Official Dental Journal of Suez Canal University
DENTAL SCIENCE Updates
Print ISSN 2636-3836
Online ISSN 2636-3844
www.dsujournals.ekb.eg
DSU
DSU — Vol. 1, No. 1, March (2020) — PP. 15:22

EFFECT OF SURFACE TREATMENTS ON THE COLOR CHANGE AND SHEAR BOND STRENGTH OF PORCELAIN LAMINATE VENEER

Passant Tarek Abdelhamid Hafez[1], Mosaad Ali Elgabarouny[2], Latifa Mohamed Abdelgawad[3], Amr Abdelaziz Shebl[4]

DOI: 10.21608/dsu.2020.14074.1003

KEYWORDS

Co2 laser,
Hydrofluoric acid,
Lithium disilicate.

- E-mail address:
  email: poso_mouse@hotmail.com

1. B.D.S (2009) - Misr International University
2. Professor of Crown and Bridge- Faculty of Dentistry - Suez Canal University
3. Professor of Oral Laser Application, National Institute of Laser Enhanced Sciences - Cairo University
4. Lecturer of Crown and Bridge, Faculty of Dentistry, Suez Canal University

ABSTRACT

Aim of the study: the purpose of this In-vitro study was to evaluate the effect of surface treatments on the color change and shear bond strength of lithium disilicate glass ceramic veneers. **Materials & Methods**: Twenty square samples with dimensions (8x8x2) and another twenty samples with smaller dimensions (4x4x2) were cut from five IPS e-max CAD blocks of shade A3. The discs were divided into two groups: 1) Half of the small and large blocks were subjected to hydrofluoric acid (HF); 2) the other half was subjected to Co2 laser irradiation. The conditioned samples were subdivided according to the bonding agent: A) Silane application for 60 seconds; B) Single bond universal light cured for 10 seconds. Each small sample was cemented on the top of a large sample using RelyX veneer cement with translucent shade. The color change was measured using spectrophotometer. The shear bond strength was tested using a universal testing machine. **Results:** HF resulted in higher bond shear bond strength and ΔE than Co2 laser. Single bond universal resulted in higher shear bond strength values than silane. **Conclusion:** HF followed by either single bond universal or silane could be the best surface treatment for e-max CAD ceramic. However, Co2 laser could be a promising alternative surface treatment.

INTRODUCTION

Patients demand to restore the lost natural appearance is one of the most critical topics in the dental practice. Recently, ceramic veneer restorations have been proposed as a satisfying treatment option for a wide range of clinical cases including hypoplasia, fluorosis, tetracycline discoloration and diastema closure [(1)].

IPS e-max CAD is the machineable form of lithium disilicate glass ceramic that was introduced in 2007 by Ivoclar Vivadent to be milled using CAD/CAM technology. It has become always the material of choice to fabricate esthetic restorations especially ceramic veneers because of its light diffusion property which is capable of replicating the natural tooth structure. However, there are many requirements for success of veneers. The most fundamental requirements are ensuring proper color selection, perfect bond strength and proper cementation [(2)].

Many conventional methods were used to improve the bond strength of ceramic veneers to the resin cement such as air-particle abrasion with aluminum oxide particles and etching with hydrofluoric or phosphoric acid. Hydrofluoric acid etching is the most commonly used surface conditioning method together with the use of bonding agents such as silane primer and single bond universal to improve bond strength between resin cement and ceramic prior to cementation [3].

Recently many types of lasers have been proposed to be used to enhance the shear bond strength of resin cement to glass ceramics including neodymium: yttrium aluminum garnet (Nd:YAG), erbium (Er):YAG, erbium, chromium: yttrium, scandium, gallium, garnet (Er,Cr:YSGG) and carbon dioxide (Co_2) laser. The term laser stands for "light Amplification by the Stimulated Emission of Radiation". This study evaluated the effect of carbon dioxide laser irradiation and hydrofluoric acid etching on the shear bond strength and color changes of IPS e-max CAD ceramic [4].

MATERIALS AND METHODS

20 square samples with dimensions (8x8x2) and another 20 samples with smaller dimensions (4x4x2) were cut from five IPS emax CAD blocks of shade A3 with low translucency. The blocks were sectioned in the blue state before crystallization using a low speed cutting saw machine. A diamond disk of 0.6 mm thickness was used with cutting speed 2500 rpm and feeding rate 10mm/ min under water cooling. The thickness of each sample was checked with a digital caliper & then sintered at 850°C in Ceramill furnace. Crystallization process ranges from 20-30 min. and then the samples were allowed to cool down in room temperature after completing the process.

The samples were divided into two groups according to the conditioning technique: **Group 1:** Ten large and small samples and were acid etched from one side by hydrofluoric acid (8%) for 60 seconds. All the discs were rinsed after surface conditioning in distilled water and then dried using oil free compressed air. **Group 2:** Ten large and small samples were subjected to laser irradiation using Co2 laser source in a circular movement to the sample surface at distance 1mm. The Co2 laser was used at power setting of 5Watt for 20 seconds in a continuous mode. Each sample group was divided into 2 subgroups as follows: **Subgroup A:** Silane coupling agent was applied to the conditioned surfaces of each five small and large samples for one minute and then dried with an oil free compressed air & **Subgroup B**: Single bond universal was applied to the conditioned surfaces of each five small and large samples. It was then air dried and light cured for 10 seconds.

Cementation: Each small sample was cemented on the middle of a large samples using Rely-x translucent veneer cement according to manufacturer recommendations. A 1-kg weight was placed on the top of the samples to ensure a uniform thickness of cement and excess cement was removed then light cured for 20 seconds.

Evaluation of colour changes (ΔE) of the cemented specimens:

The cemented specimens were placed on a white sheet to act as a constant background. The change in color (ΔE) between the selected shade A3 of the cemented specimens and the resulted shade after the surface conditioning was measured using digital spectrophotometer (Vita Easy shade). The tip of the probe was held at the centre of the specimens and the probe tip was maintained perpendicular to the surface of each specimen. After that either (Good), (Fair) or (Adjust) will be displayed on the screen. This process was repeated three times for each specimen in the four subgroups and after each reading the easy shade was recalibrated.

Evaluation of shear bond strength of the cemented specimens:

The shear bond strength of each specimen was measured using a universal testing machine. A shear force was applied using the chisel metallic rod placed at the cement interface between the two cemented samples and the machine was operated a cross-head speed of 0.5 mm/min. The results were displayed on a computer screen with a diagram for each specimen showing the fracture point. The load at which failure occurred was recorded in Newton (N) and then transformed into Megapascals (MPa).

Samples were viewed under scanning electron microscope (SEM) before and after surface conditioning to evaluate the surface roughness & surface morphology.

Statistical analysis

The color change (ΔE) and shear bond strength results were tabulated and statistically analysed. Analysis of variance test (ANOVA) was used to calculate the results of the four subgroups.

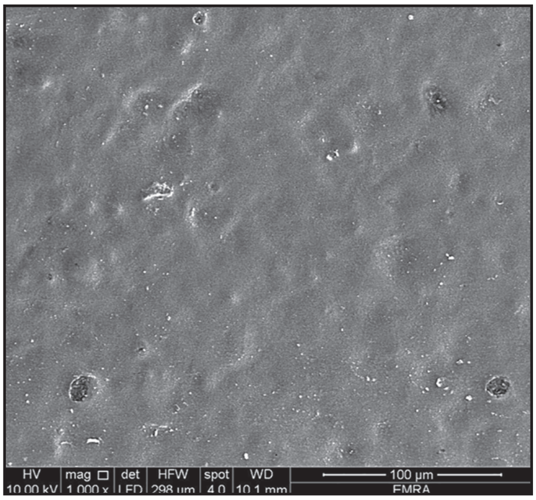


Fig. (1) Surface view under SEM before surface conditioning.

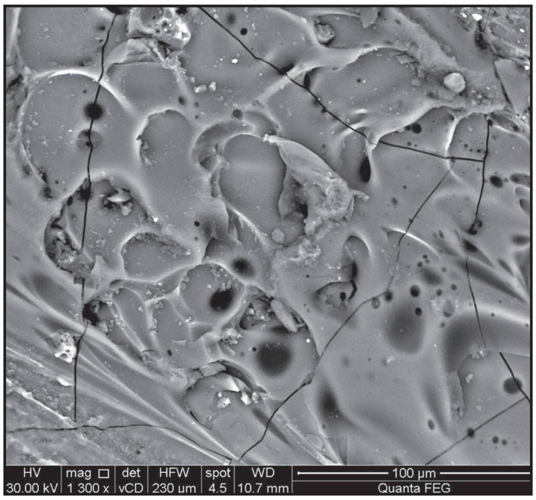


Fig. (2) Surface view under electron microscope after surface conditioning with Co2 laser.

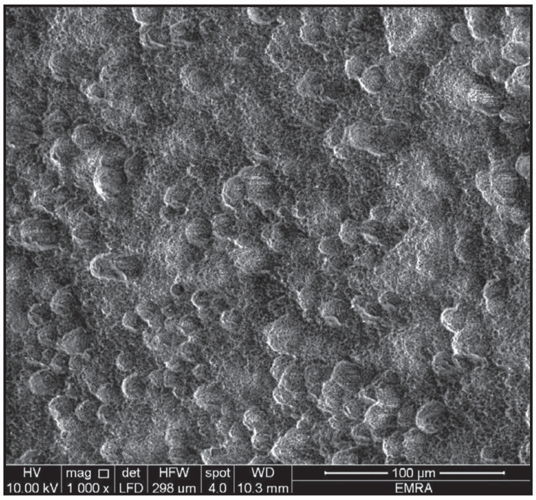


Fig. (3) Surface view under electron microscope after surface treatment with hydrofluoric acid.

RESULTS

Analysis of variance test (ANOVA) was used to calculate the results of the four subgroups.

Color change ΔE

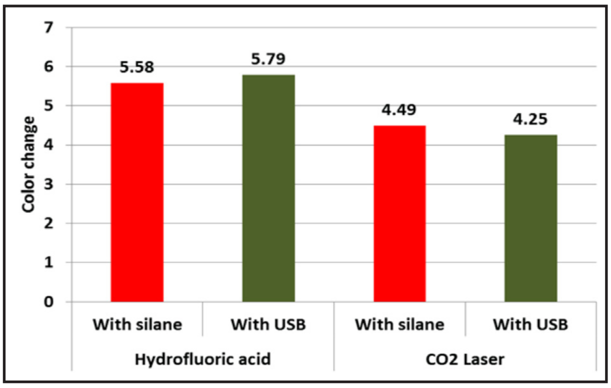
The mean ΔE of the subgroup **A1** showed higher value than subgroup **A2**. The statistical analysis of ΔE of both subgroups **A1** & **A2** revealed a statistically significant difference (P value = 0.009) as shown in table 1. The mean ΔE of the subgroup **B1** showed higher value than subgroup **B2** of value. The statistical analysis of ΔE between both subgroups **B1** and **B2** revealed a statistically significant difference (P-value= 0.009) as shown in table 2. All results were represented in graph 1.

Table (1): *Mean and SD of Color change of subgroup A1 & A2*

Color change	Hydrofluoric acid with silane (subgroup A1)	CO2 Laserwithsilane (subgroup A2)	p-value
Mean ± SD	5.58 ± 0.59	4.49 ± 0.19	0.009

Table (2): *Mean and Standard deviation (SD) of Color change between subgroup B1 & B2*

Color change	Hydrofluoric acid with universal single bond (B1)	CO2 Laser with universal single bond (B2)	p-value
Mean ± SD	5.79 ± 0.4	4.25 ± 0.38	0.009



Graph (1): Color change ΔE with different surface treatments.

Shear bond strength

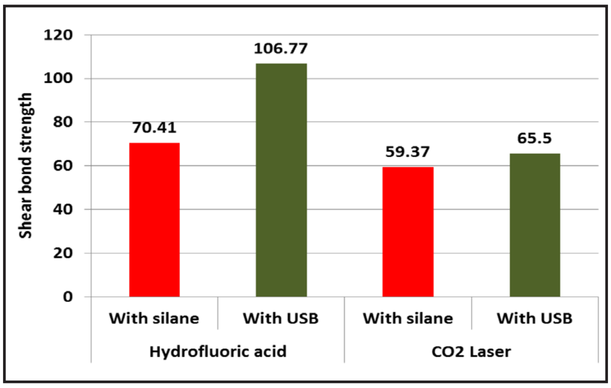
The mean shear bond strength of subgroup **A1** showed higher value than subgroup **A2**. The statistical analysis of mean and standard deviation of both subgroups revealed that there was no statistically significant difference between the two subgroups (P-value=0.08) as shown in table 3. The mean shear bond strength of subgroup **B1** showed higher value than subgroup **B2**. The statistical analysis of mean and standard deviation of both subgroups **B1** & **B2** revealed a statistically significant difference (P value = 0.009) as shown in table 4. All results were represented in graph 2.

Table (3): *Mean shear bond strength between A1 and A2.*

Shear bond strength	Hydrofluoric acid with silane (subgroup A1)	CO_2 Laser with silane (subgroup A2)	P-value
Mean ± SD	70.41 ± 46.62	59.37 ± 17.11	0.08

Table (4): Mean shear bond strength between B1 & B2.

Shear bond strength	Hydrofluoric acid with universal single bond (subgroup B1)	CO_2 Laser with single bond universal (subgroup B2)	p-value
Mean ± SD	106.77± 74.53	65.5 ± 24.95	0.009*



Graph (2): Shear bond strength with different surface treatments.

DISCUSSION

In the current study, Co_2 laser was chosen to be an alternative surface treatment method for hydrofluoric acid because it might be hazardous for both the operator and patient. The operator must be protected from skin and eye damage, and any remaining HF acid must be removed completely with before cementation [5, 6]. At the same time, Co_2 laser irradiation is a relatively safe and easy surface treatment method. Carbon dioxide laser has the highest power beam of infrared light with the principal wavelength 10.6 micrometers (10600 nm) compared to other types of lasers (Erbium:YAG lasers: 2940 nm, Nd-YAG Lasers: 1068 nm and Diode lasers: 800 nm). It was applied at a power setting 5W. This power is able to create smooth and shallow depressions and pores in ceramic surface that are adequate for proper micro mechanical adhesion with minor crack formation [7, 8].

Samples treated with hydrofluoric acid in both subgroups (silane and SBU) produced higher values of mean shear bond strength than those subjected to Co_2 laser irradiation subgroups. This could be related to the different mechanisms of action of both hydrofluoric acid and Co_2 laser irradiation in altering the morphology of the ceramic veneers. IPS e-max CAD material consists of two crystalline phases; the main crystalline phase consists of elongated lithium disilicate crystals while the second crystalline phase consists of lithium orthophosphate and a glass matrix surrounds both crystalline phases[9-11]. Hydrofluoric acid was capable to remove the glass matrix and the lithium orthophosphate crystalline phase exposing only lithium disilicate crystals, which create an irregular rough surface thus increasing the surface area favorable to a good micromechanical adhesion [12-14]. This could explain why HF samples under SEM represented much rough surface with porous appearance.

On the other hand, Co2 laser caused thermal vaporization of the substrate by absorbing laser light allowing laser energy to convert to thermal energy thus creating thermo-mechanical effects on the ceramic substrates [15]. Laser energy discharge irradiation worked out by fusing and melting the thin most superficial layer of ceramic surface and its re-solidification forming micromechanical retention pattern which is different from the other surface treatments [16, 17].

In this study specimens subjected to application of Single Bond Universal exhibited the higher shear bond strength when compared to those treated with silane. This could be contributed to the fact that both universal single bond and silane have different chemical composition.

Silanes are bifunctional hybrid organic compounds that could be used to increase the physical, chemical and mechanical adhesion through the creation of a chemical covalent siloxane bond (Si-O-Si) with the hydroxyl groups on the ceramic surface. [18-20].

On the other hand, Single Bond Universal adhesives contain 10-methacryloxydecyl dihydrogenphosphate monomer (MDP), vitrebond copolymer, silane, Bisphenol A-glycidyl methacrylate (Bis-GMA), hydroxyl ethyl methacrylate (HEMA), together with fillers and water [20]. MDP is a functional monomer that is embedded in an aqueous solution. It possesses the ideal bonding agent property where the polar phosphate group of functional monomer is initially hydrophilic and becomes more hydrophobic after polymerization. When it is applied the hydrogen group of the phosphate monomer and the oxygen group of the ceramics slowly react to produce water molecules and form a stable covalent bond that provide a low PH environment at the interface and allow the adhesive bond (self-etching property) [21, 22]. Vitrebond copolymer is a type of methacrylate-modified polyalkenoic acid copolymer. This component may contribute to less technical sensitivity and its use could result in improved application procedures by allowing bonding to moist or to dry surface and thus it could manage the hydrphobicity of MDP after polymerization [9]. Bis-GMA increased the viscosity and the mechanical strength of the coupling layer applied. [21, 23]. HEMA is a co-polymer which could improve the bond strength through acting as a solvent preventing the separation of both the hydrophilic and hydrophobic phases [24].

Some authors suggested that silane available in the universal adhesives does not play a role in adhesion of resin cement to ceramic. This could be in agreement with **Yao *et al* (2017)** [9] who reported that single bond universal containing silane resulted in higher shear bond strength than silane free universal adhesives, but with no statistically significant difference. They reported that the higher results could be contributed to the other components (monomers) in single bond universal not to silane.

There was no statistically significant difference between the shear bond strength of samples subjected to silane application after Co_2 laser and those subjected to single bond universal. This is because Co_2 laser enhanced the effect of silane coupling agent on shear bond strength. It has been reported by **Chen (2010)** [26] that heat induced from Co2 laser effectively achieved this goal because it was able to consolidate three layers of silane into a monolayer without any inter-phase layer. This heat generation could successfully be induced through the Co_2 irradiation where the mechanism of adhesion enhancement between ceramic veneers and resin cement using both chemical process achieved with silane and mechanical processes done by Co_2 irradiation.

Changes in the surface texture and roughness as a result of the applied surface treatments could significantly affect the optical properties of ceramic. When a surface was smooth the light reflected at the same incidence and direction [10]. However, when the surface was rough diffuse reflection occurs and light reflects in different directions. The interpretation of the color of any object is affected by the nature of this object as it may transmit, reflect or absorb light [26]. If most of the light passes through this material is scattered and reflected, the object will appear opaque. If only part of the light is scattered and most of it is transmitted, the object will appear translucent [27]. Hydrofluoric acid etching could affect the translucency of ceramic where it became less translucent due to the loss of the glassy matrix and therefore less light will pass through the ceramic[28-30]. This could explain why hydrofluoric acid showed higher values of ΔE.

Single bond universal subgroup showed more color changes than the silane subgroup but with no statistically significant difference. This could be related to the oxidative reactions between the camphorquinone and the amines present in the SBU composition which resulted in yellowish color effect that could affect the translucency of ceramic[31,32].

CONCLUSION

Within the limitations and conditions of this in vitro study, it could be concluded that:

1. IPS e-max CAD ceramics conditioned with hydrofluoric acid showed higher shear bond strength values than those conditioned with Co2 laser. However, Co_2 laser conditioning showed acceptable shear bond strength.
2. IPS e-max CAD ceramics bonded with single bond universal showed higher shear bond strength than those conditioned with silane.
3. Hydrofluoric acid conditioning accompanied with the use of bonding agents changed the color of e-max CAD ceramics more than Co_2 laser conditioning accompanied with the use of bonding agents.

REFERENCES

1. Ritzberger C., Apel E., Höland W., Peschke A., and Rheinberger V. Properties and Clinical Application of Three Types of Dental Glass-Ceramics and Ceramics for CAD-CAM Technologies Mater (Basel). 2010 Jun; 3(6): 3700–13. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5521757/
2. Holand W., Rheinberger V., Apel E., Hoen C., Holand M. clinical applications of glass ceramics in dentistry. J mater sci. 2006; 17(11): 1037-42. https://www.ncbi.nlm.nih.gov/pubmed/17122916
3. Kara H., Dilber E., Koc O., Ozturk N., Bulbu M. Effect of different surface treatments on roughness of IPS Empress 2 ceramic. L Med Sci. 2012 Mar. 27 (2); 267–72. https://www.ncbi.nlm.nih.gov/pubmed/21110057
4. David C., Gupta P. Lasers in Dentistry: A Review.Int J Adv H Sci. 2015 Dec; 2(8). https://pdfs.semanticscholar.org/c4d8/53f1334b55c903664400656c1e4d2d14e8a3.pdf
5. Kursoglu P., Motro P., Yurdaguven H. Shear bond strength of resin cement to an acid etched and a laser irradiated ceramic surface. J Adv Prosthodont 2013;5: 98-103. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3675300/
6. Caprena G. & Ballarin A. Hydrofluoric Acid – Simple Things you may do not know about Something you are so habituated to Use. ODOVTOS-Int. J. Dental S.C. 2014;16: 15-23. http://www.fodo.ucr.ac.cr/sites/default/files/revista/Carpena.pdf
7. El Gamal A., Fornaini C., Rocca J., Muhammad O., Medioni E., Cucinotta A., Bouchard N. The effect of CO2 and Nd:YAP lasers on CAD/CAM Ceramics: SEM, EDS and thermal studies. Laser Therapy. 2016 Mar 31; 25(1): 27–34. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4846837/
8. Sundfeld D., Sobrinho L., Pini N., Costa A., Sundfeld R., Pfeifer C., Martins L. The Effect of Hydrofluoric Acid Concentration and Heat on the Bonding to Lithium Disilicate Glass Ceramic. Braz. Dent. J. 2016 Dec. 27(6). https://www.ncbi.nlm.nih.gov/pubmed/27982186
9. Yao C., Zhou L., Yang H., Wang Y., Sun H., Guo J., Huang C. Effect of silane pretreatment on the immediate bonding of universal adhesives to computer-aided design/computer-aided manufacturing lithium disilicate glass ceramics. Eur J Oral Sci. 2017 Apr; 125(2):173-80. https://www.ncbi.nlm.nih.gov/pubmed/28233438
10. Gre C., Lopes G., Junior S., Araujo E. silanization effect on microtensile bond strength of a self-adhesive luting material to disilicate based ceramic. RSBO.2015 Apr-Jun;12(2):179-84. http://revodonto.bvsalud.org/scielo.php?script=sci_arttext&pid=S1984-56852015000200006
11. Mokhtarpour F., Alaghehmand H., Khafri S. Effect of hydrofluoric acid surface treatments on micro-shear bond strength of CAD/CAM ceramics. Elec phys. 2017 Oct; 9(10):5487-93. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5718852/
12. Erdemir U., Sancakli H., Sancakli E., Eren M., Ozel S., Yucel T., Yildiz E. shear bond strength of a new sel adhering flowable composite resin for lithium disilicate- reinforced CAD/CAM ceramic material , J Adv Prosthodont 2014 Dec; 6(6): 434-43. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4279040/
13. Stawarczyk B., Hristova E., Sener B., Roos M., Edelhoff D., Keul C. Effect of Hydrofluoric Acid Etching Duration on Fracture Load and Surface Properties of Three CAD/CAM Glass-Ceramics. OHDM. 2014 Dec; 13(4): 1131-9. https://www.researchgate.net/publication/269390779_Effect_of_Hydrofluoric_Acid_Etching_Duration_on_Fracture_Load_and_Surface_Properties_of_Three_CADCAM_Glass-Ceramics
14. https://www.ncbi.nlm.nih.gov/pubmed/25535784
15. Kalavacharla VK, Lawson NC, Ramp LC, Burgess JO. Influence of Etching Protocol and Silane Treatment with a Universal Adhesive on Lithium Disilicate Bond Strength. Oper Dent. 2015 Jul-Aug;40(4):372-8. doi: 10.2341/14-116-L.
16. Elgamal A., Medioni E., Rocca J., Fornaini C. Bouchard N.CO2 laser dentin surface treatment most effectively increased ceramic shear bond strength. Laser Therapy. 2018; 27(1): 48-54. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5958235/
17. Cevik P., Karacam N., Eraslan O., Sari Z. Effects of different surface treatments on shear bond strength between ceramic systems and metal brackets. J Adh Sci and Tech. 2017; 31(10): 1105-15. https://www.tandfonline.com/doi/abs/10.1080/01694243.2016.1245074

18. Ahrari F., Boruziniat A., Mohammadipour H. and Alirezaei M. The effect of surface treatment with a fractional carbon dioxide laser on shear bond strength of resin cement to a lithium disilicate-based ceramic. Dent Res J. 2017 May-Jun; 14(3): 195–202. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5504872/

19. Chen L, Suh B. Bonding of resin materials to all- ceramic: a review. Cur Res Dent. 2012;3(1):7-17. https://pdfs.semanticscholar.org/d39d/bf9b5d351fe3f478878f8366bedcb61931da.pdf

20. Baratto S., Spina D., Gonzaga C., Cunha L. Fursue A., Filho F., Correr G. Silanated surface treatment: Effects on the bond strength to lithium disilicate glass-ceramic. BrazDent.J, 2015;26(5):474-7. https://www.ncbi.nlm.nih.gov/pubmed/26647931

21. Lee H., Han G., Chang J., Son H. Bonding of the silane containing multimode universal adhesive for lithium disilicate ceramics.RDE.2016:1-10. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5426215/

22. Kitahara N., Itoh K., Kusunoki M., Oikawa M., Miyazaki T. One-bottle silane coupling agent containing 4-META. Dent Mat J. 2013; 32(3): 409–12. https://www.ncbi.nlm.nih.gov/pubmed/23719001

23. Prado M, Prochnow C, Marchionatti A, Baldissara P, Valandro LF, WandscherVF.Ceramic Surface Treatment with a Single-component Primer: Resin Adhesion to Glass Ceramics. J Adh Dent.2018 Apr:19:1-7. https://www.ncbi.nlm.nih.gov/pubmed/29675515

24. Mohammed A. Effectiveness of universal adhesive bonding agents on the shear bond strength to lithium disilicate ceramics. IUPUI. 2017 Jun. (Thesis). https://scholarworks.iupui.edu/handle/1805/10256

25. Alqahtani M. influence of acid etching or double curing time on dentin bond strength of one-step self-etch adhesive. S J Dent Res. 2015; 6(2): 110-16. https://cyberleninka.org/article/n/1333136.pdf

26. Chen J. Oka K., Kawano T., Goto T., Ichikawa T. Carbon dioxide laser application enhances the effect of silane primer on the shear bond strength between porcelain and composite resin. Dent. Mat. J. Nov.2010; 29(6):731-7. https://www.ncbi.nlm.nih.gov/pubmed/21099155

27. Alqahtani M., Aijurais R., Alshaafi M. The effects of different shades of resin luting cement on the color of ceramic veneers. Dent Mat J. 2012; 31(3):354-361. https://www.ncbi.nlm.nih.gov/pubmed/22673474

28. Barizon K. Relative translucency of ceramic systems for porcelain veneers. Univ Iowa. 2011. (Thesis). https://ir.uiowa.edu/etd/923/

29. Turgut S., Bagis B., Ayaz E., Korkmaz F., Ulusoy K., BagisY. How will surface treatments affect the translucency of porcelain laminate veneers? J AdvProsthodont. 2014 Feb; 6(1): 8-13. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3942531/

30. Turgut S., Bağış B., Korkmaz F., Tamam E. Do surface treatments affect the optical properties of ceramic veneers? J Prosthet Dent. 2014 Sep;112(3):618-24. https://www.ncbi.nlm.nih.gov/pubmed/24840909

31. Yilmaz S., Cengiz E., Ongun S., Karakaya I. The Effect of Surface Treatments on the Mechanical and Optical Behaviors of CAD/CAM Restorative Materials. Amer Col prosth.2018:1-8. https://www.researchgate.net/publication/322407901_The_Effect_of_Surface_Treatments_on_the_Mechanical_and_Optical_Behaviors_of_CADCAM_Restorative_Materials_Effect_of_Surface_Treatments_on_CADCAM_Materials

32. Alabdulwahhab B., Alshethry M., Almoneef M., Almanie M., Almaziad M., Alokla M. The Effect of Dental Adhesive on Final Color Match of Direct Laminate Veneer (DLV): In Vitro Study. J Esthet Rest Dent. 2015; 27 (5): 307–13. https://www.ncbi.nlm.nih.gov/pubmed/25529510

33. Ritter D., Rocha R., Soares F., Lenzi T. Do adhesive systems influence the color match of resin composites? J App Biomater Funct Mater 2016; 14(2): e212-e16. https://www.ncbi.nlm.nih.gov/pubmed/27149943