Effect of sintering on the translucency of CAD-CAM lithium disilicate restorations: A comparative in vitro study

Running Head: TRANSLUCENCY OF SINTERED LITHIUM DISILICATE

Authors

Carlos A. Jurado, DDS, MS[1,2], Kelvin I. Afrashtehfar, DDS, MSc, Dr, FDS RCS, FRCDC[3,4], Jared Hyer, BS, DMD[5], and Abdulaziz Alhotan, BDS, PhD[6]

[1] Department of Prosthodontics, The University of Iowa College of Dentistry and Dental Clinics, Iowa City, Iowa, USA

[2]Texas Tech University Health Sciences Center, El Paso, Woody L. Hunt School of Dental Medicine, El Paso, TX, USA

[3]Clinical Sciences Department, College of Dentistry, Ajman University, Ajman City, UAE

[4]Department of Reconstructive Dentistry and Gerodontology, School of Dental Medicine, University of Bern, Bern, Switzerland

[5]A.T. Still University Arizona School of Dentistry and Oral Health, Mesa, Arizona, USA

[6]Dental Health Department, College of Applied Medical Sciences, King Saud University, Riyadh, Saudi Arabia

Correspondence

Dr. Kelvin I. Afrashtehfar, Centre of Medical and Bio-allied Health Sciences Research (CMBHSR), Ajman University, PO Box 346, Ajman Emirate, UAE.

Email: Kelvin.Afrashtehfar@unibe.ch

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AUTHORS' EMAILS AND ORCiD

Carlos A. Jurado: carlosjurado85@hotmail.com, https://orcid.org/0000-0001-7437-4855

Kelvin I. Afrashtehfar: kelvin.afrashtehfar@unibe.ch, https://orcid.org/0000-0002-6053-8967

Jared Hyer: jaredhyer1@gmail.com, https://orcid.org/0000-0001-5274-7710

Abdulaziz Alhotan: aalhotan@ksu.edu.sa, https://orcid.org/0000-0002-9036-0485

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Abstract

Purpose: The available independent data on the translucency of novel pre and fully sintered chair-side computer-aided design and computer-aided manufacturing (CAD-CAM) lithium disilicate are limited. This comparative in vitro study evaluated the translucency degree of pre and fully sintered chairside CAD-CAM lithium disilicate crowns after optional, required, and additional firing processes.

Materials and Methods: One hundred and five maxillary left central incisor crowns manufactured by three different CAD-CAM lithium disilicate brands shade A1 were assigned into 7 groups as follows (n = 15): (1) n!ce Straumann without sintering; (2) n!ce Straumann with one additional sintering process; (3) n!ce Straumann with two additional sintering processes; (4) Amber Mill with one sintering process; (5) Amber Mill with two sintering processes; (6) IPS e.max CAD with one sintering process; (7) IPS e.max CAD with two sintering processes. The translucency of all crowns was evaluated with a color imaging spectrophotometer. All statistical analyses were performed using statistical software. A standard level of significance was set at $\alpha < 0.05$.

Results: All the milled crowns presented different degrees of translucency, and additional sintering processes altered it. IPS E.max CAD with two (4.33 ±0.26) and one (4.01 ±0.15) sintering processes displayed the highest translucency, whereas n!ce Straumann with no sintering process provided the lowest value (2.82 ±0.16).

Conclusions: The translucency of chairside lithium disilicate single-unit full-coverage restorations manufactured with subtractive technology was significantly influenced by the brand and the number of sintering processes. The traditional presintered IPS e.max CAD and the fully crystallized glass-ceramic n!ce Straumann considerably increased the translucency after one additional firing process, whereas Amber Mill decreased its translucency.

Keywords: CAD-CAM, dental ceramics, disilicate lithium, esthetic dentistry, translucency, in vitro, sintering, full-coverage restoration, single crown, cosmetic dentistry, milled, machined, pre-sinterization, Subtractive computer-aided manufacturing, Computer-aided manufacturing

Chairside computer-aided design and computer-aided manufacturing (CAD-CAM) dental ceramic restorations have become a more common choice than traditional all-metal and metal-ceramic restorations for clinicians in recent years due to their expedited fabrication process, cost-effectiveness, excellent aesthetics and mechanical properties.[1-3] A recent practice-based report concluded that CAD-CAM lithium disilicate is one of the clinicians' most common options for fabricating anterior crowns.[4] Lithium disilicate is reinforced glass-ceramic, providing high fracture toughness and esthetic qualities.[5] This type of ceramic has shown reliable complication rates and survival rates similar to metal-ceramic equivalents.[6] The chairside version of the "green" or precrystalized form lithium disilicate released in 2016 needs to be sintered in the dental office before cementing the restoration in the mouth.[7] The composition varies depending on the manufacturer, but is typically ranges around 59% $LiSi_2O_5$ and 33% glass in the crystallized state containing 0.2-1.0 µm in crystal size, and it is available in all shades and high, medium, and low-translucency.[8] Currently, more companies are developing new lithium disilicate blocks with some variations.

A fully sintered chair-side lithium disilicate, n!ce Straumann (Straumann, Basel, Switzerland), was recently released to the market and compared with the traditional brand. Although the company allows an additional sintering step for glazing and staining purposes, it does not need the traditional in-office sintering process. This n!ce Straumann is a fully sintered material containing 28.5% $LiSi_2O_5$, 41.7% $LiAlSi_2O_6$, and 19.4% glass in the crystallized state, available in all shades with high, low, and medium translucency.[9,10] Another pre-sintered lithium disilicate available in the market for chair-side milling requires in-office firing processes (Amber Mill; Hass Bio, Gangwon-do, Korea). Amber Mill contains 46.1% $LiSi_2O_5$ and 33.7% glass in the crystallized state.[10] This new ceramic is available in different shades, but the translucency degree, either high, medium, or low, can be obtained within the same block by modifying the firing temperature. Even though these new materials seem to have some advantages for clinicians, more independent studies evaluating their properties are required.

Translucency is an important optical property for dental ceramics needed to mimic natural dentition. Translucency has been described as the amount of light transmitted or diffused from the substrate.[11,12] Even though pigments can be applied to dental ceramics to obtain a high translucency look, this stain can be lost within a few months after exposure to everyday products such as toothpaste and beverages such as tea and coffee.[13,14] The application of ceramic pigments may require more than one firing process to obtain the desired result, but more sintering processes increase the ceramic surface stress. Multiple firings could negatively impact the physical and mechanical properties of the ceramic.[15,16]

Although companies manufacturing lithium disilicate claim to have good translucency, minimal independent data are available comparing the new dental ceramics available in the market. Therefore, this study aimed to investigate the translucency of a traditional and two novel CAD-CAM lithium disilicate after their required and additional sintering procedures. The first null hypothesis was that there is no difference in translucency between fully sintered and presintered lithium disilicate tested brands. The second null hypothesis was that there is no difference in translucency within the same brand after the required and additional sintering processes.

Materials and methods

A maxillary left central incisor typodont tooth (1560 Dentoform, Columbia Dentoform, Lancaster, PA, USA) was prepared for an all-ceramic crown with a 1.0 mm incisal, facial, and lingual reduction and a 1.0 mm chamfer margin. A standard tessellation language (STL) file of the prepared acrylic tooth was obtained with an intraoral scanner (Primescan; Dentsply Sirona, Charlotte, NC, USA), and a crown was designed following ideal contours. One hundred and five single-unit full-coverage restorations were milled out (MCXL Milling unit, Dentsply Sirona, Charlotte, NC, USA) of different chair-side CAD-CAM lithium disilicate brands and treated with required and additional sintering processes as follows: (1) crowns fabricated from n!ce Straumann with no additional sintering process; (2) crowns fabricated from n!ce Straumann with one sintering process; (3) crowns fabricated from n!ce Straumann with two sintering processes; (4) crowns fabricated from Amber Mill with one sintering process; (5) crowns fabricated from Amber mill with two sintering processes; (6) crowns fabricated from IPS e.max CAD with one sintering process; and (7) crowns fabricated from IPS e.max CAD with two sintering processes (Table 1). The same dental laboratory technician processed all the sintering processes. A second sintering process was provided immediately after the cooling down step was completed in the groups that required two firings. This mimics the clinical conditions where after sintering a restoration and evaluating the shade by the clinician/technician, the chairside restoration may immediately be sintered for a second time to modify the shade to deliver it at the same appointment.

The sintering processes were carried out following the manufacturer's recommendation for all groups except number 1 because n!ce Straumann is a fully sintered material that has optional sintering. In-office firing processes were performed with a dental furnace (Programat CS2, Ivoclar Vivadent) with the following procedures: groups 2 and 3 (n!ce Straumann) with a customized cycle at 450°C base temperature for 25 minutes (the cooling rate is 25 °C/min); groups 4 and 5 (Amber Mill) with a customized sintering process at 400°C for 30 minutes (the vacuum cooling process starts at 550°C for 15 minutes); and groups 6 and 7 (IPS e.max CAD) with a standard cycle at 403°C standby temperature for 24 minutes (the long-term cooling process starts at 700°C). The cameo restoration surfaces of all groups were treated with a lithium disilicate polishing system (IPS e.max Chairside Adjustment & Polishing System; Brasseler USA, Savannah, GA, USA).

Each restoration was seated on the typodont tooth without any try-in paste or resin cement. Translucency evaluation was carried out with a color digital imaging spectrophotometer (Spectroshade Micro II; Oxnard, CA, USA), and images of the restorations were also recorded.[11,13,14] The facial outline of the tooth was delimited following the borders but kept 1.0 mm away from the gingival aspect as required by the software, and a translucency map was acquired for each restoration (Fig 1). Statistical analysis was performed with a nonparametric test to analyze translucency differences among the groups. The distribution among groups was evaluated with the Kruskal-Wallis test. All statistical analyses were performed using statistical software (SPSS ver. 25, IBM Corp., Armonk, NY, USA). The level of significance was set to $\alpha = 0.05$.

Results

The translucency of the chairside CAD-CAM crowns for the maxillary left central incisor varied according to the ceramic brand and the number of firing processes provided (Table 2). Statistically significant differences were displayed among all groups and the number of sintering processes (Table 2, Table 3).

Fully sintered lithium disilicate n!ce Straumann with no in-office sintering process displayed the lowest translucency value, whereas the highest translucency values were provided by IPS E.max CAD with one and two sintering processes (Table 2).

Discussion

Translucency in dental ceramics is an essential factor in mimicking natural dentition.[17] The translucency mismatching of ceramic crowns adjacent to a natural tooth can be noticeable by patients and clinicians. This may create a stressful clinical situation because it may imply an improper tooth evaluation before crown fabrication.[18] The degree of translucency can be captured by clinicians and dental technicians through visual assessment and digital techniques. Visual assessment of tooth translucency consists of placing shade guides next to the incisal edge of the natural tooth to be matched. Visual assessment of tooth translucency may sound like a simple procedure. However, this technique is subjective and has several external factors that can misguide the result, such as the ambient light, the distance between the shade guide and the tooth, and the operators' experience and sex.[19-24] Spectrophotometers are digital devices that analyze optical properties such as tooth translucency and dental restorations.[25] The present study used a SpectroShade Micro II (SpectroShade USA) to map the surface translucency. This digital noncontact and color spectrophotometer has demonstrated an accuracy rate of 96.9%, which is superior to other devices.[26,27]

The first null hypothesis, “there is no difference in translucency among fully and presintered lithium disilicate brands tested,” was partially rejected. This statement is supported since n!ce Straumann group 1 (St-0) had the lowest translucency values (2.815), being significantly below all groups except 5 (Am-2) with 2.911; but n!ce Straumann group 2 (St-1) showed 3.782 with significant differences among all the groups. The second null hypothesis, “there is a difference in translucency within the same brand after required and additional sintering processes,” was rejected. Group 1 n!ce Straumann (2.815) was significantly lower when this material had one (Group 2, 3.782) and two (Group 3, 3.336) sintering processes. Amber Mill also displayed different values with one sintering process (Group 4, 3.534) and two sintering processes (Group 5, 2.911). IPS e.max CAD also displayed significant differences with one sintering process (Group 6, 4.013) and two sintering processes (Group 7, 4.330).

Even though all tested brands are lithium disilicate ceramics, there are significant differences in their microstructure and components. For instance, the brands contain a different volume percentage of glass. The fully sintered n!ce Straumann contains the lowest glass amount with 19.4%, followed by the traditional presintered IPS e.max CAD with 29.7%, and the presintered Amber Mill contains the highest amount with 39.9%.[9] When light travels through glass, the intensity is reduced because it is partially absorbed; therefore, translucency decreases by light scattering.[28,29] When comparing the two presintered blocks, IPS e.max CAD presented higher glass content and displayed higher translucency values (groups 6 and 7) than Amber Mill (groups 4 and 5). The fully sintered n!ce Straumann is a lithium disilicate-strengthened lithium aluminosilicate,[30] whereas the other brands do not have aluminosilicate; therefore, their effects on light translucency need to be investigated.

Crystal size also differs among brands of lithium disilicate, with Amber Mill with an average crystal size of 0.2 µm,[31] n!ce Straumann crystal size of 1 µm,[31] and IPS e.max CAD with crystals of 2 to 4 µm average size.[32] It has been demonstrated that light transmission through lithium disilicate ceramics is interrupted by the crystals; therefore, their different sizes may produce different degrees of translucency.[33] A previous study comparing IPS e.max CAD low, medium, and high translucency concluded that the larger crystal sizes in the high translucency led to a lower crystal density and less scattering, contributing to higher translucency.[34] The present study concurs with those findings because IPS e.max CAD has a larger crystal size and displayed the highest values for one sintering process (Group 6, 4.013) and two sintering processes (Group 7, 4.330).

Clinicians should be aware that repeating sintering processes may cause significant changes in the optical properties of dental ceramics, and this should be considered before providing ceramic restorations in the esthetic zone. A study comparing pressable lithium disilicate, leucite, and porcelain after repeated firing demonstrated that the color was significantly affected and concluded that multiple firing processes should not be performed on glass ceramics because recrystallization causes devitrification, meaning changes in the structure.[35] A recent study evaluated the translucency of the traditional pre-sintered lithium disilicate IPS e.max CAD with 0.6 mm and 1.0 mm thicknesses after three firing processes.[36] It concluded that all 0.6 mm thickness groups had a significant translucency increase.[36] The present findings also provided higher translucency values for IPS e.max CAD after the second firing process. The fully sintered lithium disilicate n!ce Straumann also displayed higher translucency values after the first additional firing processes. Only Amber Mill decreased its translucency, which may be explained by its higher glass composition and smaller crystal size, but more studies will be needed to confirm this assumption.

The primary limitation of this study was the use of ivory teeth instead of natural teeth with dentin; however, having a single-color background may decrease significant shade variations of natural dentin and other confounding factors. The tested crown thickness was 1.0 mm; thus, future studies should also evaluate veneers with different thicknesses. Other novel lithium disilicate CAD-CAM ceramics with different compositions available on the market could be tested for translucency accordingly.

Conclusions

The present comparative in vitro study results indicate that repeating firing processes significantly change the translucency of chairside CAD-CAM lithium disilicate ceramics. The traditional pre-sintered IPS e.max CAD and the fully crystallized glass-ceramic n!ce Straumann considerably increased the translucency after one additional firing process, whereas Amber Mill decreased its translucency.

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Tables

Table 1 Description of groups and materials included in this study

Group	Type of Material	Brand	Composition	Crystal size	Sintering Process
1, 2 and 3	Fully-sintered lithium disilicate*	n!ce Straumann (Straumann, Basel, Switzerland)	*Crystallized state* • 28.5% $LiSi_2O_5$ • 41.7% $LiAlSi_2O_6$ • 19.4% glass	1 µm	Not required but optional. Optional is customized at 450°C for 25 min
4 and 5	Pre-sintered lithium disilicate	Amber Mill (Hass Bio, Gangwon-do, Korea)	*Pre-crystallized state* • 44.9% $LiSi_2O_5$ • 39.9% glass *Crystallized state* • 46.1% $LiSi_2O_5$ • 33.7% glass	0.2 µm	Required. Customized at 400°C for 30 min.
6 and 7	Pre-sintered lithium disilicate	E.max CAD (Ivoclar Vivadent, Schaan, Liechtenstein)	*Pre-crystallized state* • 32% Li_2SiO_3 • 62% glass in pre-. *Crystallized state* • 59% $LiSi_2O_5$ • 33% glass	2 – 4 µm	Required. Standard cycle mode at 403°C for 24 min.

*n!ce Straumann is sintered by the company.

Table 2 Translucency values of chairside CAD-CAM lithium disilicate crowns after required and additional sintering processes

Group	Translucency value (SE)	95% CI, lower – upper bound
Group 1 (St-0). Straumann n!ce with no sintering processes (Sintered by brand before sale).	2.815 (0.160)^{a,A}	2.519 – 3.147
Group 2 (St-1). Straumann n!ce with 1 optional sintering process.	3.782 (0.1329)^{b,B}	3.530 – 4.052
Group 3 (St-2). Straumann n!ce with 2 optional sintering processes.	3.336 (0.107)^{b,C}	3.133 – 3.553
Group 4 (Am-1). Amber Mill 1 required sintering process.	3.534 (0.107)^{b,A}	3.319 – 3.738
Group 5 (Am-2). Amber Mill with 2 sintering processes (1 requited + 1 optional)	2.911 (0.115)^{a,B}	2.695 – 3.145
Group 6 (Em-1). E.max CAD with 1 required sintering process.	4.013 (0.147)^{b,A}	3.736 – 4.311
Group 7 (Em-2). E.max CAD with 2 sintering processes (1 required + 1 optional).	4.330 (0.261)^{b,B}	3.847 – 4.873

The higher the translucency value is, the higher the translucency. The same lowercase superscript letter among all brands indicates no significant difference. The same uppercase superscript letter among the same brand indicates no significant difference. See table 3 for detailed information on Bonferroni's pairwise comparisons. Abbreviation: SE, standard error; CI, confidence interval.

Table 3 Pairwise comparisons of the translucency values of chairside CAD-CAM lithium disilicate crowns

	Group 1 (St-0)	Group 2 (St-1)	Group 3 (St-2)	Group 4 (Am-1)	Group 5 (Am-2)	Group 6 (Em-1)	Group 7 (Em-2)
Group 1 (St-0)		< 0.000	0.068	0.003	0.875	< 0.000	< 0.000
Group 2 (St-1)	< 0.000		0.068	0.641	< 0.000	0.875	0.371
Group 3 (St-2)	0.068	0.068		0.875	0.068	0.003	0.005
Group 4 (Am-1)	0.003	0.641	0.875		0.001	0.068	0.047
Group 5 (Am-2)	0.875	< 0.000	0.068	0.001		< 0.000	< 0.000
Group 6 (Em-1)	< 0.000	0.875	0.003	0.068	< 0.000		0.875
Group 7 (Em-2)	< 0.000	0.371	0.005	0.047	< 0.000	0.875	

Sequential Bonferroni significance. Abbreviation: St, Straumann; Am, Amber Mill; Em, e.max CAD.

Figure

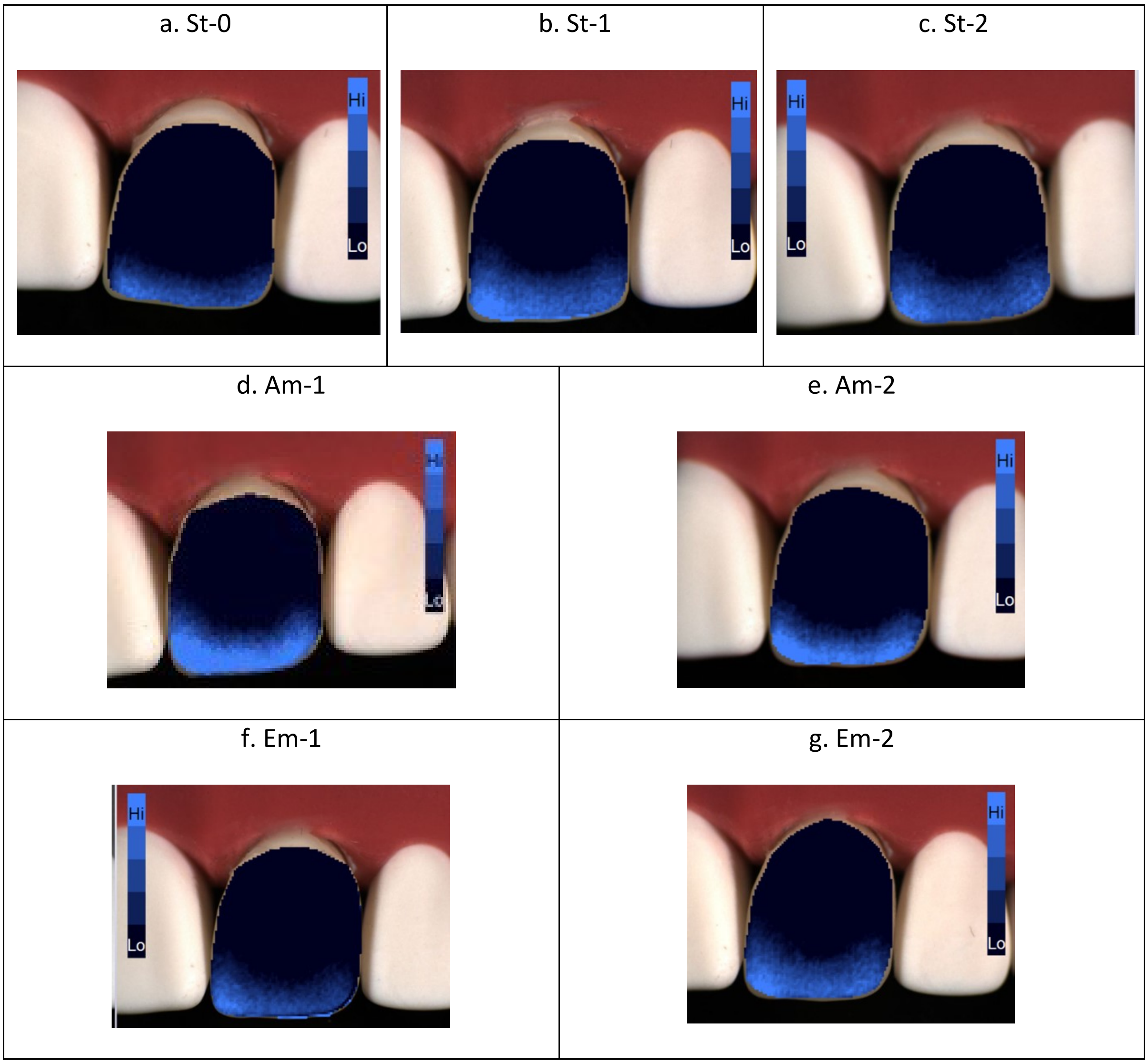

Figure 1 Translucency assessment with a spectrophotometer of milled lithium disilicate crowns after required and additional sintering processes. (a) St-0, Straumann n!ce with no sintering process. (b) St-1, Straumann n!ce with one sintering process. (c) St-2, Straumann n!ce with two sintering processes. (d) Am-1, Amber Mill with one sintering process. (e) Am-2, Amber Mill with two sintering processes; (f) Em-1, Emax CAD with one sintering process. (g) Em-2, Emax CAD with two sintering processes.