Original Article

Evaluation of Shear Bond Strength of Composite to Feldspathic Porcelain after Porcelain Surface Treatment with CO_2 and Er:YAG lasers

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Abstract

Background and Aim: Fractured ceramic crowns can sometimes be repaired with composite resin. The aim of the current study was to determine the shear bond strength of composite to feldspathic porcelain after CO_2 and Er:YAG laser porcelain surface preparation.

Materials and Methods: In this in-vitro study, 36 feldspathic porcelain blocksmeasuring 1*10*10 mm were divided into 3 groups of 12. Porcelain surfacesinthe first and second groupswere treated with 1.8W CO_2 laser and 5W Er:YAG laserirradiation, respectively. Third group specimens were subjected to 9.5% hydrofluoric acid surface conditioning. Allgroups received application ofsilane and adhesiveafterwards. A composite cylinder with 3.5 mm diameter and 5 mm height was bonded to specimens. In order to evaluate the shear bond strength,aUniversal Testing Machine withacrosshead speed of 1 mm/min was used. Statistical analysis was performed using one-way ANOVA and Tukey's HSD test and $P<0.05$ was considered statistically significant.

Results: The mean shear bond strength values (MPa) were 13.03±2.57%, 12.02 ±3.4 and 19.23±4.62, for the first, second and third groups respectively. One-way ANOVA revealed a statistically significant difference in this respect between the three groups ($P< 0.001$).

Tukey's HSD testdemonstratedsignificant differences betweenthefirst and third groups ($P= 0.000$) as well as the second and third groups ($P=0.000$). However, no significant difference was detected betweenthe first and second groups ($P =0.778$).

Conclusion: Consideringthe study results, CO_2or Er:YAG laser irradiationis not suggested as an appropriate alternative to hydrofluoric acid for surface preparationoffeldspathic porcelain.

Key Words: Dental porcelain , laser , hydrofluoric acid , shear strength

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Introduction

Demandfor esthetic dental treatmentsisrapidly growing. In a research by Goldstein about the principles of facial beauty, itwasstated thatsmile ranks second after eyes as the most important parameter of facial beautyand dentistsplay an importantrole in correcting the smile [1]. Among all esthetic dental treatments,full porcelain crownscan greatly contribute to patients' estheticsdue totheir excellent biocompatibility andhigh translucency [2]. Insufficient aesthetics or translucency, inadequate porcelain-metalbondandtotally different physical propertiesof porcelain and metalin porcelain fused to metal crownsall led to the currently growing popularity of full ceramic crowns [3-6].

In 1980, introductionof enamel etching with phosphoric acid and ceramicetching with hydrofluoric acidtechniquesled to the application of resin cements for bonding of ceramic to enamel [7]. However, full porcelaincrownsin serviceare at constant risk ofporcelainseparation, fracture or ditching due to various reasons. In these cases, otherparts ofthe crownusually remain intact. Two solutions are available under these circumstances: Replacement of the full porcelain crown which is expensive and time-consuming orrepairing the crown in patient'smouth with composite resin. Among differenttypes of currently used dental porcelains, feldspathic porcelain has many applicationsdue toits high translucency and similarity to tooth enamel and is one of the most commonlyused porcelainsin dentistry and full ceramic crownsin particular [8]. Several methods have been recommended for composite-porcelain bonding, such as porcelain surface preparation using a coarsebur,sandblasting with aluminum oxideparticles and etching with hydrofluoric acid [9,10]. Also, application ofSilane Coupling agent has been introduced as an effective measure for increasing bondstrength [11-14]. Application of hydrofluoric acidproducesporosities and dissolves the glassy phaseof ceramic. Silaneconditions the surfaceand enhances the formation of a covalentbond between ceramic and composite [15]. Laser irradiation for porcelain surface preparationis a recent techniqueforachieving a higher quality bond between the porcelain and composite. Different types oflasers are used in dentistry [16]. Akovaet al. showed that CO_2 laser irradiation (Super Pulse, 2W, 20 seconds) providedsufficientbond of brackets to feldspathic porcelain and silane applicationincreased the bond stability [17]. Akyilet al. reported that application of9.5% hydrofluoric acid created the highest bondstrength to feldspathic porcelain. Also, application of acid and lasertogetherincreasedthe bondstrength, but this strengthwas lower thanthat of acidconditioningalone [18]. Ferreira et al.demonstrated that Er: YAG laser application caused the highest bond strengthfollowed by acid and Nd:YAG laser application; however, the differences between these three groups were notsignificant. They concluded that Nd:YAG and Er:YAG laser can beused instead of acid for porcelain surfacepreparation [19]. The obtained controversial results indicate thatporcelain surface preparation with laser needsto be further investigated. The goal of this study was to determinethe shear bond strengthofcomposite to feldspathic porcelain followingporcelain surface preparation with CO_2 and Er:YAG lasers.

Materials and Methods

This laboratory, experimental study was conducted on 48 porcelain blocks.

Preparation of porcelain blocks:

Porcelain blocks measuring 1×10×10 mm werefabricatedbyusing EX3feldspathic porcelain (Noritake, Japan) infurnace (P30, Ivoclar, Liechtenstein, Switzerland) at 930^{o}Cfor 15 minutes.

Laser irradiation:

A) Pilot study: Since the majority of studies onporcelain surface preparation are implemented on Zirconium, at first two different powers of CO_2 and Er:YAG (Deka, Italy) laserswere tested on 12 feldspathic porcelain blocksand the SEM (Scanning Electron Microscopy) results wereexamined by three experts as single blind to find out which $Co_2$and Er:YAG laser powers have the greatest effect on feldspathic porcelain for use in this study. Prior tolaser irradiation,surface glaze of feldspathic porcelain was removed by composite polishingbur 850.016 (Tizkavan, Tehran, Iran). In Er:YAG laser group, Er:YAG laser withawavelengthof 2940 nanometer at two different powersalong with Graphitepowder (Sosmar, Iran) was used [19]. Porcelain surface was coated with graphite powder prior to laser irradiation. Non-contact mode Er:YAG laser with 4 and 5 W power,10Hzfrequency, 400 mJenergy, 450 microsecond pulse duration, 0.5 J/mm2 energy density, 5mm distance, 15 secondsexposure time and 1mm beam diameter was irradiated. In Co_2 laser group, first laserwith 10600 nanometer wavelength, 1.8 Wattpower, 1 mmbeam diameter, 10Hz frequency, 5 millisecond pulse duration and0.01 J/mm^{2}energy densitywith surface atfocal distancewas irradiatedfor 15 seconds andthen CO2 laser with 2.4 Wpower, 10600 nanometer wavelength, 20Hz frequency, 2.5 millisecond pulse duration, 0.008

J/mm2energy density and 1mm beamdiameter with surface at focal distance was radiated for 15 seconds.

B) Main study: After selectingthepowerforeach laser, 12 porcelain blocksin group 1 and 12 porcelain blocksingroup 2 received CO2 and Er:YAG laser irradiationforsurfacepreparation, respectively.

Porcelain etching:

Surfaceglazeof 12 porcelain blocks in group 3wasremoved by composite polishing bur 850.016 and 9.5% hydrofluoric acid (Basico, USA) wasapplied to the surface, remained for two minutes, rinsed for 15 secondsand air dried for 5 seconds.

SEM:

Acid and laser-treated specimensweregold coated by Gold- Palladiumalloyusing Sputter Coater Apparatus model SC7620 (Leo, Germany) and examined by Scanning Electron Microscope model 1450 VP (Leo, Germany) set at20 kV acceleration voltage, 3 nanometer resolutionand 1000 xmagnification.

Application of bonding agent and composite resin:First, athin layer of silanewasappliedtoallsamples, air dried for 30 seconds with air spray, and thenScotch bond multipurpose adhesive (3M, USA) from the third bottle was used. The adhesivewas light cured from 1mmdistance for 20 secondsbythelight-curing unit (Astralis 7, Vivadent, Liechtenstein, Switzerland) with 450 mW/ Cm^2 intensity. In order to fabricate acomposite cylinderto be bonded toporcelain surface, atransparent cylinder with 2 mminternal diameter and 4mm heightand composite Z_{250} (3M, USA)with A2 shadewereused. With a suitable handinstrument, the compositewasapplied to the transparent cylinder.The cylinder was then perpendicularly placed inthe center ofthe porcelain surfaceand light curedat1mm distance from the top and both sides for 20 seconds each. For measuring the shear bond strength, Universal Testing Machine was used with a cross-head speed of1mm/minute,preload of 2N and 2 kNload cell. The samples were subjected to load until failure. A computer and a data acquisition system recorded the data.Fracture modes werestudiedby astereomicroscope (SZ 40, Olympus, Tokyo, Japan) with 40X magnificationand werecategorized as cohesive (in composite or porcelain), adhesive (at the composite-porcelain interface) and mixed (a combination of both). The obtained data were analyzed usingSPSS version 13.0 software. One-way ANOVA was applied and pair-wise comparisonof groups for shear bond strength was carried out using Tukey's HSD test. ($P<0.05$) was considered statistically significant.

Results

A) Result ofthe pilot study:

The SEM resultsrevealed that CO_2 laser with 1.8 Wpower and Er:YAG laser with 5 Wpowercausedminor cracksand the highest surface roughnesson feldspathic porcelain (Figure, 1-3).

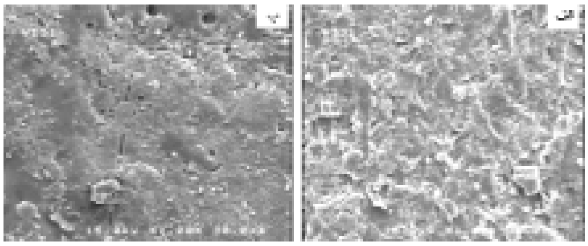

Fig 1: Porcelain surface preparedwith CO_2laser: A) 1.8 Watt and B) 2.4 Watt

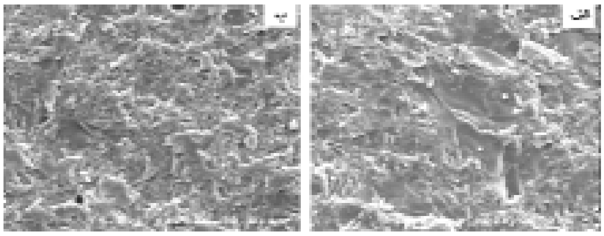

Fig 2: Porcelain surface preparedwith Er:YAGlaser: A) 4 W and B) 5 W

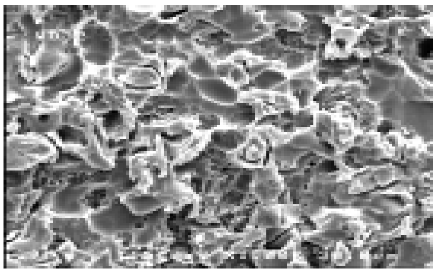

Fig 3: Porcelain surfaceprepared with hydrofluoric acid

B) The results of main study:

Mean, standard deviation, minimum and maximum values ofshear bond strength (MPa) in 3 studygroups are shown in Table 1. In order to ensure the normal distribution of samples, One Sample Kolmogorov Smirnov testand for statistical analysis, univariate ANOVA were applied and revealed significant differences in meanshear bond strength of different understudy groups ($P<0.001$). The resultsof Tukey's HSD test demonstrated significantly highershear bond strength in acidtreated group compared to the laser groups ($P<0.001$). However, no statistically significant differences were noted betweenthe laser groups (1 and 2) ($P=0.778$). The frequency of various modes of failure is presented in Table 2.

Table 1: Porcelain surfaceprepared with hydrofluoric acid

Group	Number	Minimum	Maximum	Mean± SD
1	12	7/11	15/94	13/03±2/57
2	12	6/49	15/65	12/02±3/4
3	12	11/63	24/91	19/23±4/62

Table 2: Frequency distribution of different failure modes in understudy groups

Failure type	Group 1	Group 2	Group 3	Total
Adhesive	8	10	3	21
Cohesive	0	0	5	5
Mixed	4	2	4	10

Discussion

At present, use of laser in dentistry is becoming increasingly popular and it is necessary to clarify its different clinical applications. On the other hand, demand forfull porcelain crownsis increasing because oftheir high translucency and excellentbiocompatibility [3, 8]. Full porcelain crowns may undergo fracture or chipping during their clinical use; in these cases we mayuse composite resins to repair the porcelain.In order to achieve a strong bond between the composite and porcelain, several techniques are used for porcelain surface preparation.Limited number ofstudies have evaluated porcelain surface preparation with laser yielding different results. In this study, 1.8 and 2.4 W powers of CO_2 laser and 4 and 5 Wpowersof Er:YAGlaser were selected and then SEM was used to find out the optimal power with the best effect on porcelain. Studieshave shownthat lower powers of Er:YAGlaser do not have an adequate effect on porcelain surface and are not able to create optimal surface roughness [18,19]. The conventional graphite causedgreaterabsorption of Er:YAG laser by the porcelain surface [19].

In this study,after porcelain surface preparation with acid or laser, silane wasappliedto enhance the bond betweencomposite and porcelain. Shear bond strength of composite to feldspathic porcelain following porcelain surface preparation with hydrofluoric acid was greater than the rate following porcelain surface preparationwith CO_2 and Er:YAG lasers. Due to the dissolution of minerals by hydrofluoric acid, porosities are formed ontheporcelain surface causing micromechanicalretention; while CO_2 and Er:YAG laser screateporcelain surface roughness but are not able to dissolve the mineral contentyielding low or nomicromechanical retention.

Akovaet al, in their study on porcelain surface preparationwith CO_2 laser for bondingof brackets to feldspathic porcelain in ceramic-metal crowns concluded that CO_2 laser canprovide sufficient bond between bracket and feldspathic porcelain of ceramic-metal crowns. Akyilet al.evaluated theshear bond strengthof composite resin to feldspathic porcelainafter porcelain surface treatment withlaser and acid etching and concluded that preparation with hydrofluoric acid createdhigher bond strength than preparation with Er:YAGand Nd:YAG lasers. Ferreiaet al.studied theshear bond strengthof resin cement to feldspathic porcelain following porcelain preparation by sandblastingwithaluminum oxide particlesand Er:YAG and Nd:YAGlasers and demonstrated that the efficacy of porcelainsurface preparationwith Er:YAG and Nd:YAG laserswas similar to that of hydrofluoric acid providing optimalshear bond strength of resin cement to feldspathic porcelain. However, different results were obtained in our study. This differencemay be attributed to different laboratory conditions, use of hydroxyapatiteprior toEr:YAG laser irradiation and application of different bondingagents and composite resins.

The mode offailure was adhesive or mixed in CO_2 and Er:YAG laser groupsand the cohesive failure was not observed. In hydrofluoric acidgroup, the observed mode of failure was of cohesive type in the composite resin. The adhesive mode of failure is due to the weak bond between the porcelain surface prepared with laser and composite resin. In laser groups, failures were mostly of adhesive or mixed types at the resin-porcelain interface. In hydrofluoric acid group, the majority of observed failures were of cohesive type attributed to the higher bond strength of composite to feldspathic porcelain.

Conclusion

Based on the obtained results, preparation of feldspathic porcelain surface with hydrofluoric acid is more effectivethan Er:YAG and CO_2 laserapplication for achieving a suitable bond strength between composite resin and feldspathic porcelain. Role of other laser parametersneeds to be illuminated in future studies to further improve the efficacy of laser for porcelain surface treatment.

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