

Color Stability, Translucency, and Wettability of a Lithium Disilicate Dental Ceramics Submitted to Different Surface Treatments

Eduardo J Soares¹, Rebeca F de Lima Oliveira², Francisca D Jardimino Silame³, Rafaella Tonani-Torrieri⁴, Rodrigo Franca⁵, Fernanda de CP Pires-de-Souza⁶

ABSTRACT

Aim and objective: This study aimed to evaluate the color stability, translucency, and wettability of a lithium disilicate dental ceramic.

Materials and methods: Forty specimens (6 × 1 mm) of lithium disilicate dental ceramic were fabricated. Initial color and translucency readings were measured using a spectrophotometer. Then, the specimens were randomly separated into four groups ($n = 10$), according to the different types of surface treatment (control: control group; HF + S: hydrofluoric acid gel and silane; AI + HF + S: Al₂O₃, hydrofluoric acid gel, and silane; AI + S: Al₂O₃ and silane) and new color and translucency readings were done. The wettability was analyzed using the sessile drop method in all specimens, and the results were statistically analyzed using one-way ANOVA and the Tukey test ($p < 0.05$).

Results: The results showed higher color and translucency changes to the groups treated (HF + S, AI + HF + S, and AI + S), different ($p < 0.05$) from the control group, and without significance between them. All groups demonstrated different wettability ($p < 0.05$), lower for the control group.

Conclusion: It is possible to conclude that the surface treatment can influence the color, translucency, and wettability of lithium disilicate dental ceramics.

Keywords: Ceramic bonding, Color stability, Lithium disilicate, Translucency, Wettability.

International Journal of Prosthodontics and Restorative Dentistry (2021): 10.5005/jp-journals-10019-1304

INTRODUCTION

Currently, cosmetic treatments are common due to the esthetic appeal in modern society. Dental ceramics are the first-choice material for prosthetic restorations of anterior teeth because of its translucency and optical properties, which are similar to those of the teeth.¹⁻³

Besides having a pleasant esthetic, dental ceramic is an inert material and has excellent mechanical properties, like elastic modulus of 900 GPa, flexural strength of 900 MPa, and fracture strength of 3–7 MPa when submitted to static forces.⁴⁻⁷ The same properties evaluated in resin composites showed values of 8–15 GPa, 70–130 MPa, and 0.7–1.5 MPa, respectively.^{6,8,9} Thus, dental ceramic has been demonstrated to have superior mechanical properties and could be the material of choice for esthetic treatments.

The success of ceramic veneers depends on different aspects like the adhesion between the resin cement and substrate (enamel or dentin), between the resin cement and the internal surface of the dental ceramic,¹⁰ and also on the esthetic outcome.

The esthetics of ceramic veneers can be influenced by many factors. One of them is the resin cement shade which can improve or jeopardize the final color of the restoration.¹¹⁻¹⁴ The shade selection of resin cement is a challenging procedure, and the correct choice can reduce the color change of the final restoration. However, the thickness of the resin cement can also influence the esthetic restoration.¹¹ According to Vichi et al.,¹¹ the thicker the resin cement, the higher is the alteration of the ceramics' optical properties when associated with a lower dental ceramic thickness.

^{1,2,4,6}Department of Dental Materials and Prosthodontics, Ribeirão Preto School of Dentistry, University of São Paulo, Ribeirão Preto, São Paulo, Brazil

³Department of Clinical Pathology and Dental Surgery, School of Dentistry, Federal University of Minas Gerais, Belo Horizonte, Minas Gerais Brazil

⁵Department of Restorative Dentistry, College of Dentistry, Faculty of Health Sciences University of Manitoba, Winnipeg, Canada

Corresponding Author: Fernanda de CP Pires-de-Souza, Department of Dental Materials and Prosthodontics, Ribeirão Preto School of Dentistry, University of São Paulo, Ribeirão Preto, São Paulo, Brazil, Phone: +55 16 3315 3973, e-mail: ferpanzeri@usp.br

How to cite this article: Soares EJ, de Lima Oliveira RF, Jardimino Silame FD, et al. Color Stability, Translucency, and Wettability of a Lithium Disilicate Dental Ceramics Submitted to Different Surface Treatments. *Int J Prosthodont Restor Dent* 2021;11(1):4–8.

Source of support: Nil

Conflict of interest: None

The dental ceramic surface treatment is essential to the fixation of the restoration and when it is performed, creates microporosity that improves the micromechanical retention and adhesion of resin cement.^{15,16} Thus, the interaction between the resin cement and the dental ceramic surface is also improved, causing a better flow and penetration of the luting agent, and consequently a smaller thickness of the resin cement.¹³ Nevertheless, the factual results of the interaction between ceramics' wettability and resin cement thickness are still not known.

There are different ceramic surface treatments like air abrasion with aluminum oxide and silane or hydrofluoric acid etching and silane, or the combination of air abrasion with aluminum oxide, hydrofluoric acid etching, and silane. All these treatments aim to improve the contact area between the resin cement and the dental ceramic.^{17,18}

There are many techniques and fixation protocols, which generates doubt among dentists about which technique to choose. Despite much research and advances in this area, there is still not enough evidence to provide theoretical, practical, and scientific knowledge for dentists to affirm which technique is best.¹⁹ Cosmetic treatments require a lot of skill and knowledge from dentists, to be able to understand the patients' needs and choose the best technique for each situation.

Researchers have investigated the influence of different types of surface treatments and bond strength.^{19–22} The variation of roughness can change the ceramics' optical properties. Although the translucency and color change of dental ceramics have been evaluated in the literature, the influence of different kinds of surface treatments on the ceramics' optical properties should be better clarified.

This study aimed to investigate the influence of different types of surface treatments on the color change, translucency, and wettability of a lithium disilicate dental ceramic. The null hypothesis of the study was that there would be no difference in color change, translucency, and wettability regardless of the type of surface treatment of dental ceramics.

MATERIALS AND METHODS

In this study, 40 samples of lithium disilicate-based dental ceramic (IPS e.max Press, Ivoclar Vivadent, Schaan, Liechtenstein) were used to test three different types of surface treatments which are hydrofluoric acid and silane; aluminum oxide abrasion, hydrofluoric acid, and silane; aluminum oxide abrasion and silane. Alterations in color, translucency, and wettability were measured before and after the treatments.

Sample Preparation

Lithium disilicate-based dental ceramic (IPS e.max Press; Ivoclar Vivadent, Schaan, Liechtenstein) was used to fabricate 40 samples (6 mm diameter × 1 mm thickness) using the lost wax casting method. The 1 mm thickness was chosen because this would be the greater thickness possible to a ceramic laminate, according to the recommendation of this kind of restoration. For this purpose, melted wax (Ceras Rainbow Ltda; Porto Ferreira, Brazil) was placed in a Teflon mold. After cooling, the wax patterns were placed inside the silicon rings (IPS Silicon Ring; Ivoclar Vivadent, Schaan, Liechtenstein) following the manufacturer's guidelines. The investment material (IPS PressVest; Ivoclar Vivadent, Schaan, Liechtenstein) was measured, mixed with the proper liquids, and poured into the silicon rings.

After the material set, the silicon rings were removed, and the investment cylinder was processed (3000-3P EDG, EDG Equipamentos e Controles; São Carlos, Brazil) at 850°C to burn out the wax. The dental ceramic was heat pressed (Programat EP 5000; Ivoclar Vivadent, Schaan, Liechtenstein) according to the manufacturer's recommendations (Technical Manual IPS e.max Press, 2009).

After cooling, the specimens were separated, finished with microsphere abrasion (Renfert; Hilzingen, Germany), and polished

using abrasive stones, diamond burs, and specific rubber discs (EVE; Ernst Vetter GmbH; Pforzheim, Germany). The samples were cleaned ultrasonically for 1 minute and 30 seconds (Cuba de Ultrassom, Cristófoli Equipamentos de Biossegurança LTDA; Campo Mourão, Brazil) using 10 mL of Invex liquid (Ivoclar Vivadent, Schaan, Liechtenstein), rinsed under running water, dried with air, and air abraded with spherical aluminum oxide particles at 1–2 bar pressure.

Each sample was polished (Polipan-U, Panambra; São Paulo, Brazil) with abrasive papers (Norton 600, 1000, and 1200 grits), and the final thickness was measured with a digital caliper (Digimess, Instruments Precision LTDA; São Paulo, Brazil). The dental ceramic specimens were cleaned ultrasonically with 90% ethanol for 4 minutes and glazed at 403°C for 6 minutes and 770°C for 1 minute and 30 seconds.

Surface Treatments

The samples were randomly separated into four groups (Control, HF + S, Al + HF + S, and Al + S) according to the surface treatment received ($n = 10$). The power mean (92.94%) was calculated by the comparison of means with a confidence interval of 95% (openepi.com/power/powermean.htm).

Control (Control Group)

No surface treatment was performed.

HF + S

The dental ceramic samples were etched with 5% hydrofluoric acid (HF) gel (Condicionador de Porcelanas, Dentsply; Petrópolis, Brazil) for 20 seconds, rinsed, and dried with air. Silane was applied for 1 minute (Monobond S, Ivoclar Vivadent; Schaan, Liechtenstein).

Al + HF + S

The dental ceramic surfaces were air-abraded with aluminum oxide particles at 10 mm of distance at 1 bar pressure (15 psi). Then, the samples were etched with 5% hydrofluoric acid gel (Condicionador de Porcelanas, Dentsply; Petrópolis, Brazil) for 20 seconds, rinsed, dried with air, and silane was applied for 1 minute (Monobond S; Ivoclar Vivadent; Schaan, Liechtenstein).

Al + S

The specimens were air-abraded with aluminum oxide particles at 10 mm of distance at 1 bar pressure (15 psi). Then, silane was applied for one minute (Monobond S; Ivoclar Vivadent; Schaan, Liechtenstein).

Color and Translucency Alteration

Figure 1 summarizes all the methods applied on the study. Color measurements were performed in all samples on the polished surface (Vita Easyshade, VITA Zahnfabrik; Bad Säckingen, Germany), on a black and white background (BYK, Mast; Santo André, Brazil). The equipment has a 6 mm diameter digital pointer, with 19 individual optical fibers that illuminate the restorative material and two spectrophotometric sensors able to read color numerically. For color readings, the pointer was centralized and placed on the specimen and occupied its entire diameter, allowing the readings to be done in the same position every time.

The optical geometry of color measurement of this device is circular, with the specular component excluded, which simulates a 45/0 measurement. The standard illuminant used was D65 and a standard observer of 2°. The excluded specular component is

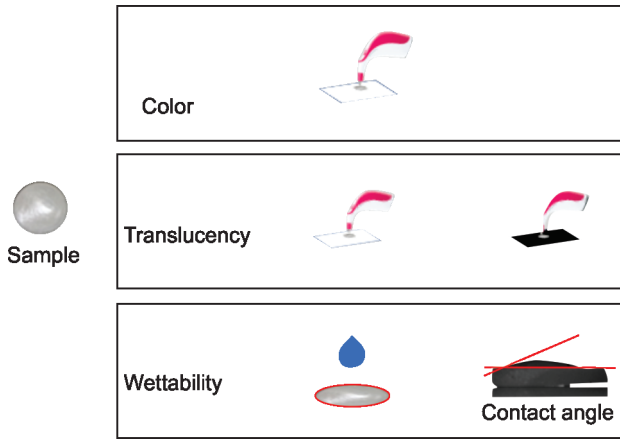


Fig. 1: Flow diagram shows how the study was conducted

related to the color measurement on the sample surface to prevent the interference of surface brightness.^{23,24}

Color measurements (before and after treatments) were made in a standardized lightbox (Gester International; Fujian Province, China) with a neutral-grey (Munsell N-7) background and under primary standard illuminant D65, which simulates the light spectrum of the day.

For color analysis, the observation standard followed the CIEDE 2000 system, defined by the following formula: $\Delta E_{00} = (\Delta L/K_L \cdot S_L) + (\Delta C/K_C \cdot S_C)^2 + (\Delta H/K_H \cdot S_H)^2 + RT$. $(\Delta C/K_C \cdot S_C) \times (\Delta H/K_H \cdot S_H)^{0.5}$, where ΔL , ΔC , and ΔH are the differences in lightness, chroma, and hue between two specimens, respectively, and RT (rotation function) is a function that accounts for the interaction between chroma and hue differences in the blue region. S_L , S_C , and S_H are the weighting functions for the lightness, chroma, and hue components, respectively. K_L , K_C , and K_H are the parametric factors according to different viewing parameters that were set to one. For clinical relevance, 50:50% perceptibility and acceptability thresholds used were 0.8 and 1.8, respectively.²⁵

The translucency was calculated by the translucency parameter (TP). This calculation is obtained by the color difference between the sample over the white background and then over the black background using the following formula:²

$$TP^* = \left((L^*_b - L^*_w)^2 + (a^*_b - a^*_w)^2 + (b^*_b - b^*_w)^2 \right)^{1/2}$$

Where “w” refers to the color coordinates over the white background and “b” refers to the color coordinates over the black background. The adopted perceptibility threshold (PT) was 0.62, and the acceptability threshold (AT) was 2.62.²⁶

The color and translucency change data were statistically analyzed by one-way ANOVA and the Tukey test ($\alpha = 0.05$).

Wettability

The evaluation of the influence of different ceramic surface treatments on wettability was performed by measuring the contact angle (CA) using the sessile drop method. This method consists of measuring the angle between the tangent plane, the liquid surface, and the horizontal plane.

A droplet of distilled water (1 µL) was placed on the treated surface of the dental ceramic samples, and the CA was measured, before and after the treatments, using a goniometer (CAM200, KSV

Table 1: Color change (CIEDE 2000), translucency (TP), and contact angle mean (±standard deviation) comparisons for all groups

Groups	CIEDE 2000	Translucency	Contact angle
Control	0.31 ± 0.2 ^B	1.10 ± 0.7 ^B	59.86 ± 0.5 ^A
HF + S	0.96 ± 0.4 ^A	4.93 ± 2.6 ^A	21.25 ± 3.1 ^B
Al + HF + S	1.42 ± 0.7 ^A	3.09 ± 1.8 ^{AB}	34.77 ± 7.8 ^C
Al + S	1.22 ± 0.5 ^A	1.43 ± 0.7 ^B	11.97 ± 3.1 ^D

Means followed by different superscript capital letters in columns represent statistically significant differences (one-way ANOVA, the Tukey test, $p < 0.05$)

Instruments; Helsinki, Finland). Then, the CA was calculated using the ImageJ software (Research Services Branch, National Institute of Mental Health; Bethesda, MD, USA).

The data were analyzed according to its normality (Shapiro–Wilk) and the data did not meet the assumption of the equality of variance across groups (Levene’s test, $p < 0.05$). One variation factor was analyzed (surface treatment), the data were submitted to variance analysis (one-way ANOVA), followed by *post hoc* Tukey’s test ($\alpha = 0.05$).

RESULTS

The mean comparisons (one-way ANOVA, the Tukey test, $p < 0.05$) for all results are presented in Table 1. For color change, the smaller alteration occurred for control (control group), statistically different ($p < 0.05$) from the other groups that showed similar results ($p > 0.05$) to each other. All color change values were below the AT, but all the treatments showed color change above the PT.

The treatment with HF + silane produced higher translucency of the dental ceramic, differently ($p < 0.05$) from Control, which showed less translucency, and Al + S, with no difference between them. The ceramic translucency after treatment with Al₂O₃ + HF + silane was similar to all other treatments ($p > 0.05$). All groups showed translucency above the PT, but only HF + S and Al + S showed greater than the AT. For wettability, there were differences between all groups ($p < 0.05$). Thus, the wettability was higher for Al + S > HF + S > Al + HF + S > Control (greater CA).

DISCUSSION

This study analyzed the influence of different types of surface treatments on the color change, translucency, and wettability of a lithium disilicate dental ceramic. The null hypothesis proposed was rejected, as there were statistical differences among the results.

Color measurement was made by a spectrophotometer because this equipment can detect minor color differences in a spectrum not detected by the human eye.²⁷ The color change can be calculated by CIELAB metric or CIEDE 2000, but in this study, the authors used the CIEDE 2000 equation because recent studies proved this method is more efficient and should be the first option in dentistry.^{27,28}

It is common knowledge that surface treatments affect the roughness and bond strength of dental ceramics,^{16,19–22} and that the success of ceramic restorations depends on many factors, including its color stability and optical properties²⁹ which can be influenced by the ceramics surface roughness.^{29–31} However, few studies have reported the interaction of surface treatment with color change and translucency.^{17,32} All the different surface treatments used in



this study were able to perceptibly change the color of the dental ceramic but within the acceptability threshold.^{25,33} This can be explained because the surface treatment changes the ceramics' surface roughness.

The etching and air-abrasion with aluminum oxide procedures remove the vitreous matrix and increases the crystalline phase of the ceramic³⁴ which produces a rougher surface in vitreous ceramics. These findings agree with the literature, which affirms that rough surfaces present more color changes than smooth ones.^{29–31,35} So, all the treated groups demonstrated higher ΔE than the control group. However, the type of surface treatment was not significant for color change. The surface treatment, however, affects other properties. HF + S resulted in higher translucency than Al + S, which resulted in a lower ceramic translucency, similar to the control group, with no treatment. Thus, it was found that the aluminum oxide produces higher ceramic surface alteration than the hydrofluoric acid, which cannot be hidden with silane. When all treatments are associated, the translucency levels are similar to the control and HF + S groups.

Another study found translucency alteration due to surface treatment,³² the authors tested three different types of surface treatments (hydrofluoric acid etching, sandblasting with aluminum oxide, and Er:YAG laser irradiation), and found that the groups treated with aluminum oxide and Er:YAG laser had the lower TP values in comparison to the control group and the HF acid etching group. These results corroborate the ones found in the present study, where the aluminum oxide caused lower translucency than the acid etching. This can be justified because the removal of the vitreous phase of the ceramic after the acid etching is more regular than the one caused by the aluminum oxide air abrasion, due to the force of the aluminum oxide application associated with the process.^{36,37} Still, according to different studies the ceramics microstructure like type, size, amount of crystal, and porosity can influence its optical properties such as light transmission and scattering changing the material translucency,^{38–40} which also justifies the higher translucency caused by the acid etching.

When the treatments were associated, the acid etching possibly removed additional vitreous parts, after the removal by the air abrasion. As this acid removal is more homogeneous than the first treatment, the surface energy will be higher and there will be greater penetration of the silane on the ceramic surface^{41,42} which will allow better penetration and smaller thickness of the resin cement,⁴³ resulting in higher translucency.¹³

The dental ceramic surface should present enough wettability to produce maximum contact with the adhesive materials applied to the surface. The wettability depends on the roughness and energy of the surface,¹⁸ because irregular surfaces possess higher surface energy, and consequently a higher wettability (lower contact angle) improving the contact between the coupling agents and the dental ceramic surface.^{42,44,45} Thus, in the present study, the surface treatment of ceramic interfered in the wettability at different levels, according to the roughness produced by each kind of surface treatment. Surfaces with a more homogeneous roughness, as when the HF is used,^{18,36} presented a lower wettability than the ones that were air-abraded with aluminum oxide, which produced more irregular surfaces, resulting in a lower contact angle. Therefore, air abrasion with aluminum oxide produced an irregular surface that increased the superficial area and improved wettability, and these results are in accordance with the ones found in different studies.^{18,36}

The use of only one kind and one shade of dental ceramic is a limiting factor of this study. Therefore, other studies are needed to verify the optical behavior of different dental ceramics and shades when submitted to surface treatment.

CONCLUSION

Despite the limitations of this study, it is possible to conclude that the surface treatments used produced color and translucency changes in a lithium disilicate-based dental ceramic and influenced its surface's wettability.

REFERENCES

1. Stawarczyk B, Liebermann A, Eichberger M, et al. Evaluation of mechanical and optical behavior of current esthetic dental restorative CAD/CAM composites. *J Mech Behav Biomed Mater* 2016;55:1–11. DOI: 10.1016/j.jmbbm.2015.10.004.
2. Bagis B, Turgut S. Optical properties of current ceramics systems for laminate veneers. *J Dent* 2013;41:e24–e30. DOI: 10.1016/j.jdent.2012.11.013.
3. Wang H, Xiong F, Zhenhua L. Influence of varied surface texture of dentin porcelain on optical properties of porcelain specimens. *J Prosthet Dent* 2011;105(4):242–248. DOI: 10.1016/S0022-3913(11)60039-5.
4. van de Sande FH, Opdam NJ, Da Rosa Rodolpho PA, et al. Patient risk factors' influence on survival of posterior composites. *J Dent Res* 2013;92(7_suppl):S78–S83. DOI: 10.1177/0022034513484337.
5. Quinn JB, Sundar V, Lloyd IK. Influence of microstructure and chemistry on the fracture toughness of dental ceramics. *Dent Mater* 2003;19(7):603–611. DOI: 10.1016/S0109-5641(03)00002-2.
6. Borba M, de Araújo MD, Fukushima KA, et al. Effect of the microstructure on the lifetime of dental ceramics. *Dent Mater* 2011;27(7):710–721. DOI: 10.1016/j.dental.2011.04.003.
7. Della Bona A, Mecholsky JJ, Anusavice KJ. Fracture behavior of lithia disilicate- and leucite-based ceramics. *Dent Mater* 2004;20(10):956–962. DOI: 10.1016/j.dental.2004.02.004.
8. Ferracane JL. Resin composite--state of the art. *Dent Mater* 2011;27(1):29–38. DOI: 10.1016/j.dental.2010.10.020.
9. Gonzaga CC, Cesar PF, Miranda WG, et al. Slow crack growth and reliability of dental ceramics. *Dent Mater* 2011;27(4):394–406. DOI: 10.1016/j.dental.2010.10.025.
10. Addison O, Marquis PM, Fleming GJP. The impact of hydrofluoric acid surface treatments on the performance of a porcelain laminate restorative material. *Dent Mater* 2007;23(4):461–468. DOI: 10.1016/j.dental.2006.03.002.
11. Vichi A, Ferrari M, Davidson CL. Influence of ceramic and cement thickness on the masking of various types of opaque posts. *J Prosthet Dent* 2000;83(4):412–417. DOI: 10.1016/S0022-3913(00)70035-7.
12. Barath VS, Faber FJ, Westland S. Spectrophotometric analysis of all-ceramic materials and their interaction with luting agents and different backgrounds. *Adv Dent Res* 2003;17(1):55–60. DOI: 10.1177%2F154407370301700113.
13. Öztürk E, Chiang Y-C, Coşgun E. Effect of resin shades on opacity of ceramic veneers and polymerization efficiency through ceramics. *J Dent* 2013;41:e8–e14. DOI: 10.1016/j.jdent.2013.06.001.
14. Bayindir F, Koseoglu M. The effect of restoration thickness and resin cement shade on the color and translucency of a high-translucency monolithic zirconia. *J Prosthet Dent* 2020;123(1):149–154. DOI: 10.1016/j.prosdent.2018.11.002.
15. Addison O, Marquis PM, Fleming GJP. Adhesive luting of all-ceramic restorations-The impact of cementation variables and short-term water storage on the strength of a feldspathic dental ceramic. *J Adhes Dent* 2008;10(4):285–293. DOI: 10.3290/j.jad.a13739.
16. Hayakawa T, Horie K, Aida M. The influence of surface conditions and silane agents on the bond of resin to dental porcelain. *Dent Mater* 1992;8(4):238–240. DOI: 10.1016/0109-5641(92)90092-Q.

17. Turgut S, Bağış B, Korkmaz FM. Do surface treatments affect the optical properties of ceramic veneers? *J Prosthet Dent* 2014;112(3):618–624. DOI: 10.1016/j.prosdent.2014.04.001.
18. El Gamal A, Medioni E, Rocca JP. Shear bond, wettability, and AFM evaluations on CO₂ laser-irradiated CAD/CAM ceramic surfaces. *Lasers Med Sci* 2017;32(4):779–785. DOI: 10.1007/s10103-017-2171-4.
19. Yavuz T, Özyılmaz ÖY, Dilber E. Effect of Different Surface Treatments on Porcelain-Resin Bond Strength. *J Prosthodont* 2017;26(5):446–454. DOI: 10.1111/jopr.12387.
20. Kara HB, Dilber E, Koc O. Effect of different surface treatments on roughness of IPS Empress 2 ceramic. *Lasers Med Sci* 2012;27(2):267–272. DOI: 10.1007/s10103-010-0860-3.
21. Barghi N, Berry T, Chung K. Effects of timing and heat treatment of silanated porcelain on the bond strength. *J Oral Rehabil* 2000;27(5):407–412. DOI: 10.1046/j.1365-2842.2000.00508.x.
22. Yavuz T, Dilber E, Kara HB. Effects of different surface treatments on shear bond strength in two different ceramic systems. *Lasers Med Sci* 2013;28(5):1233–1239. DOI: 10.1007/s10103-012-1201-5.
23. Devigus A, Lombardi G, Shading Vita In-ceram YZ. substructures: influence on value and chroma, part II. *Int J Comput Dent* 2004;7(4):379–388.
24. Devigus A, Lombardi G. Shading Vita YZ substructures: influence on value and chroma, part I. *Int J Comput Dent* 2004;7(3):293–301.
25. Paravina RD, Ghinea R, Herrera LJ. Color difference thresholds in dentistry. *J Esthet Restor Dent* 2015;27:51–59. DOI: 10.1111/jerd.12149.
26. Salas M, Lucena C, Herrera LJ. Translucency thresholds for dental materials. *Dent Mater* 2018;34(8):1168–1174. DOI: 10.1016/j.dental.2018.05.001.
27. Perroni AP, Kaizer MR, Della Bona A. Influence of light-cured luting agents and associated factors on the color of ceramic laminate veneers: A systematic review of in vitro studies. *Dent Mater* 2018;34(11):1610–1624. DOI: 10.1016/j.dental.2018.08.298.
28. Pecho OE, Perez MM, Lightness GR. Chroma and hue differences on visual shade matching. *Dent Mater* 2016;32(11):1362–1373. DOI: 10.1016/j.dental.2016.08.218.
29. Haralur SB, Alqahtani NRS, Mujayri FA. Effect of hydrothermal aging and beverages on color stability of lithium disilicate and zirconia based ceramics. *Medicina* 2019;55(11):749. DOI: 10.3390/medicina55110749.
30. Dos Santos DM, Da Silva EVF, Watanabe D. Effect of different acidic solutions on the optical behavior of lithium disilicate ceramics. *J Prosthet Dent* 2017;118(3):430–436. DOI: 10.1016/j.prosdent.2016.10.023.
31. Palla ES, Kontonasaki E, Kantiranis N. Color stability of lithium disilicate ceramics after aging and immersion in common beverages. *J Prosthet Dent* 2018;119(4):632–642. DOI: 10.1016/j.prosdent.2017.04.031.
32. Turgut S, Bagis B, Ayaz EA. How will surface treatments affect the translucency of porcelain laminate veneers? *J Adv Prosthodont* 2014;6(1):8–13. DOI: 10.4047/jap.2014.6.1.8.
33. Paravina RD, Pérez MM, Ghinea R. Acceptability and perceptibility thresholds in dentistry: comprehensive review of clinical and research applications. *J Esthet Restor Dent* 2019;31(2):103–112. DOI: 10.1111/jerd.12465.
34. França R, Bebsch M, Haimeur A. Physicochemical surface characterizations of four dental CAD/CAM lithium disilicate-based glass ceramics on HF etching: An XPS study. *Ceram Int* 2020;46(2):1411–1418. DOI: 10.1016/j.ceramint.2019.09.105.
35. Motro PFK, Kursoglu P, Kazazoglu E. Effects of different surface treatments on stainability of ceramics. *J Prosthet Dent* 2012;108(4):231–237. DOI: 10.1016/S0022-3913(12)60168-1.
36. Dilber A, Yavuz T, Kara HB. Comparison of the effects of surface treatments on roughness of two ceramic systems. *Photomed Laser Surg* 2012;30(6):308–314. DOI: 10.1089/pho.2011.3153.
37. Lima CM, da Silva NR, Martins JD. Effect of different surface treatments on the biaxial flexure strength, Weibull characteristics, roughness, and surface topography of bonded CAD/CAM silica-based ceramics. *Dent Mat* 2020;37(3):e151–e161. DOI: 10.1016/j.dental.2020.11.009.
38. Yildirim B, Recen D, Simsek AT. Effect of cement color and tooth-shaded background on the final color of lithium disilicate and zirconia-reinforced lithium silicate ceramics: An in vitro study. *J Esthet Restor Dent* 2021;33(2):380–386. DOI: 10.1111/jerd.12611.
39. Vasiliu RD, Porojan SD, Birdeanu MI. Effect of thermocycling, surface treatments and microstructure on the optical properties and roughness of CAD-CAM and heat-pressed glass ceramics. *Materials* 2020;13(2):381. DOI: 10.3390/ma13020381.
40. Porojan L, Vasiliu RD, Birdeanu MI. Surface characterization and optical properties of reinforced dental glass-ceramics related to artificial aging. *Molecules* 2020;25(15):3407. DOI: 10.3390/molecules25153407.
41. Lung CYK, Matinlinna JP. Aspects of silane coupling agents and surface conditioning in dentistry: An overview. *Dent Mat* 2012;28(5):467–477. DOI: 10.1016/j.dental.2012.02.009.
42. Ramakrishnaiah R, Alkheraif AA, Divakar DD. The effect of hydrofluoric acid etching duration on the surface micromorphology, roughness, and wettability of dental ceramics. *Int J Mol Sci* 2016;17(6):822. DOI: 10.3390/ijms17060822.
43. Lawson NC, Jurado CA, Huang CT. Effect of surface treatment and cement on fracture load of traditional zirconia (3Y), translucent zirconia (5Y), and lithium disilicate crowns. *J Prosthodont* 2019;28(6):659–665. DOI: 10.1111/jopr.13088.
44. Strasser T, Preis V, Behr M. Roughness, surface energy, and superficial damages of CAD/CAM materials after surface treatment. *Clin Oral Investig* 2018;22(8):2787–2797. DOI: 10.1007/s00784-018-2365-6.
45. Sudré JP, Salvio LA, Baroudi K. Influence of surface treatment of Lithium disilicate on roughness and bond strength. *Int J Prosthodont* 2020;33(2):212–216. DOI: 10.11607/ijp.6453.