Effect of Artificial Aging on Translucency of Zirconia Reinforced Lithium Silicate and Lithium Disilicate Ceramics: A Systematic Review

Keywords

Glass Ceramics
Translucency
Computer-Aided Manufacturing
Lithium Disilicate
Zirconia Reinforced Lithium Silicate
Computer-Aided Designing

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Received: 21.07.2023
Accepted: 23.11.2023
doi: 10.1922/EJPRD_2602Potdukhe09

ABSTRACT

Introduction: Digital dentistry and advanced ceramic materials have been widely used but which material has a better esthetically durable outcome needs to be evaluated. The purpose of this systematic review and meta-analysis was to evaluate the difference in the translucency of CAD zirconia-reinforced lithium silicate and CAD lithium disilicate glass ceramics after being subjected to artificial aging. Material and Methods: Two independent reviewers searched the MEDLINE/ PubMed, Embase, and EBSCO databases and the Google Scholar search engine for in-vitro studies published from January 2010 to May 2023 to identify relevant studies measuring the translucency of CAD ZLS and CAD lithium disilicate glass ceramics after being subjected to different artificial aging conditions using the coffee solution, 4% acetic acid, distilled water and UV aging. Results: For qualitative synthesis, 10 studies were included. A statistically significant difference was observed between CAD zirconia-reinforced lithium silicate and CAD lithium disilicate glass ceramics ($P<0.05$, mean difference=-0.25 [-0.38,-0.11]). Translucency of CAD ZLS was less than CAD lithium disilicate glass ceramics. Conclusions: Artificial aging has decreased the translucency of glass ceramics. For fixed prosthetic rehabilitation clinicians can opt for CAD lithium disilicate glass-ceramic as a more esthetically pleasing and durable material in oral environment.

INTRODUCTION

Milled ceramic materials are manufactured by computer-aided design computer-aided manufacturing (CAD-CAM) technology.[1] CAD lithium disilicate glass-ceramic has been widely and popularly used as esthetic ceramic material for fixed prosthetic rehabilitation of anterior teeth, single posterior teeth, three-unit fixed dental prosthesis, full mouth rehabilitation, onlays, veneers, and laminates.[2,3] CAD zirconia-reinforced lithium silicate glass ceramic (ZLS) has been developed as an esthetic ceramic material with enhanced mechanical properties due to the addition of 10 % weight of zirconium in the glass matrix.[4,5]

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Translucency is one of the parameters for esthetics, giving a life-like appearance to the restoration and is significant for the selection of ceramic materials. Natural tooth exhibits translucency by absorbing, and reflecting light due to the variation in the structure of the dentin and enamel. The objective of dental ceramics is to mimic the natural tooth esthetic and vitality by appropriate absorption and scattering of light passing through it.[5-8] Translucency is one of the essential optical property enhancing the esthetics outcome, measured by using the contrast ratio or Translucency Parameter (TP).[5-8] The translucency parameter is the color difference of a material that is optically uniform over its thickness and which is in optical contact with ideal white and black backgrounds.[5-8] TP is evaluated either by spectrophotometric analysis or by using the CIEDE2000 formula.[9] Different types of spectrophotometers such as digital, lab, benchtop, and reflection spectrophotometer are used for the measurement of translucency parameter.[10] The CIEDE 2000 color difference formula has also been used for calculating TP.[9] The translucency of ceramic material depends upon the composition of the material, the material thickness, the surrounding conditions, the device used for the measurement, the number of firings, and different staining conditions.[11] The complexity of the oral environment has an effect on material properties.[12] To imitate the temperature fluctuations which occur in the oral environment thermocycling can be done which results in intensive aging due to the occurrence of internal stress caused by dimensional changes in the materials.[12] For *in-vitro* replication of the oral conditions, artificial aging is performed under different conditions using different staining solutions such as coffee solution, distilled water, acetic acid, artificial saliva, beverages and thermocycler at different cycles.[12] Artificial aging leads to the leaching of products, reduction in strength, hardness, changes in color and optical properties.[12,13] Artificial aging can lead to decrease or increase in the translucency of ceramic material. Similarly, the optical properties of CAD ZLS and CAD lithium disilicate glass ceramics have been affected by artificial aging as reported in the *in-vitro* studies. However, few studies reported higher translucency values of CAD lithium disilicate and few studies reported higher translucency values for CAD ZLS after being subjected to artificial aging.[14-17] No clear results were available on the effect of artificial aging on the translucency of CAD ZLS and CAD lithium disilicate glass ceramics.

This systematic review aimed to determine the difference in the translucency of CAD zirconia-reinforced lithium silicate and CAD Lithium disilicate glass ceramics after being subjected to artificial aging so as to give the clinician a choice of CAD ceramic material which is esthetically pleasing for longer duration in normal oral condition as translucency is one of the reliable parameter to opt for highly esthetically durable digital ceramic material for fixed prosthetic rehabilitation. The null hypothesis was that no statistically significant difference would be found in the translucency between CAD ZLS and CAD lithium disilicate glass-ceramic after being subjected to artificial aging.

METHODS

According to Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines this systematic review was conducted.[18-23]

The methodology included formulation of the following review question according to population, intervention, comparison, outcome, and study design (PICOS) framework[22-25]: "Is there a difference in the translucency of CAD zirconia-reinforced lithium silicate and CAD lithium disilicate glass ceramics after being subjected to artificial aging?" The population was zirconia-reinforced lithium silicate and lithium disilicate samples, crowns, onlays, and veneers fabricated using CAD/CAM technology. The intervention was CAD/CAM zirconia-reinforced lithium silicate samples, crowns, onlays, and veneers. The comparison was CAD/CAM lithium disilicate samples, crowns, onlays, and veneers. The outcome was the translucency parameter of CAD/CAM zirconia-reinforced lithium silicate and CAD/CAM lithium disilicate glass-ceramics after being subjected to artificial aging. The study design was *in vitro* studies evaluating the translucency parameter of CAD/CAM zirconia-reinforced lithium silicate and CAD/CAM lithium disilicate glass ceramics after being subjected to artificial aging.

Inclusion criteria included *in vitro* studies that evaluated the translucency parameter of CAD/CAM zirconia-reinforced lithium silicate and CAD/CAM lithium disilicate glass-ceramics samples, crowns, onlays, and veneers after being subjected to artificial aging. Full-text articles published in English between January 2010 and March 2023 were included. Exclusion criteria were studies not in English published before January 2010, measuring the translucency of pressable ZLS and lithium disilicate samples, crowns, onlays, and veneers, case reports, case series, questionnaires, surveys, and animal studies.

Studies selection was done according to PICOS selection criteria. To determine eligible studies, 2 reviewers (S.P., J.I.) assessed the titles and abstracts with the opinion of a third reviewer (A.M.) to resolve any disagreements.[26-29] The Cohen kappa score was 0.94.[30] The primary outcome measured was the translucency parameter of CAD/CAM zirconia-reinforced lithium silicate and CAD/CAM lithium disilicate glass-ceramics samples, crowns, onlays, and veneers after being subjected to artificial aging. The various staining solutions used for artificial aging were the coffee solution, 4% acetic acid, distilled water and UV aging as they mimic the common oral conditions. The advanced search of articles was conducted in the MEDLINE/PubMed, Embase, EBSCO database and Google Scholar search engine using Boolean operators, MeSH terms, and keywords as listed in *(Table 1)*. The following search strategy used for articles search from different databases are specified in *(Table 2)*.[26-29] The terms entered in Google Scholar were zirconia-reinforced lithium silicate, lithium disilicate, computer-aided designing, computer-aided manufacturing, glass ceramics, and translucency.

Table 1. Terms used in search strategy as per population, intervention, comparison, outcome, and study design framework.

Population	Intervention	Control	Outcome	Study design
Adult	Zirconia reinforced lithium silicate, ZLS, Glass ceramics, Computer-aided designing, computer-aided manufacturing, CAD/CAM	Lithium disilicate, LDS, Glass ceramics, Computer-aided designing, computer-aided manufacturing, CAD/CAM	Translucency, translucency parameter, artificial aging, thermocycling	*in vitro* studies, *in-vitro* studies, clinical trials, clinical studies

Table 2. Search strategy in different databases.

Sr. no.	Search Strategy
1.	Search strategy in PubMed was ((((((Zirconia reinforced lithium silicate) AND lithium disilicate) AND translucency) OR translucency parameter) AND artificial aging))
2.	Search strategy in EBSCO was ((((((Zirconia reinforced lithium silicate) AND lithium disilicate) AND translucency) OR translucency parameter) AND artificial aging))

The title and abstract of each study were independently reviewed and critically assessed by two authors (S.P., J.I.). The following method was used for selection criteria: assessing searched outcomes to delete duplicates, examining titles and abstracts to delete irrelevant articles, establishing relevant full-text articles, examining the degree of compliance of full-text articles as per the eligibility criteria, study inclusion, and gathering of data.[31,32] Ten articles were included from all the databases and 2 reviewers (S.P., J.I.) independently conducted data extraction with a Cohen kappa score of 0.94. The following main characteristics of the included studies appeared in the evidence table in spreadsheets (Excel; Microsoft Corp) for all primary outcomes: study identification, study design, sample size, translucency parameter for the intervention group, translucency parameter for the comparison group, conclusion, statistical analysis, and other relevant data.[33]

Methodological Index for Non-Randomized Studies (MINORS) tool was used for the quality assessment of selected *in-vitro* studies done by 2 reviewers (S.P., J.I.) and included the key domains of clearly stated aim, the inclusion of consecutive patients, prospective data collection, endpoints appropriate to study aim, unbiased assessment of study endpoint, follow-up period appropriate to study aim, <5% lost to follow-up, prospective calculation of study size, adequate control group, contemporary groups, baseline equivalence of groups, and adequate statistical analyses.[34,35] A software program (Review Manager Version 5.4; Cochrane) was used for quality assessment.[36]

RESULTS

STUDY SELECTION AND STUDY CHARACTERISTICS

A total of 232 titles were obtained by electronic database search, of which 35 were duplicates. A total of 197 abstracts were screened, and 170 not relevant to the topic were excluded. Twenty-seven articles were eligible for full-text assessment. After the screening of full-text articles as per the selection criteria, 17 studies with inappropriate outcomes measured were excluded. For qualitative synthesis, 10 studies were included as shown in the PRISMA flow diagram *(Figure 1)*. The qualitative characteristic data of all selected studies were mentioned in *(Table 3)*. Ten included studies were *in-vitro* studies.[14-17,37-42]

CHARACTERISTICS OF CAD ZLS AND CAD LITHIUM DISILICATE SPECIMENS

In this review, 193 samples each of CAD ZLS and CAD lithium disilicate were included.[14-17,37-42] All 10 studies were carried out using CAD IPS Emax (Ivoclar, Vivadent, Lichtenstein) composed of Lithium disilicate glass ceramic containing 57–80% of SiO_2, 11%–19% of Li_2O, 0%–13% of K_2O, 0%–11% of P_2O_5, 0%–8% of ZrO_2, 0%–8% of ZnO, 0%–8% of coloring oxides and Vita Suprinity composed of Zirconia-reinforced lithium silicate containing 56%–64% of SiO_2, 15%–21% of Li_2O, 8%–12% of ZrO_2, 3%–8% of P_2O_5, 1%–4% of K_2O, 1%–4% of Al_2O_3, 0%–4% of CeO_2, 0%–4% pigments.[14-17,37-42] Four studies[15,37,38,41] used polished ceramic samples while 7 studies[14,16,17,38,39,41,42] used glazed samples. The thickness of the samples ranged from 0.5 mm to 1.5 mm. Five studies used 1 mm thick samples,[16,17,37,39,42] 4 studies used 1.5 mm thick samples,[15,38,40,41] 2 studies used 0.7 mm samples,[40,42] and 1 study each used 0.5 mm,1.2 mm and 1.3 mm thick samples to measure the translucency.[14,40,42]

ARTIFICIAL AGING CONDITIONS

The included studies have reported different artificial staining procedures. The various staining solutions used were the coffee solution, 4% acetic acid, distilled water and UV aging.[14-17,37-42] Among 10 included studies; 5 studies used coffee solution,[14,37,40-42] 3 studies used distilled water,[15,38,39] and 1 study each used 4% acetic acid[16] and UV aging[17] for artificial

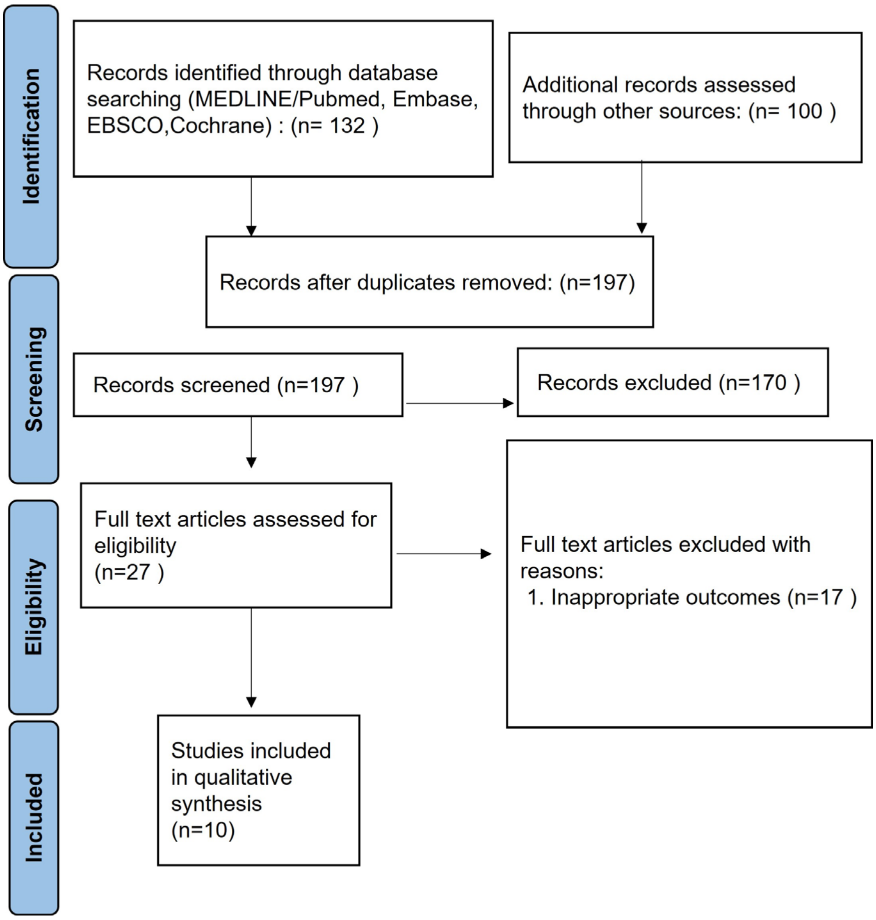

Figure 1: PRISMA Flow diagram.

aging. Four studies underwent thermocycling at 5000 cycles at 5 and 55 degree Celsius with a dwell time of 30 seconds and a transfer time of 10 seconds according to ISO.[14,39,41,42] One study underwent thermocycling at 6000 cycles at 5 and 55 degree Celsius with a dwell time of 30 seconds and a transfer time of 10 seconds.[40] Two studies used a thermocycler at 10,000 cycles at 5 and 55 degree Celsius.[15,38] One study underwent thermocycling at two cycles of 150 KJ/m^2 at 60 hours and 120 hours.[37] One study underwent thermocycling with a beaker placed in the water bath for 16 hours at 80 degrees Celsius.[16] One study underwent UV aging for 300 hours at 150KJ/m^2.[17]

TRANSLUCENCY MEASUREMENT

All 10 included studies measured the translucency using the translucency parameter.[14-17,37-42] Out of 10 included studies, 7 studies used a spectrophotometer to measure translucency parameter.[14-17,37-39] Among 7 studies, 3 studies used a VITA Easyshade guide spectrophotometer,[15,17,38] and 1 study each used a digital spectrophotometer,[14] benchtop spectrophotometer,[37] reflection spectrophotometer,[16] and lab spectrophotometer.[39] Out of 10 included studies, 3 studies used CIEDE 2000 color difference formula for relative translucency parameter measurement.[40-42]

COMPARISON OF BOTH THE MATERIALS

Six studies reported translucency parameter values before and after thermocycling.[14-17,38,39] One study reported translucency parameter values after thermocycling.[37] Three studies didn't report the translucency parameter values.[40-42] Out of 10 studies, 7 studies showed higher translucency values for CAD lithium disilicate than CAD ZLS.[14,15,38-42] Two studies showed higher translucency values for CAD ZLS than CAD lithium disilicate glass-ceramic.[16,17] One study reported no difference in the translucency of CAD ZLS and CAD lithium disilicate glass-ceramic.[37] Out of 10 studies, 6 studies reported that artificial aging decreased the translucency of glass ceramics.[14,16,17,37,38,41] Two studies reported that artificial aging increased the translucency of glass ceramics.[15,39] One study reported no effect of artificial aging on translucency.[42]

QUALITATIVE ASSESSMENT

The quality assessment done using the MINORS tool was good for 7 *in-vitro* studies and was fair for 3 studies as shown in *(Table 4)*.[34]

Table 3. Data extraction table of included studies.

Sr. no.	Study ID	No of samples (n)	Thickness of sample	Sample s conditioning	Staining	Artificial aging condition	Timeline	Device use for TP measurement	TP before thermocycling for	TP after thermocycling for	Conclusion
1	Demirel 202214	10	1.2 mm	Crystallized, Glazed	Coffee thermocycling	5000 cycles, 5 and 55 degree Celsius, dwell time 30 s	Every 12 hours	Digital spectrophotometer (CM-26d; Konica Minolta)	ZLS:22.47(0.8) LDS:27.82(0.52)	ZLS 20.32 (0.89) LDS 27.89 (0.81)	LDS had the highest RTP values than ZLS both before and after thermocycling.
2	Tango 202137	28	1mm	Polished	Coffee, Wine, Accelerated aging	Two cycles of 150 KJ/m2 for T1 & T2 respectively	T0: Baseline, T1: 60hrs, T2: 120 hrs	Benchtop spectrophotometer	NR	ZLS:11.8(1.3) LDS: 11.9(0.8)	Translucency Parameter was decreased upon staining/aging. TP was same for IPS Emax and ZLS
3	Habib 202016	12	1mm	Crystallised, glazed	10 ml of 4% acetic acid. IPS Ivocolor	Placed in water bath for 16 h at of 80°C.	NR	Reflection spectrophotometer (Cary 5000 Spectrophotometer, Agilent Technologies)	ZLS:14.83(0.24) LDS:14.58(0.12)	ZLS: 13.48(0.27) LDS: 13.29(0.05)	Artificial aging had significantly decreased the translucency (TP) of all stained ceramics. ZLS showed higher TP values than LDS.
4	Porojan 202015	16	1.5 mm	Polished	Distilled water	Thermocycler (SD Mechatronik, Feldkirchen-Westerham, Germany)10,000 cycles, 5°and 55°C	NR	Spectrophotometer (Vita Easyshade IV)	ZLS:13.857 LDS:14.803	ZLS: 12.454 LDS:13.840	LDS samples have higher TP values than ZLS samples. Thermal aging had increased the translucency of both the samples.
5	Vasiliu 202038	48	1.5 mm	Glazed, polished	Distilled water	Thermocycler (SD Mechatronik, Feldkirchen-Westerham, Germany)10,000 cycles, 5°and 55°C	NR	Spectrophotometer (Vita Easyshade)	ZLS:13(1) LDS:14(1.1)	ZLS: 13.36 (1) LDS: 14.61 (0.95)	ZLS showed more significant loss in translucency than LDS. TP was decreased for all the samples after thermocycling.

Table 3 continued overleaf

Table 3 Continued.

6	Aljanobi 202039	12	1mm	Glazed	Thermocycler (THE 1100 SD Mechatronik GmbH, Germany)	5°C and 55°C,30s dwell time, 10s transfer time	T1:Baseline T2: 10,000 cycles (1 yr of use) T3:30,000 cycles(3yrs of use) T4: 50,000 cycles(5 yrs of use)	Spectrophotometer (LabScan XE Spectrophotometer, Hunter Associates Laboratory Inc., Reston, VA)	ZLS: NR LDS:16.2	ZLS: NR LDS:16.9	Higher TP for LDS before and after aging compared to ZLS.
7	Turgut 201817	10	1mm	Glazed	UV aging	300 hours in an Atlas UV 2000 testing Machine at 150 KJ/m2	NR	Spectrophotometer (VITA Easyshade)	ZLS:22.5(0.7) LDS:20.6(0.5)	ZLS: 20.6(1.3) LDS:20(0.3)	RTP values decreased after aging. ZLS showed higher TP values than LDS.
8	Arif 201840	5	0.7,1.3 & 1.5 mm		Coffee thermocycling	6000 thermocycles,5°C and 55°C,30s of dwell time, 10s of transfer time	8hrs	RTP calculated using CIEDE 2000 color difference Formula	NR	NR	The translucency of the LDS laminate veneer thickness was higher after coffee thermocycling.
9	Alp 201841	18	1.5 mm	Glazed, polished	Coffee solution	5000 thermocycles,5°C and 55°C,30s of dwell time, 10s of transfer time	NR	CIEDE 2000 color difference and RTP formula.	NR	NR	Coffee thermocycling decreased the translucency. LDS was more translucent than ZLS before and after coffee thermocycling.
10	Subasi 201842	4	0.5,0.7 & 1mm	Glazed	Coffee solution	5000 thermocycles,5°C and 55°C,30s of dwell time, 10s of transfer time	12 hr	CIEDE 2000 color difference formula.	NR	NR	Coffee thermocycling was not found to affect the translucency. LDS showed higher TP values than ZLS.

LDS, Lithium disilicate; NR, Not reported; TP, Translucency parameter; ZLS, Zirconia reinforced lithium silicate

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Table 4. Risk of bias assessment using Methodological Index for Non-Randomized Studies (MINORS) tool.

Sr. No.	Study Id	Clearly Stated Aim	Inclusion of Consecutive Patients	Prospective Data Collection	Endpoints Appropriate to Study Aim	Unbiased Assessment of Study Endpoint	Follow-Up Period Appropriate to Study Aim	<5% Lost to Follow-Up	Prospective Calculation of Study Size	Adequate Control Group	Contemporary Groups	Baseline Equivalence of Groups	Adequate Statistical Analyses	Total Score
1	Demirel 2022[14]	2	NA	2	2	2	2	NA	2	2	2	2	2	20
2	Tango 2021[37]	2	NA	2	2	2	2	NA	2	2	2	2	2	20
3	Habib 2020[16]	2	NA	2	2	2	2	NA	2	2	2	2	2	20
4	Porojan 2020[15]	2	NA	2	2	2	2	NA	2	2	2	2	2	20
5	Vasiliu 2020[38]	2	NA	2	2	2	2	NA	2	2	2	2	2	20
6	Aljanobi 2020[39]	2	NA	2	2	2	2	NA	2	2	2	2	2	20
7	Turgut 2018[17]	2	NA	2	2	2	2	NA	2	2	2	2	2	20
8	Arif 2018[40]	2	NA	2	2	2	2	NA	2	2	2	2	0	18
9	Alp 2018[41]	2	NA	2	2	2	2	NA	2	2	2	2	0	18
10	Subasi 2018[42]	2	NA	2	2	2	2	NA	2	2	2	2	0	18

***Not applicable**

DISCUSSION

Spectrophotometric analysis of translucency parameter to determine the esthetic outcome of glass ceramics is important.[14-17,37-39] Improper shade selection, shade matching, and improper selection of the type of material either translucent or opaque will lead to failure of the final ceramic prosthesis. The cervical, middle and incisal third of the natural tooth depict different shades and different amounts of translucency with the incisal half being more translucent. To depict a lifelike appearance in an artificial prosthesis the dental ceramic material needs to be highly translucent. The durability of any ceramic material in normal oral conditions can be duplicated in the laboratory by subjective artificial aging using different staining solutions.[37-42] The present qualitative synthesis was conducted to compare the difference in the translucency of CAD ZLS and CAD lithium disilicate glass ceramics after being subjected to different artificial aging conditions. For translucency, the null hypothesis was rejected as CAD lithium disilicate glass ceramics showed higher translucency values than CAD ZLS after artificial aging. This result was in accordance with the studies done by Demiral *et al*.,[14] Arif *et al*.,[40] Alp *et al*.,[41] and Subasi *et al*.[42] they reported higher translucency parameter values for CAD lithium disilicate than CAD ZLS after being subjected to artificial aging with the coffee solution.[14,40-42] Porojan *et al*.,[15] Vasiliu *et al*.,[38] and Aljanobi *et al*.[39] reported the same results with distilled water and thermocycler respectively.[15,38,39] The higher TP values of CAD lithium disilicate after being subjected to artificial aging with the coffee solution, distilled water, and thermocycler may be due to the amorphous glass matrix made up of 70% lithium disilicate orthorhombic crystal, smaller particle size and comparatively more silica particles than CAD ZLS.[3,4] However, studies done by Habib *et al*.[16] and Turgut *et al*.[17] reported higher translucency parameter values for CAD ZLS than CAD lithium disilicate after being subjected to artificial aging with different conditions. The higher values of CAD ZLS may be due to differences in thermocycling conditions and small sample size. The null hypothesis was accepted for the translucency parameter as the study done by Tango *et al*.[37] reported no difference between the translucency of both ceramics.

Most of the studies reported a decrease in the translucency parameter values after thermocycling compared to before.[16,38] Artificial aging in terms of thermocycling imparts thermal stresses and changes in the microstructures affecting the translucency parameter measurement values of CAD glass ceramics.[11] The difference in the results obtained may be due to the heterogeneity in the included study's methodologies, the potential source of operator bias, selection bias, bias due to study design, improper sampling, improper artificial aging conditioning and differences in the outcome analysis.

CAD lithium disilicate can be a better ceramic material option for prosthetic rehabilitation in the esthetic zone for a longer duration. However, subjectively CAD ZLS can also be used as an esthetic choice of material by the clinician for fixed prosthetic rehabilitation in cases where the CAD lithium disilicate is contraindicated. Limitations of this review were the inclusion of only *in-vitro* studies, human errors, laboratory errors, use of different artificial aging conditions and different artificial aging solutions, inclusion of only thermal and color aging conditions in the present review and inclusion of studies published only in English. However, for more precise, validated, and clinical results further laboratory studies can be conducted with different oral conditions such as chemical changes, temperature, and pH changes and long-term clinical trials can be done to assess the translucency parameter of ceramics in natural oral habitats.

CONCLUSIONS

The following conclusion was drawn based on the findings of this systematic review:

Artificial aging has a significant effect on the translucency of glass ceramics. Both glass ceramics showed a decrease in translucency after being subjected to artificial aging. However, the translucency reported for CAD ZLS was comparatively less than CAD lithium disilicate glass ceramics after being subjected to artificial aging.

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