of the present study, as the clinically perceptible threshold value. Therefore, these results should be substantiated with future in vivo studies to better interpret the color stability of tested materials.

Regardless of coffee thermocycling, RTP values of tested materials were listed as LDS, ALDS-N, ALDS-S, and ZLS in a decreasing order. In addition, coffee thermocycling reduced the RTP values of all materials other than LDS. Therefore, the second hypothesis was accepted. Translucency is related to several different material-based factors that include chemical composition, crystalline structure, and grain size.[16] Among tested materials, LDS differs from the others as it primarily comprises lithium disilicate crystals, whereas ALDS and ZLS also contain either virgilite or zirconia in their matrix.[2] Even though LDS (lithium disilicate crystals >1 μm)[8] has larger crystals than those of ALDS (lithium disilicate crystals of 0.5 μm and virgilite crystals of 0.2–0.3 μm)[10] and ZLS (lithium disilicate crystals of 0.5 μm and zirconia dissolved in glassy matrix),[18,20] the results of the present study may indicate that chemical composition and crystalline structure have a greater influence on translucency. In addition, previous studies focusing on the translucency of LDS and ZLS[4,16,25] have also reported similar results to those of the present study.

To the authors' knowledge, the present study was first to evaluate the effect of different glaze firing parameters on the translucency of ALDS. A previous study on the topographical features of ALDS has reported that the material comprised fissures with different depths before mandatory heat treatment, which disappeared after firing.[10] Gradual increase of temperature while using a conventional porcelain furnace for the mandatory heat treatment of ALDS may have led to an improved glassy matrix fusion and higher RTP compared with firing by using induction chairside furnace. In addition, the manufacturer of ALDS has claimed that reduced firing duration leads to formation of new virgilite crystals.[24] Even though this could also be associated with the reduced RTP values of ALDS-S when compared with ALDS-N, it has been reported that neither the number nor the size of virgilite crystals changed after mandatory heat treatment.[10] Thus, the results of the present study need to be substantiated with studies that investigate topographical and chemical properties of ALDS after different glaze firing durations. Nevertheless, a recent study has visually compared the translucency of four different lithium disilicate ceramics including LDS and ALDS, and stated that significant differences were perceivable among tested materials.[10] Even though the present study has also revealed significant differences, a direct comparison might be misleading. In addition, no study has compared ALDS with ZLS in terms of translucency; thus, the results of the present study could not be compared and needs further corroboration.

The difference between before and after coffee thermocycling RTP values of only LDS was below the clinical perceptibility threshold of 0.62.[35] Even though other materials had perceptible RTP changes, it can be speculated that all materials could maintain their translucency at an acceptable level after long-term coffee consumption as

5000 thermal cycles approximately simulate 6 months of intraoral use.[16,25] Nevertheless, a recent study has concluded that RTP was a time, staining medium, and material dependent parameter.[26]

Finally, the third hypothesis was also accepted as significant differences were observed among the BFS values of tested materials as ZLS had the highest values, while LDS had similar values to those of ALDS groups. However, it should be noted that all materials had mean BFS values that were higher than 300 MPa, which, according to ISO 6872:2015 is the required threshold for a monolithic crown or a three-unit fixed partial denture that does not involve molar teeth.[31] This similarity between LDS and ALDS groups substantiates the findings of a recent study.[23] In addition, ALDS-N had significantly higher values than that of ALDS-S. However, this difference between ALDS-N and ALDS-S should be interpreted carefully. Even though the present study focused on the BFS values of tested materials after coffee thermocycling, the effect of reduced glaze firing duration on mechanical properties should be elaborated with studies investigating baseline values. A previous study reported that LDS specimens crystallized by using the induction chairside furnace used in the present study led to lower fracture resistance values when compared with those crystallized by using conventional furnaces,[6] which may indicate possible effect of induction chairside furnace to the properties of restorative materials.

Even though BFS tests were in line with ISO 6872:2015 standards,[31] color coordinate measurements were performed with a spectrophotometer that was used to evaluate the optical properties of CAD-CAM ceramics,[15] and ΔE_{00} and RTP values were calculated similar to previous studies,[4,16,25,28] the results of the present study should be carefully interpreted. CIEDE2000 formula was used in the present study with the parametric factors set as 1. However, a previous study concluded that changing the parametric factor of kL to 2 leads to a better evaluation of ΔE_{00} values due to the influence of a specimen's surface texture to its lightness.[32] In addition, different color measurement devices may lead to different results, given the various number of instruments available.[33] Considering that the results of the present study identify visually and statistically significant differences in RTP values, these significant differences are expected to be valid. Nevertheless, limited illumination area relative to the measurement area can cause edge-loss, which could lead to reduced color differences and might be associated with the nonsignificant ΔE_{00} values among tested materials. Therefore, the spectrophotometer used in the present study should be evaluated in terms of edge-loss, validity, and repeatability in future studies.

Chairside dentistry has become a common treatment modality with the integration of CAD-CAM technologies into dental practice. However, time needed for a restoration to be prepared (fabrication, crystallization/sintering, and characterization) for delivery still comprises a considerable part of treatment duration. ALDS substantially reduces glaze firing duration while using an induction chairside furnace and the authors consider the results on the optical and mechanical properties of ALDS as promising. Therefore, this material may be a suitable alternative to other commercially available CAD-CAM ceramics with similar chemical and crystalline structure, particularly for complete-coverage restorations.

A limitation of the present study was that in vitro coffee thermocycling stains both surfaces of specimens. However, intaglio surface of a restoration is isolated from any staining solution in ideal clinical situations.[16] Therefore, ΔE_{00} values of the present study may have been amplified. Even though the specimens were prepared according to the ISO standard 6872:2015[31] to be used both for BFS tests and color coordinate measurements, constant specimen thickness was a limitation. In addition, only one staining solution was tested in the present study and previous studies have shown the significant effect of these parameters on ΔE_{00} and RTP values.[4,16,28] Another limitation was that only two optical parameters were evaluated in the present study. However, diversifying the parameters to evaluate the transmittance or opalescence of the tested materials would elaborate the knowledge on their optical characteristics. Finally, all specimens were glazed in line with manufacturers' recommendations as the present study also aimed to compare the effect of different glaze firings on the properties of ALDS. In addition, glazing was reported to lead to higher color stability and better mechanical properties.[27,29] However, different surface treatments may lead to different results.[25] Considering the novelty of ALDS, future studies investigating optical and mechanical properties of this material after different processes such as brushing, thermomechanical aging, and cyclic loading are needed to comprehensively understand its limitations.

5 | CONCLUSIONS

Within the limitations of this current study, it was concluded that:

1. All materials had similar color changes, which were acceptable considering the reported thresholds.
2. Lithium disilicate had the highest translucency regardless of coffee thermocycling along with the highest resistance to discoloration caused by coffee thermocycling. However, all materials maintained their translucency at an acceptable level when reported thresholds were considered.
3. Zirconia reinforced lithium silicate had the highest and advanced lithium disilicate subjected to reduced glaze firing duration had the lowest biaxial flexural strength values after coffee thermocycling. However, all materials had biaxial flexural strength values to be used as crowns and 3-unit fixed partial dentures that do not involve molar teeth.

ACKNOWLEDGMENT AND DISCLOSURE

The authors would like to thank Dentsply Sirona for their collaboration. The authors declare no conflict of interest and do not have any financial interest in the companies whose materials are included in this article. Open access funding provided by Universitat Bern.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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How to cite this article: Demirel M, Diken Türksayar AA, Donmez MB. Translucency, color stability, and biaxial flexural strength of advanced lithium disilicate ceramic after coffee thermocycling. *J Esthet Restor Dent*. 2022;1-7. doi:10.1111/jerd.12960