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Efficacy of phototherapy with different conventional surface treatments on adhesive quality of lithium disilicate ceramics

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ABSTRACT

Aim: The aim of the present study was to evaluate shear bond strength (SBS) of LDC and resin composite in combination with phototherapy and different ceramic surface treatments.

Materials and Method: Forty Lithium Disilicate Glass Ceramic (LDC) disks measuring (4 × 4 x 9 mm) were fabricated. The specimens were randomly divided into four groups (n = 10 each) according to the surface treatment. Group 1 H F + Silane (Control); Group 2 HF + Ultrasonic bath + Silane; Group 3 SECP (Self etch ceramic primer) and Group 4 phototherapy (Er, Cr: YSGG) + Silane. On each ceramic disk a resin build-up was done. For SBS the specimens were subjected to increasing load with a transversal velocity of 1 ml/min on a universal testing machine on a ceramic resin interface. Failure mode was evaluated using digital microscope. The failure modes were divided into adhesive, cohesive and admixed interface. Data through bond strength testing was tabulated using statistical program for social science (SPSS). Means and standard deviations were compared using analysis of variance and Tukey's post hoc test ($p < 0.05$).

Results: The maximum and minimum bond strength was observed in group 2 [19.58(1.011)] and group 1 [17.14(1.122)] respectively. The bond strength among experimental group 1 [17.14 (1.122)] and group 4 [17.48(1.145)] were found to be comparable. Specimens in Group 2 displayed significantly higher bond strength among all experimental groups. Commonly adhesive failure mode was observed in the present study, with an incidence of 60%, 100% and 70% in groups 1,2 and 3 correspondingly.

Conclusion: Phototherapy using laser at frequency 30 Hz and 4.5 W can be used as a surface conditioner for LDC alternate to HF acid. Conditioning of LDC using Self-etch ceramic primer showed better SBS outcomes as compared to phototherapy (Er, Cr: YSGG laser).

1. Introduction

Favourable aesthetics, biocompatibility, translucency and ability to mimic dental structure makes lithium disilicate ceramics (LDC) a popular choice for direct and indirect restorations [1,2]. The success and longevity of LDC is not only dependent on these characteristics, but are also reliant on surface conditioning techniques, relationship between substrates and cementing agents [3,4].

Currently, conditioning of the LDC with hydrofluoric (HF) acid followed by silanization is the most effective method to improve bond strength and is considered as a gold standard [4,5]. The bond formed between LDC and resin composite is both mechanical via HF acid conditioning and chemical by silane coupling agent [6]. Application of HF acid on glass ceramic produces micro porosities and undercuts which enhances retention [7]. However, HF acid is highly corrosive and increases the risk of toxic accidents in clinical settings, is easily absorbed by bones, skin and blood and weakens the ceramic structure [8–10]. Therefore, other conditioning methods such as use of phosphoric acid, bicarbonate [11], Er, Cr: YSGG laser and self-etch ceramic primer (SECP) has been suggested [12].

SECP, a single step self-etch ceramic primer (Monobond, Etch and prime Ivoclar vivadent / U52056) is introduced as an alternate to HF acid for surface treatments. This novel material tends to eliminate the harmful effects of HF acid along with low technique sensitivity and time consumption [12]. However, the efficiency of SECP in binding to luting cements is still controversial and few studies have shown anecdotal

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results [12,13]. Alternatively, contemporary laser strategies have been used in different surface treatment of dental materials and is found to be safe, convenient and easy [14–16]. Among lasers, Er, Cr: YSGG have been used for surface conditioning in repair of zirconia and LDS ceramics showing effective outcomes [17,18].

To our knowledge, from indexed literature the use of Er, Cr: YSGG laser as an alternate to HF acid for surface conditioning of LDC is limited. In addition, the comparative efficacy of Er, Cr: YSGG laser for conditioning of LDC with other surface treatment methods is inconclusive. It is hypothesized that Er, Cr: YSGG laser will exhibit comparable bond strength outcomes to resin composite when associated to conventional surface treatments for LDC. Therefore, the aim of the present study was to evaluate shear bond strength (SBS) of LDC and resin composite in combination with Er, Cr: YSGG laser and different ceramic surface treatments.

2. Material and methods

This research follows the general guidelines as described in the CRIS (checklist for Reporting In-vitro Studies). Forty Lithium Disilicate Glass Ceramic (LDC) (IPS e.max Press, Ivoclar Vivadent AG) disks measuring (4 × 4 × 9 mm) were fabricated by autopolymerising acrylic resin using lost wax technique. The surface of the specimen was cleaned in distilled water (Pure Steam Distilled H_2O - 1100 ml by Innovative Naturopathics) for 5 min. followed by a bath in 99.3% ethyl alcohol solution (B-Grade Anhydrous Ethyl Alcohol) for 2 min, air dried and polished on an automated polishing machine (Aropol 2 V, Arotec) at a velocity of 300 rpm.

After the procedure, the specimens were randomly divided into four groups (n = 10 each) according to the surface treatment. Group 1 H F + Silane (Control); Group 2 HF + Ultrasonic bath + Silane; Group 3 SECP (Self etch ceramic primer) and Group 4 Er, Cr: YSGG + Silane. Treatment protocol performed were as following

Group 1: Specimens were conditioned by HF acid with concentration of 9.6% (IPS ceramic etching gel Ivoclar vivadent / U39349) for 1 min. Silanization was done using thin layer of silane (Monobond Plus Ceramic primer Ivoclar vivadent / U29880) in accordance to manufacturer recommendation.

Group 2: Samples conditioned by HF acid with concentration of 9.6% (IPS ceramic etching gel Ivoclar vivadent / U39349) for 1 min. Followed by ultrasound bath in distilled water (Pure Steam Distilled H2O - 1100 ml by Innovative Naturopathics) and dried. Silanization was done using thin layer of silane (Monobond Plus Ceramic primer Ivoclar vivadent / U29880) in accordance to manufacturer recommendation.

Group 3: Specimens conditioned by Self-etch ceramic primer (Monobond, Etch and prime

Ivoclar vivadent / U52056) according to manufacturer's recommendation

Group 4: Specimens exposed to Er, Cr: YSGG laser (Biolase-Waterlase I-Plus) with power 4.5 W and frequency 30 Hz in a non-contact mode at 2 mm using (tip MZ = 10) for 60 s. Silanization was done using thin layer of silane (Monobond Plus Ceramic primer Ivoclar vivadent / U29880) in accordance to manufacturer recommendation

On each ceramic disk a resin build-up (Variolink Esthetic Dual Cure, Ivoclar Vivadent, Schaan, Liechtenstein) adapted into a silicon mould (2 × 2 x 3 mm) via an incremental technique. The resin cement was light cured ((Bluephase®, Ivoclar Vivadent, Schaan, Liechtenstein) for 45 s at an intensity of 1200 mW/cm2. Additional light curing session of 15 s was performed after removal of the mould from all around the build-up. A digital calliper was used to standardize the dimensions. All the specimens were kept in artificial saliva (NeutraSal) at 37C for 24 h and thermocycled (TC) between 5 and 55 C for 5000 cycles for 30 s before shear bond strength testing

3. Shear bond strength (SBS) testing and failure mode assessment

For SBS the specimens were subjected to increasing load with a transversal velocity of 1 ml/min on a universal testing machine (Instron Model 4400 Universal Testing System, Instron Corporation) on a ceramic resin interface. After SBS testing and debonding of the specimens the failure mode were evaluated using digital microscope (Hirox-KH7700) at x50 magnification. The failure modes were divided into adhesive, cohesive and admixed interface.

4. Scanning Electron microscope (SEM) assessment

For fractographic analysis, two paired specimens from each group was assessed using scanning electron microscope (SEM) (Philips XL 30, FEI Co. Netherlands). A sputter coater (Fine coat ion sputter JFC-1100, JEOL Ltd., Tokyo, Japan) for 200 s at 40 mA was used to gold plate the ceramic surface already cleansed with alcohol wipes. A single operator examined the specimens under SEM at 4000 magnification at 20 kV.

5. Statistical analysis

Data through bond strength testing was tabulated using statistical program for social science (SPSS). Means and standard deviations were compared using analysis of variance and Tukey's post hoc test ($p < 0.05$)

6. Results

The maximum and minimum bond strength was observed in group 2 [19.58(1.011)] and group 1 [17.14(1.122)] respectively. The standard deviations and bond strength of groups are concluded in Table 1.

The bond strength among experimental group 1 [17.14(1.122)] and group 4 [17.48(1.145)] were found to be comparable. For bond strength values, analysis of variance (ANOVA) showed significant difference among the study groups ($p < 0.002$). Specimens in Group 2 displayed significantly higher bond strength among all experimental groups ($p < 0.002$). Bond strength of group 1 and group 4 were significantly lower than group 2 and group 3 respectively ($p < 0.002$). The bond strength in group 3 was significantly greater than group 1 and group 4, however it showed lower SBS than group 2 respectively (Table 1).

Failure modes of the sample are showed in Table 2. Commonly adhesive failure mode was observed in the present study, with an incidence of 60%, 100% and 70% in groups 1,2 and 3 correspondingly. Remarkably, in group 4 admixed failures were more common. The failure mode assessment was confirmed through SEM.

Table 1
Means and SD for bond strength values among study groups using ANOVA and Tukey multiple comparisons test.

Experimental groups	Mean (Mpa)	SD (Mpa)	Variance	P value[!]
Group 1 [†] HF + Silane (Control)	**17.14**	1.122	1.015	< 0.002
Group 2 [¶] HF + Ultrasonic bath + Silane	**19.58**	1.011	1.030	
Group 3 [*] SECP	**18.18**	1.111	1.354	
Group 4 [†] Er, Cr: YSGG + Silane	**17.48**	1.145	1.215	

(Tukey multiple comparison test).

[†] Significantly different from groups- Group 2 and Group 3 ($p < 0.05$).

[¶] Significantly different from all other groups- Group 1; Group 3 and Group 4 ($p < 0.05$).

[*] Significantly different from groups- Group 1; Group 2 and Group 4 ($p < 0.05$).

[!] Showing significant difference among study group (ANOVA).

Table 2
Modes of failure among study groups specimens.

Study Groups	Adhesive (%)	Cohesive (%)	Admixed (%)
Group 1 HF + Silane (Control)	60	40	–
Group 2 HF + Ultrasonic bath + Silane	100	–	–
Group 3 SECP	70	30	–
Group 4 Er, Cr: YSGG + Silane	30	–	70

7. Discussion

In the present study LDC was conditioned with different surface treatment whereas resin cement was standardized across all the groups. The bonding efficacy was evaluated using SBS whereas the mode of failure of the specimen was assessed by topographic analysis via SEM. In the current study it was hypothesized that LDC treated with Er, Cr: YSGG laser would show comparable bond strength to conventional HF acid when bonded to resin cement. Remarkably, the hypothesis was accepted as specimens treated with Er, Cr: YSGG at frequency 30 Hz and power 4.5 W exhibited comparable SBS values to hydrofluoric acid group.

LDC is majorly composed of two components lithium oxide crystals and silica [19]. Treatment of LDC with HF acid and silane is a gold standard before adhesive cementation [12]. HF acid when exposed to glass matrix forms hexafluoro silicates, preferably forming a rough surface for micromechanical retention [20]. However, over use of HF acid have a disadvantage of weakening the ceramic structure, decreasing flexural strength and application of silane to promote adhesion introduces an extra clinical step inviting a chance of inaccuracy [21,22]. In addition, use of HF acid can be toxic and harmful to patients as well [10].

In the present study, SBS of lithium disilicate glass ceramic was assessed using universal testing machine to follow consistency and standardization [23]. The testing machine measures specific variable while other parameters are kept constant [23]. In the current study the mean bond strength of group 1 (HF acid + silane) was found to be less [17.14(1.122)] than group 2 (HF acid + cleaned with ultrasonic bath + silane) [19.58(1.011)]. These findings were found to be in concurrent with studies by Al Zaid et al. [24] and Bruzi et al. [25]. A possible explanation for better bond strength is cleaning of precipitates formed after HF acid on ceramic surface improving bonding efficiency and bond strength. Studies have showed that failure to remove acid residual comprises bond strength by fifty percent [3,19].

Similarly, SBS values of group 3 [18.18(1.11)] treated with self-etch ceramic primer (SECP) was better than group 1 (HF acid + silane) [17.14(1.122)]. SECP is a single step system and was introduced to simplify the bonding process. It consists of trimethoxypropyl methactylate for silanization and ammonium poly fluoride for etching with no HF acid [12,13]. Better SBS in SECP group can be attributed to better bonding between silica in LDC and ammonium tri-fluoride in SECP. It is believed that both have better chemical affinity for each other forming an extremely strong bond between silica and fluoride [13,26].The findings of the present study was in line with the results by Hatem et al. [12], Alrahlah et al. [13], and Lyann et al. [26]

Alternatively, Er,Cr:YSGG (erbium, chromium:yttrium–scandium–gallium–garnet) is considered to be conservative, precise, efficient and safe in dental procedures [27]. Er, Cr: YSGG has been used in surface conditioning of different dental materials and the results are overwhelming [14,15,28]. Captivatingly, In the present study SBS values were found to be comparable between specimens of group 1 (HF acid and silane) and group 4 (Er, Cr: YSGG and silane) at 4.5 W and 30 Hz. However, the prevailing evidence on this subject is contradictory. A study by Chaharom et al. [18], demonstrated that bond strength of LDC specimen treated with HF acid showed better repair bond strength compared to specimen treated with Er, Cr: YSGG and Er: YAG. A possible explanation for these contradictory results are different laser parameters, treatment duration, laser power, frequency, distance from surface, type of bonding system and type of ceramic used [28,15,16].

Interestingly in the present study most of the failure modes was adhesive. However, fracture in lased group showed admixed failure. There was no study done to relate these finding of mode of failure by Er, Cr: YSGG on LDC. However, the author suggests that thermo-mechanical impact of laser treatment effects the physical properties including hardness, showing admixed adhesive failures in laser treated specimens. Specimen treated with SECP showed no surface irregularities. Whereas, surface treated HF acid and silane demonstrated dissolution of matrix with surface irregularities, corelating the SBS scores. A possible clinical implication of these results indicate that use of Er,Cr:YSGG for conditioning of LDC and alternate to HF acid can be used. This may decrease the inherent effect of HF acid on biological tissues. Within the limitation of this study more clinical studies are required to extrapolate the findings of the present study. The results are applicable only on the type of laser used, applied bonding agent and ceramic type. Furthermore, Surface profilometry of the ceramic should be investigated

8. Conclusion

Within the limitations of the present study, phototherapy using laser at frequency 30 Hz and 4.5 W can be used as a surface conditioner for LDC alternate to HF acid. Conditioning of LDC using Self-etch ceramic primer showed better SBS outcomes as compared to phototherapy (Er, Cr: YSGG laser).

Conflict of interest

The authors declare no conflict of interest.

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