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INFLUENCE OF DIFFERENT LASER IRRADIATION ENERGY ON CERAMIC BOND STRENGTH

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ABSTRACT

Objective: This study aimed to verify the influence of differentsNd:YAG laser energy parameters on the bond strength between lithium disilicate ceramic and resin cement. **Methods**: One hundred Lithium disilicate ceramic specimens with truncated cones shape were prepared and divided into 5 groups (n=10): 1- Control(without laser irradiation); 2- 80Nd – laser irradiation with Nd:YAG laser at 80mJ energy intensity for 1 min; 3- 100Nd - irradiation with Nd:YAG laser with an intensity of 100 mJ for 1 min; 4- 120Nd - Nd:YAG laser irradiation at 120mJ energy intensity parameters for 1 min; 5- 140Nd - Nd: YAG laser irradiation at 140mJ energy intensity parameters for 1 min. The laser irradiation on the specimen was performed in lower base of thetruncated cones shape. After all lasers treatments the groups were etched with hydrofluoric acid at 10% for 1 minute and silanized. Half of the treated ceramic specimens were cemented with resin cement (Variolink II-Ivoclar-Vivadent) to the other half resultingin hourglasses-shaped specimens.The bonded specimens were cycled thermomechanicallyand stressed to failure under tension.Data were analyzed using ANOVA and Tukey tests (α=0.05).

Results: One-way ANOVAindicated that the factor "laser energy",statistically significant differences were observed among groups (p= 0.0), The 80Nd group (21.22 ± 6.00) showed greater results means than the other groups (Control-12.37 ± 3.46; 100Nd-15.15 ± 5.89; 120Nd-14.61 ± 2.53; 140Nd-10.12 ± 4.23)(Results in MPa). The other groups, including the control, were not statistically different.

Conclusions: Laser energy intensity parameter significantly affected tensile strength of the resin cement to the lithium disilicate ceramic.

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INTRODUCTION

Using an adhesive cementation strategy for treatments involving pure ceramics, generated the need of bond improvement between the resin cement and the ceramic substrate. In the last decade several studies have been conducted to bring solutions to this problem (Carvalho *et al*., 2011; Cavalcanti *et al*., 2009; Demir *et al*., 2012; Kirmali *et al*., 2014). Among the treatments evidenced are sandblasting with aluminum oxide particles (5.6), the silane drying with hot air (1.7) and the irradiation on surfaces with high power laser such as Er:YAG laser (erbium-doped: yttrium aluminum garnet) and Nd:YAG laser (neodymium-doped: yttrium aluminum garnet).Some studies have indicated that the use of Nd:YAG laser increase the roughness on the surface and bond strength improvement in adhesive resin bonding (Cavalcanti *et al*., 2009; Demir *et al*., 2012; Foxton *et al*., 2011; Guarda *et al*., 2013; Kirmali *et al*., 2014; Nagai, 2005).

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Studies has shown that treatment of the ceramic surface with neodymium laser results in a higher bond strength between ceramic and resin cement when compared to conventional treatment with 10% hydrofluoric acid for 1 minute and sandblasting with aluminum oxide particles (Akın *et al*., 2011; Nagai *et al*., 2005).However, there are studies that reported the influence of the use of Nd: YAG laser on the bond strength between pure ceramic and resin cement, doesn't exist consensus on which parameters is indicated for the types of ceramics available in the market, so that its clinical use is still restricted (Akın *et al*., 2011; Usumez *et al*., 2013). A gap regarding this aspect relates to the fact that there are few studies in the treatment on vitreous ceramic surface of lithium di-silicate, one of the most used in current clinical with the disproportion in the number of articles about ceramics based on zirconia (Akın *et al*., 2011; Cavalcanti *et al*., 2009; Demir *et al*., 2012; Foxton *et al*., 2011; Ozcan *et al*., 2008; Usumez *et al*., 2013). Due to the growing demonstration of the advantages of Nd: YAG laser irradiation as a way of increasing the bond strength between resin cement and ceramic, together with the fact that there are few articles in the current literature relating lithium di-silicate ceramics with High power laser, this study have as objective to test different parameters of irradiation of the Nd: YAG laser on ceramic surface of lithium di-silicate and after cementation a simulation and mechanical tensile test, to verify the influence of the parameters tested in the bond strength between the substrates.

MATERIALS AND METHODS

Ethical aspects

This article does not contain any studies with human participants or animals performed by any of the authors.

Specimen preparation

One hundred lithium disilicate truncated cones (IPS e.max Press; Ivoclar Vivadent) were fabricated from low contraction wax (Renfert Geo; Renfert GmbH), using a 4-mm thick metal device with a 2-mm diameter wide base and a 4-mm diameter wide top surface. The specimens were heat-pressed using the lost-wax technique according to the manufacturer´s instructions (Esquivel-Upshaw *et al.*, 2004; Valenti *et al.*, 2009).

The 100 ceramic specimens were randomly divided into 5 equal groups. All specimens were cleaned in ultrasonic bath with 96% isopropanol for 3 min. And then submitted to the proposed treatments:

- Control. Specimens were etched with HF (60 sec), rinsed with water spray for 60 sec, silanized with Monobond Plus (Ivoclar Vivadent) for 60 sec and air-dried.
- 80Nd. Specimens were irradiated using a Nd:YAG laser (Pulse Master 600 IQ; American Dental Technologies) with 80 mJ energy, using a pulse repetition rate set at 15 pps, using a 320 μm diameter laser optical fiber placed in contact with the specimen surface for 1 min with water spray cooling (5 sec). After irradiation, as surfaces were cleaned on ultrasonic bath with distilled water for 3 min. Following a surface was conditioned for 1 min. With 10% hydrofluoric acid, and silane actively for 60s followed by air-jet drying.
- 100Nd. The process is similar to those described in the second group.Specimens were irradiated using a Nd:YAG laser with 100 mJ energy intensity.
- 120Nd. The process is similar to those described in the second group.Specimens were irradiated using a Nd:YAG laser with 120 mJ energy intensity.
- 140Nd. The process is similar to those described in the second group.Specimens were irradiated using a Nd:YAG laser with 140 mJ energy intensity.

Bonding procedures

After surfaces treatment, the specimens were joined by applying the Variolink II dual resin cement (IvoclarVivadent, Liechtenstein), handled in a ratio of 1:1 for 10s, following the manufacturer's recommendations resulting in 10 specimens per group (n=10). Each set was positioned in adapted eyeliner to the cementation with the bonding surface perpendicular to the application of a static vertical load of 630g.

After positioning of the ceramic / cement / ceramic set, a photopolymerization with LED light curing (Radii cal - SDI) was light-cured for 40s, starting at the proximal edges of each side of the set, obtaining 50 sets (n/2) (Figure 1).

Thermomechanical aging

The bonded specimens were subjected to thermomechanical challenge that consisted of 24,000 mechanical cycles (30 N load at 4 Hz) and 1,000 thermal cycles (30 sec dwell-time in each water bath with temperatures maintained at 5°C, 37°C and 55°C, respectively). Aging was conducted simultaneously in a thermomechanical cycler (Model ER-37000; ERIOS, São Paulo, Brazil).

Tensile bond strength

Bond strength was evaluated in a universal testing machine (model DI-1000; EMICSão José dos Pinhais, Brazil) by attaching a specimen to a custom-made device (Figure 2), using a 10 kg load cell at a cross-head speed of 1 mm/min. Loading was performed in tension until failure. Results of tensile testing (in MPa) were statistically analyzed using one-factor analysis of variance (ANOVA) and Tukey after affirming that the normality and equal variance assumptions of the data were not violated.

The null hypotheses tested were.

H0: The alteration of the irradiation parameters of the Nd: YAG laser does not interfere in the bond strength between ceramic and resin cement.

H1: Nd: YAG laser irradiation followed by conditioning with 10% hydrofluoric acid gives lower tensile strength results than treatment with only 10% hydrofluoric acid.

RESULTS

Analysis of fractured interface

The failures due to the mechanical tensile test were predominantly adhesive, and the cohesive failures in ceramic (one in the 80Nd group and one in the 120Nd group) were disregarded from the statistical test.

Tensile bond strength

The analysis of the 1-factor ANOVA test showed significant differences between the different groups studied (p value <5%). The 1-factor ANOVA test results are showed in Table 1.

Table 1. Variance Analysis Results - ANOVA 1 factor.

Source of variation	gl	QM	F	p*
Treatment	690,5	4	172,6	0,001*
Residual	965,1	45	21,45	
Total	1656	49		

*p<5%

The Tukey's test was applied to the factor Surface treatment in order to compare the different treatments to which the ceramics were submitted. Tukey's test results are showed in Table 2.

Table 2. Tukey's test for the comparison between the different irradiation parameters of the Nd: YAG laser on the ceramic surface

Groups	Means (Mpa)	Groups Homogeneous	
140Nd	10,12	A	
Control	12,37	A	
120Nd	14,62	A	
100Nd	15,15	A	
80Nd	21,22		B

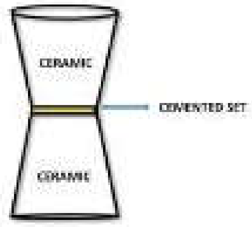

Figure 1 - Final view of ceramic specimens cemented with resin cement

Figure 2 - Adaptation of the ceramic specimens in the metallic model for mechanical testing

According to the Tukey test result for the different irradiation parameters of the Nd: YAG laser on the ceramic surface it can be observed that the 80Nd group was statistically superior to the other groups, while all other groups were similar to each other.

Analysis of Treated Ceramic Surfaces

Two samples referring to each of the groups were submitted to Scanning Electron Microscopy (SEM) (Figures 3-7) for qualitative analysis of the surfaces.The photomicrographs show that there was no change in the morphological pattern of the ceramics for any group, but in the groups 100Nd and 120Nd it is possible to verify the appearance of irregularities that appear to arise from the pulses of laser irradiation.

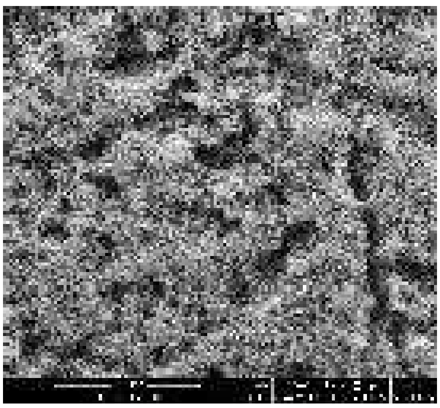

Figure 3 - Control group with a 2000x magnification, showing the conventional microstructure of the ceramic used, with needle type lithium disilicate crystals with the appearance of agglutination with each other and in the vitreous matrix in which they are embedded.

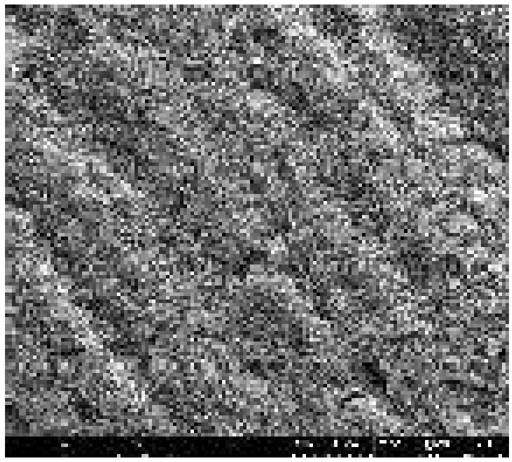

Figure 4 - Group 80Nd with 2000x magnification, showing structural normality, but with a higher exposure of lithium disilicate crystals

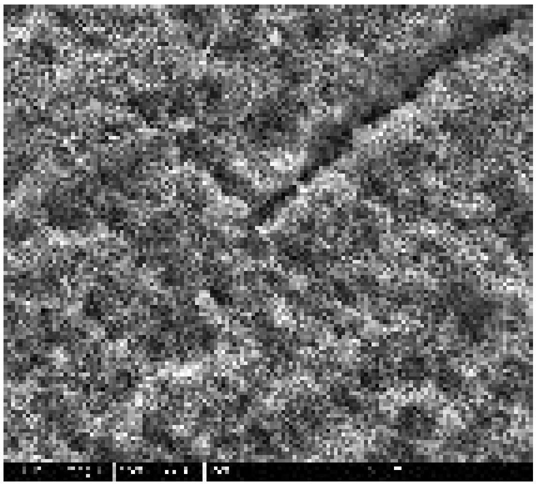

Figure 5. Group 100Nd with increase of 2000x. Is possible to detect striking surface irregularities due to the laser emission pulses

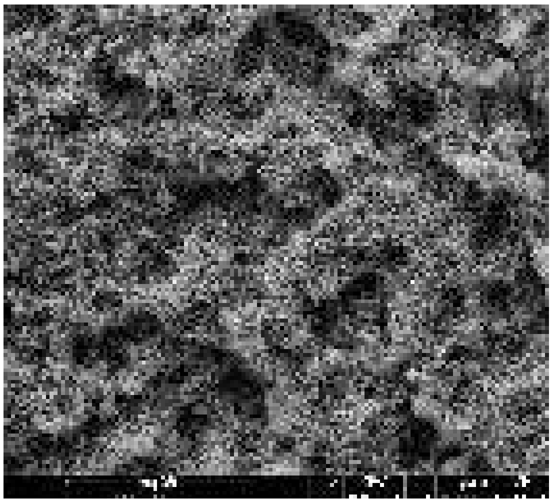

Figure 6 - Group 120Nd with increase of 2000x. Surface irregularities due to laser emission pulses are even more evidente

In the 140Nd group these irregularities appear deeper and more continuous in some areas, suggesting cracks in the ceramic surface. The 80Nd group has the preserved ceramic structure, but differs from the Control group because it exhibits a greater exposure of the crystals of lithium disilicate in the form of a needle.

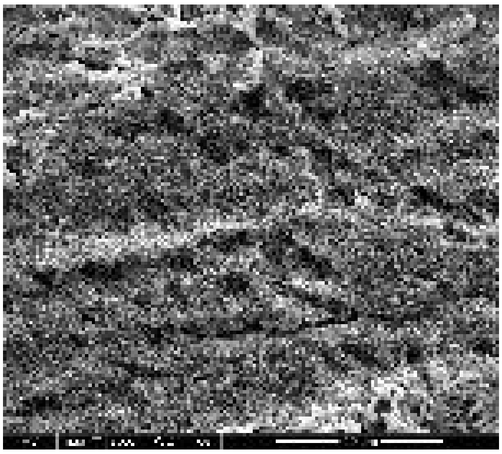

Figure 7. Group 140Nd with increase of 2000x. The image suggests the presence of deep irregularities and cracks

DISCUSSION

The results obtained in current study demonstrate an increase in bond strength values between lithium disilicate vitreous ceramic and resin cement after irradiation of ceramic surface with Nd: YAG laser in the parameters of 80mJ of energy intensity and 15Hz of frequency with Constant air cooling followed by conditioning with 10% hydrofluoric acid for 1 minute.Therefore, the null hypothesis was not accepted, since the alteration of the irradiation parameters of the Nd: YAG laser interfered in the bond strength between ceramic and resin cement, and the irradiation with Nd: YAG laser followed by the conditioning with hydrofluoric acid to 10 % gave results of tensile strength higher than treatment with only 10% hydrofluoric acid.

The lithium disilicate ceramic IPS E.max Press has indication for anterior and posterior regions, with the possibility of using the same material for infrastructure and cover.The choice of this ceramics for the preparation of the specimens was based on its extensive clinical use, which has been showing positive results regarding the duration rate in the buccal medium, low index of fractures besides good color maintenance (Etman *et al*., 2010; Taskonak, 2006; Toman *et al*., 2015). Studies have shown that the area of the adhesive surface to be tested is directly proportional to the type of failure obtained (Sano *et al*., 1994; Sano *et al*., 1994). Larger surfaces usually result in a prevalence of cohesive failures, while cross-sections of less than 2mm result in most adhesive failures (Sano *et al*., 1994; Sano *et al*., 1994; Ghassemieh *et al*., 2008). According to the literature, the smaller the surface of the specimen, the smaller the area available for failure, resulting in better bond strength results (Escribano *et al*., 2003). The larger the test area, the lower the adhesive strength, and up to 3mm the results are more favorable for macrotracking tests (Kara *et al*., 2012). In order to obtain results closer to the reality of the adhesive resistance between the materials and based on the parameters reported above, in this study was used a model of test specimen of small dimensions, with cementation area of 2mm in diameter, made in single body and Prepared for a macrotrace test with the smallest possible dimensions without the disadvantages of samples obtained from various sections of a test piece (sticks), but with the advantage of the test in a small area. The faults obtained from the macrotrace test were mostly adhesive (there was only 1 cohesive failure in ceramic in the 80Nd group and 1 in the 120Nd group). This result corroborates with that described by Sano *et al*., 1994 since the size of the surface possibly influenced the type of failure obtained. The results concerning cohesive failures were removed from the statistical analysis of union resistance since these do not adequately represent their groups and maintaining them could induce a false result.In the present study 10% hydrofluoric acid was used for 1 minute (control group), however the means found were lower than those in the 80Nd, 100Nd and 120Nd groups. A previous study showed that the use of 10% HF created clear pores and exposure of crystals of disilicate due to the marked dissolution of the vitreous matrix (Prochnow *et al*., 2016).These data indicate a probable increase in the surface roughness of the ceramic, which acts as an element favorable to the bond strength. SEM photomicrographs suggest areas of agglutination between crystals of lithium di-silicate and vitreous matrix in the control group (Figure 3), while in the 80Nd, 100Nd and 120Nd groups it is possible to visualize a larger exposure of the surface crystals, which may have interfered with In the quality of the union (Figures 4-6).

The best results of bond strength were found in the irradiated group with 80mJ of Energy intensity and 15Hz of frequency). According to Tukey's test, the 80Nd group was the only one that differed statistically from the others. These results differ from those found by Akyil *et al*., 2011, where comparing different surface treatments in feldspathic ceramics found that surface treatment with hydrofluoric acid was more effective when compared to the use of Nd: YAG and Er: YAG lasers and Even when applied to the surface after irradiation with both lasers (Akyıl *et al*., 2011). SEM photomicrograph for the 140Nd group shows areas that suggest cracks and faults in the ceramic surface (Figure 7). The slits also appear in the study of Liu *et al*., 2015, when using the Nd: YAG laser in the parameters of 100mJ and 1 and 2W for the irradiation of the zirconia surface. However, as mentioned previously, the surfaces of zirconia and lithium disilicate have very different structures, which makes comparison impossible. In this study, the cementation of two identical ceramic substrates was used with the purpose of not include another substrate that could provide, for example, cohesive failure in the non-ceramic substrate, compromising the work goal and masking the obtained results. Although the results obtained by this research regarding the bond strength of the vitreous ceramics of lithium di-silicate to resin cement can not be directly extrapolated to a clinical situation, we can suggest them for new strategies of surface treatment of this type of ceramic a So that indirect restorations with longer longevity can be performed.

Conclusion

The results of this study allow us to conclude that irradiation with Nd: YAG laser in the parameters of 80mJ of energy intensity and 15 Hz of frequency with constant cooling air followed by conditioning with 10% hydrofluoric acid for 1 minute is the most suitable for Vitreous ceramic of lithium disilicate used among the treatments tested, being superior to the treatment with only 10% hydrofluoric acid for 1 minute and to the other parameters tested.

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