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Evaluation of Different Types of Lasers in Surface Conditioning of Porcelains: A Review Article

Amirhossin Mirhashemi[1], Nastaran Sharifi[2], Mohammad Moharrami[2], Nasim Chiniforush[3*]

[1]Department of Orthodontics, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran
[2]School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran
[3]Laser Research Center of Dentistry, Dentistry Research Institute, Tehran University of Medical Sciences, Tehran, Iran

***Correspondence to**
Dr. Nasim Chiniforush, DDS, PhD; Laser Research Center of Dentistry, Dentistry Research Institute, Tehran University of Medical Sciences, Tehran, Iran. Tel: +98-2188994824; Email: n-chiniforush@farabi.tums.ac.ir

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Abstract

To achieve proper bond strength for porcelains, adequate surface roughness is essential, which is traditionally gained by sandblasting or acid etching with hydrofluoric (HF) acid. Nowadays with the development of laser systems, serious efforts were made to apply this new instrument for surface etching of porcelains due to easy usage, safety, and more efficiency. There are different kinds of lasers and porcelains, so choosing the ones which will be good match for each other is crucial. Besides that, changing the irradiation setting can be beneficial as well. This article reviewed 33 related studies and summarized results of etching accomplished by Nd:YAG, Er:YAG, Er,Cr:YSGG and CO_2 lasers on different types of porcelains considering different laser settings and evaluation methods to bring a comprehensive insight.

Keywords: Porcelain; Nd:YAG; Er:YAG; Er,Cr:YSGG; CO2; Conditioning; Orthodontics.

Introduction

Porcelains have been used for many years in cosmetic dentistry for their specific physical characteristics, such as, resistance and delicacy; this material is fragile due to a low tensile and high compressive strength.[1]

Categorizing dental porcelains is made using different criteria such as microstructure. Dental porcelains are put into four groups with respect to the crystalline to glass phase ratio:

1. Glass-based with the majority of silica as the main ingredient. It consists of silicon dioxide and can contain a different percentage of alumina.
2. Glass-based with crystalline fillers which are generally Lucite or lithium disilicate. Glass-crystalline ratio is increased and categorized in 3 subclass: (*a*) feldspathic porcelains with minimum to moderate Lucite, (*b*) contain approximately 50% Lucite, and glass phase is based on aluminosilicate; this group is available in form of powder-liquid, machinable and pressable, and (*c*) lithium disilicate ceramics like IPS Empress 2 in which lithium oxide is added to aluminosilicate.
3. Crystalline-based with glass fillers like alumina. In-Cerams are examples of these glass-infiltrated porcelains.
4. Polycrystalline solids like alumina oxide and zirconias which lack any glass phase.[2,3]

Etching of inert surfaces is needed for maximum adhesion and bonding of porcelains for restorative and orthodontic purposes. There are several techniques for achieving this goal, such as air abrasion which provides acceptable bonding in spite of probable adverse effects which cause irreversible changes in porcelain itself. Using chemical substances like orthophosphoric acid, acidulated phosphate fluoride and hydrofluoric (HF) acid are other acceptable substances used frequently for etching, but adverse effects like removing glaze layer of porcelain and also the difficulty during application in the oral cavity and possibility of injury to surrounding tissues can limit their use.[4-7]

There is a growing tendency toward a newly developed technique for its proven safe characteristics and efficient effects, recently. Lasers can accumulate high amounts of energy and concentrate it on target area which is mainly absorbed near the surface in opaque substances. In some cases, lasers cause chemical reactions and change the morphology and in some cases just cause physical modifications.

Initiation of tissue ablation occurs at energies above the threshold level which depends on tissue absorption mechanisms that rely on the properties of forming particles, infrastructures, and morphology; laser parameters like wavelength, frequency, pulse width and etc also play important roles in the procedure.[8-10]

Many studies measured and evaluated lasers and their parameters like irradiation time, output power, the number of pulses, characteristic of irradiated surface and also the ability of each laser to change hard tissue structure like: melting, changing the form of crystals or forming bubble-shaped inclusions or micro-explosion.

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In order to evaluate the impacts of lasers on surface modifications, measurements took place on shear bond strength (SBS) and tensile bond strength.

Lasers Used for Porcelain Etching

CO_2: The active part of this laser consists of a gas and it emits at a wavelength of 10 600 nm which is best absorbed by water and hydroxyl apatite; this wavelength is appropriate to be absorbed by porcelain and can create cavities using superficial heat; these micro-cavities can enhance mechanical strength between resins and ceramics.

There are some advantages related to CO_2 laser (fractional type) like affecting several points with distinct borders with a single emission; this feature leads to decrease in handpiece movements and making an homogenous surface on the sample. Despite this major advantage, fractional laser can increase heat compared with regular ones.[11,12]

Nd:YAG: This laser emits at a wavelength of 1064 nm which is best absorbed by water and pigmented tissues. This laser is best fit for soft tissue surgeries and hemostasis. The irradiation can also be absorbed by hard tissues and be used for modifying surface characteristics.

Nd:YAG laser causes surface roughness by melting and random re-crystallization which increases the strength of resin-ceramic bond; Nd:YAG lasers cause morphologic changes on the surface of zirconia-based porcelain samples but cannot form acceptable bond strength; however, some recent studies exhibited acceptable results using this laser on zirconium-bases porcelains. Unlike controversies mentioned for zirconium-based porcelains, the application of this laser for feldspathics was beneficial.[13,14]

Erbium lasers: These groups of lasers consist of Er:YAG and Er,Cr:YSGG with irradiation wavelengths of 2940 nm and 2780 nm respectively; these lasers are best absorbed by water and hydroxyl apatite at the invisible spectrum. Although there are similarities between these two lasers, differences like wavelengths, tissue ablation ability, thermogenesis potential, and penetration depth make them distinct.

Recent studies showed that level of absorption of Er:YAG lasers were 150 mm^{-1} and 200 mm^{-1} in enamel and dentin respectively; the absorption ability is one-third for Er:YSGG. As the absorption ability is higher in Er:YAG, the penetration depth is lower, so the irradiation time and energy are decreased in this type. Once erbium lasers are irradiated on hard tissues, the resulting energy increases temperature of tissue water and eventually vaporizes it. This reaction causes micro-exposures and makes it possible to remove hard tissues without damaging underlying tissues. Based on previous studies and proofs, Erbium lasers are appropriate choices for tissue ablation. Between these two lasers, Er:YAGs have the better absorbing ability and in addition to that, with a newly developed technique called variable square pulse (VSP), clinician are capable of defining the range of each pulse precisely. The laser can produce 2 kinds of pulses (super short pulse [SSP] and very long pulse [VLP]); the first one is used for tissue removal and the second for coagulation. In a study, it was demonstrated that the distance of the laser's head from the irradiated surface can affect the quality of etching on both Erbium lasers. The best distance was set at 1-2 mm for Er:YAG and 1 mm for Er,Cr:YSGG in order to get best results.[15,16]

Lasers change phosphor-calcium ratio and reduce carbon –phosphor ratio; by decreasing organic substances and water, the surface resistance against acid dissolution increases.[17]

Several studies were conducted in order to evaluate the efficiency of Er:YAG lasers considering energy, pulse type, and output power. Such studies are fewer for Er,Cr:YSGG, however, reports indicate that with an energy equal to Er:YAG but with less irradiation time, acceptable bond strength can be achieved.

Methods

Search for related articles and studies was conducted through archives of Cochrane, Google Scholar, and PubMed and using "shear bond strength, laser conditioning, porcelain etching and scanning electron microscope (SEM)" combination from 2004 to 2016. Overall 33 articles were evaluated and results were categorized in tables based on the type of lasers, type of porcelains, sample volume, laser settings and methods used for measuring the etching.

Results

After selection according to the inclusion and exclusion criteria, 33 researches were collected. These studies evaluated the effects of various parameters in different laser irradiation on bond strength and structural modifications of porcelain surface as shown in Table 1.

- In order to evaluate Nd:YAG effects on bond strength and surface modification 16 articles are collected. According to the studies this laser is as effective as other methods and can be used for surface conditioning in both high and low strength dental ceramics.
- In femtosecond laser 3 articles were found that reported more efficacy for this laser on high strength ceramics than other types.
- For evaluation of the effects of Er:YAG on dental ceramics 15 articles reported contradictory results in spite of similar parameters. According to these studies Er:YAG can be effective on 2 types of porcelain, but it seems that in low strength dental ceramics, the output power and irradiation duration are lower for surface conditioning without structural deterioration than high strength porcelain.
- Five researches evaluated the effect of CO_2 laser on different ceramic surfaces; these studies determined the efficacy of this laser on surface conditioning. This laser in lower parameters such as output power, irradiation duration and frequency can be more

Table 1. Studies Using Different Lasers on Ceramic Surfaces.

Author/Year	Type of Porcelain	Sample Volume	Mode of Laser	Laser Properties	Results Based on	Results	Final Result
Liu et al/2015[19]	Zirconia	In 11 groups: 1. Control group, 2. Air abrasion group 3-11. Nine laser groups	Nd:YAG	Power: 1, 2, 3 W; frequency: 10, 20, and 30 Hz; T: 30, 90, 60 s; pulse duration: 150 µs; energy density: 141.54 J/cm^2; pulse energy: 100 mJ with no water spray	SBS	Nd: YAG laser irradiation cannot improve the surface properties of zirconia ceramics and cannot increase the bond strength of the ceramics	–
Akpinar et al/ 2015[20]	Feldespatic	80, in 4 groups: 1.sandblast$_{50\ lm\ Al2O3\ for\ 3\ s}$ 2.HFA $_{9.6\%\ for\ 4\ min}$ 3.Nd:YAG laser 4. Femtosecond laser	Nd:YAG Femtosecond	Power: 4 W (MSP); frequency: 40 Hz; T: 20 s; pulse duration:100 µs; energy density: 0.354 J/cm^2; 1 mm distance, scanning motion Wavelength: 800 nm, T: 90 fs; Frequency:1 kHz; pulse duration: 90 fs; energy density: 2033 J/cm^2; scan at various scanning speeds, controlled by the software; back focal length: 11 cm	SBS SEM ARI	The bond strength in group NY was significantly lower than the other groups. FS treatment produced high SBS of the bracket bonded to porcelain.	+ -
Sadeghi et al/ 2015[21]	Feldespatic	72, in 6 groups: 1. Control group$_{no\ treatment)}$ 2. HF$_{9\%,\ 90\ s}$ 3-6: Laser	Er:YAG	Power/energy: 2.2 W, 100 mJ; 3.3 W, 150 mJ; 4.4 W, 200 mJ; 5.5 W, 250 mJ; frequency: 6.20 Hz; long pulse 20 s, 80% water & 40% air flow, sweeping, motion 1 mm distance	SBS ARI	The highest SBS was obtained with HF. The lowest SBS was observed in G4Although, Er:YAG laser irradiation at 5 W, 250 mJ/20 Hz was effective in promoting adhesion of resin composite to feldspathic porcelain compared with the control group, it cannot be used as a safe alternative method to H	–
Kara et al/ 2015[22]	Zirconia	72, in 2 groups and 3 subgroups: 1. Zirkonzahn 2. Zirkonzahn Prettau and 3 subgroup according to surface treatment	Femtosecond Nd:YAG Er:YAG	Power: 400 mW/pulse; frequency: 1 kHz; T: 90 fs; WL: 800 nm Frequency: 20; power: 2 W; pulse energy: 100 mJ; energy density: 141.54 J/cm^2; pulse duration: 150 µs; 1 mm distance, scanning Power: 6 W; frequency: 20 Hz; pulse energy: 300 mJ; pulse duration: 75 µs; 1 mm distance, scanning with water and air cooled	SBS SEM	The group irradiated with FS laser had significantly higher roughness and MPa n the SEM, the surfaces of the FS group were rougher. It appears to be an effective method for bonding resin cement to zirconia ceramic surfaces. No significant difference was found between the NY laser and EY laser groups	+ –
Erdur et al/ 2015[23]	Feldspathic	150, in 2 groups and 5 subgroups: 1. Sandblasting 50 µm, aluminum oxide particles for 20 s and 60 s for feldspathic 2. HFA 5% for 20 s 3. Nd:YAG laser 4. Er:YAG laser 5. Ti:sapphire laser	Er:YAG Ti:sapphire Nd:YAG	Power: 1.6 W; frequency: 20 Hz; T: 20 s; pulse energy: 80 mJ; pulse duration: 100 µs; with water spray, scanning motion; 1 mm distance Power: 0.45 W; frequency: 1 kHz; λ: 800 nm; Frequency: 85.5 MHz, pulse energy: 225 mJ; pulse duration: 90 fs; scanning motion, marking speed of 30 mm/s and skipping speed of 125 mm/s Power: 2 W; frequency: 20 Hz; T: 20s; pulse energy: 100 mJ; pulse duration: 150 µs; scanning motion;1 mm distance	SEM SBS ARI	Feldspathic and IPS Empress e-Max ceramics had similar SBS values. The Ti:sapphire femtosecond laser produced the highest mean bond strength. The Er:YAG and Nd:YAG laser groups were similar and had the lowest SBS values. More homogeneous and regular surfaces were observed in the ablation pattern with the Ti:sapphire laser than with the other treatments by SEM analysis	– + –
Aksakalli et al/ 2014[24]	Porcelain laminate veneer	39, in 3 groups: 1. Sandblast $_{10\ s,}$ 50 µm. 2. Laser 3. HFA $_{9.6\%\ for\ 4\ min}$	Er:YAG	Power: 2 W; frequency: 10 Hz; pulse energy: 200 mJ; pulse duration: 100 µs; energy density: 25.31 J/cm^2; directed perpendicular to the porcelain; distance: 1 mm	SBS SEM ARI	The highest shear bond strength values were obtained with Group HFA and Group ER, whereas Group SB revealed the lowest values. The Er: YAG laser therefore can be selected	+

Table 1. Continued

Rocca et al/ 2014[25]	1. Zirconia (IPS e.max ZirCAD) 2. Lithium disilicate (IPS e.max)	32 CAD/CAM In 2 groups: CO2 Nd:YAP	CO2 Nd:YAP	Power: 20, 25, 30 W; power densities: 63 662 W/cm², 79 577 W/cm² and 95 493 W/cm²; distance 2 mm λ: 1340 nm; power: 10 W; power density: 31 831 W/cm²; frequency: 30 Hz	SEM EDS XRD	The macroscopic observation showed a shinier structure in all the groups, while at the SEM observation only CO_2 25 W and 30 W treated groups showed cracks and fissures. CO_2 and Nd:YAP with used create chemical and physical surface modifications	+ +
Murthy et al/ 2014[26]	Zirconia	25, in 5 groups: 1. Untreated 2. Sandblasted with $_{110\ \mu m\ alumina,15\ s}$ 3. Sandblasted $_{with\ 250\ \mu m\ alumina,15\ s}$ 4. HFA $_{9.6\%,\ 30\ s}$ 5. Laser radiation	CO_2	Power: 3 W; frequency: 1000 Hz; pulse duration: 160 ms; delivered perpendicular to the surface in non-contact mode 1 mm distance.	SBS	Highest SBS were obtained with laser treatment. Laser treatment increased the SBS values significantly	+
Zarif Najafi et al/2014[27]	Feldspathic	48, in 4 groups: 1. Deglazed + HFA$_{9.6\%\ for\ 4\ min}$ 2. Deglazed +CO2 group 3. CO2 group 4.sandblasting$_{50\ lm\ alminumum\ 5\ s}$	CO_2 (with and without roughening)	Power: 2 W the super pulse mode (15 ms, 2 Hz); T: for 20 s	SBS ARI	Deglazing + HFA etching produced the highest BS, but CO_2 provided adequate BS. Deglazing is not recommended as a preliminary step before CO_2 laser condition in highest ARI & BS=HF.	+
Akhavan Zanjani et al/2014[28]	Zirconia	61 in 4 groups: 1. Sandblasting with 50-lm aluminum oxide in 50 s 2. CO2 laser 3,4. Er,Cr:YSGG laser	Co2 Er:Cr:YSGG	Power: 4 W; T: 50 s; pulse duration: 2-ms; 2-mm-diameter perio tip with a air/water cooling system Power: 3 W(c) 4W(d); frequency: 50 Hz; T: 50 s; pulse duration: 140 μs; distance of 1 mm. Tip. under an air/water (50%/1%) cooling system	SEM SBS ARI	Air abrasion showed the highest microshear bond strength among all groups. CO2 and Er,Cr:YSGG 3 W laser showed significantly higher bond strength than Er,Cr:YSGG 2 W. Apparent micromechanical roughening and irregularities were seen in the air abrasion-treated samples. CO2 laser at 4 W and Er,Cr:YSGG laser at only 3-W output power can be regarded as surface treatment options for roughening the zirconia surface to establish better bond strength with resin cements	+ +
Tai et al/2013[29]	Metal ceramic prosthesis	In 6 groups: 1. Control 2. HFA 9.6% 3. Deglazed + 9.6% HF 4. Nd: YAG (0.75 W) +HF 5. Nd: YAG (1.05 W) + HF 6. Laser (1.45 W) + HF	Nd:YAG	Power: 0.75 W, 1.05 W, 1.45 W	SEM	Shape of circle were observed on the ceramic surface after treatment with energy parameters of 1.05 W Nd: YAG laser irradiation and 9.6% HF etching	+
Hosseini et al/ 2013[30]	Feldspathic	In 4 groups: 1. After porcelain surface roughness creation by carbide bur and deglazing, samples were etched With 9.6% HF($_{2MIN}$) 2-4: samples were put under Nd:YAG	Nd:YAG	Power: 0.75, 1.5 and 2 W; frequency: 10 Hz; pulse duration: 100 μs via sweeping motion; 2 mm distance	SEM	Etching quality from a porosity point of view was similar for group 2 and HF group. Laser with power of 0.75 W has little potential to create mechanical porosity.	+

Table 1. Continued

Hosseini et al/ 2013[31]	Feldspathic	72, in 6 groups: 1: HF 9.6%($_{4\ min}$) 2-6: Laser with different power	Nd:YAG	P: 0.75, 1, 1.25, 1.5, 2 W; F: 10 Hz; T: 10 s; pulse duration: 100 µs via sweeping motion. 2-mm distance	SBS ARI	No significant differences were found between the HF group and the laser groups with power of 1.5 or 2 W Nd:YAG laser with appropriate parameters can be used	+
Usumez et al/2013[32]	Y-TZP	75, in 5 groups: 1. Glaze applied, and 9.5 %HF$_{60\ s}$ 2. Alumina sandblasting $_{for\ 20\ s}$ 3,4: Nd:YAG + coated with graphite $_{prior\ to\ laser\ irradiation\ to\ increase\ energy\ absorption}$ 5: Control	Nd:YAG	Frequency: 10 Hz; T: 60 s; pulse energy: 200 mJ/ pulse; pulse duration: 180 µs & 320 µs scanning motion	SBS SEM XRD	The Nd:YAG laser-irradiated specimens resulted in both increased surface roughness and BS. The highest surface roughness and bond strength values were achieved with short pulse duration	+
Yassaei et al/ 2013[33]	Feldspathic	100, in 4 groups: 1. HFA $_{9.6\%\ for\ 2\ min}$ 2-4: Er:YAG irradiation	Er:YAG	2. Power: 1.6 W; 3. Power: 2 W; 4. Power: 3.2 W; F: 20 Hz; T: 15 s; 10 mm distance from head	SBS SEM	The mean shear bond strength in the laser group with power of 1.6 W was more than that of the HF, 2-W power, and 3.2-W power, but this difference was not statistically significant.	+
Kursoglu et al. 2013[34]	IPS Empress 2	55, in 5 groups: 1. HFA $_{9.5\%\ for\ 60\ s}$ 2 to 4: Er,Cr:YSGG laser 5. Not treated	Er:CrYSGG	Power: 1.5, 2.5, 6 W; T: 60 s; pulse energy: 300 mJ sweeping fashion air and vapor were adjusted to 50% of the laser unit	SEM SBS	Adhesion was significantly stronger in 1.5 W & 2.5 W than in control group. Er,Cr:YSGG at 1.5 and 2.5 W increased SBS between ceramic and resin cement compared with untreated ceramic surfaces.	+
Kara et al/ 2012[35]	IPS Empress 2	40, In 4 groups: 1. Air abrasion $_{for\ 20\ s}$ 2. Acid etching 3. Nd:YAG laser 4. Er:YAG laser	Nd:YAG Er:YAG	Power:2 W; F: 20 Hz; Pulse energy: 100 mJ; pulse duration: 150 µs; energy density: 141.54 J/cm^2 water scanning 1 mm distance Power: 10 W; F: 20 Hz; Pulse energy: 500 mJ; Pulse duration: 75 µs. 1 mm distance, water scanning.	SEM	No significant difference was found between the acid etching and laser irradiation (both Er:YAG and Nd:YAG) groups	+ +
Subaşı et al/2012[36]	Zirconia	80, in 4 groups: 1. Control: No conditioning 2. Laser treatment 3. Silica coating 15 s, 30 µm Al2O3 4. Air abrasion 110 µm Al2O3,15 s	Er:YAG	P: 4 W MSP mode; F: 10 Hz; T: 15 s; pulse energy: 400 mJ; pulse duration: 100 µs; Scanning motion with water distance 1- mm,	AFM SEM	SEM and AFM analyses revealed changes in surface topography after surface treatments, especially in the laser group(prior to cementation);	+
Poosti et al/ 2012[37]	Feldspathic	100, In 5 groups: 1. Only deglazed and roughened by diamond burs. 2. After roughening and deglazing etched by 9.6% (4 min) 3-5: 0.8-W Nd:YAG, 2-W Er:YAG, 3-W Er:YAG	Nd:YAG Er:YAG	Power: 0.8 W; T: 10 s Power: 2, 3 W; T: 10 s	SBS	SBS of 9.6% hydrofluoric acid and Nd:YAG Laser was in an acceptable range for orthodontic treatment, Er:YAG laser was not a suitable	+ –

Table 1. Continued

Dilber et al/ 2012[38]	Feldespatic IPS empress2	50, in 5 groups: 1: C (untreated control 2: Group SB (sandblasting) for 20s 3: Group SB-L (sandblasting + Er:YAG laser 4: Group HF-L (acid etching + Er:YAG laser).HF: 20 s, 20 s rins, 20 s air compress 5: Group L (Er:YAG laser)	Er:YAG	Power: 10 W; Frequency: 20 Hz; 1-mm distance; pulse energy: 500 mJ; MSP mode (100 ls pulse length); energy density: 37,68 J/cm^2 scanning motion	Surface roughness	SB and SB-L had significantly higher mean roughness values. There was no significant difference in surface roughness between the HF acid etching, Er:YAG	+
Ahrari et al/ 2012[39]	Feldespatic	80, in 4 groups: Half of the specimens were roughened with a diamond bur to remove the glaze before conditioning. 1-3: Fractional CO2 4. HFA 9,6% for 2 min	CO_2	Power: 10 W for group 1, 15 W for group 2, 20 W for group 3; Frequency: 200 Hz; T: 10 s; pulse energy:10 mJ; 10 mm distance manually perpendicular to the porcelain	SBS	BS of 10 W and 15 W laser groups were significantly higher than that of the HF Laser conditioning with a fractional CO2 laser can be recommended	+
Akyıl MS et al. 2010(40)	Feldespatic	78, In 6 groups: 1. No treatment (control 2 .HFA 9.5% HFA etching,2min 3. Er:YAG laser irradiation 4. Nd:YAG laser irradiation 5. Er:YAG+HFA 6. Nd:YAG+HFA	Nd:YAG Er:YAG	Power: 1-W pulse energy:100 mJ Frequency: 10 Hz T: 1 min pulse duration:150µs fiber tip$_{(\text{ water and air cooling})}$ Power: 3-W Frequency:10 Hz T: 1 min pulse energy:300 mJ pulse duration:75µsec water and air cooling	SEM SBS	The highest shear bond strength was found after HFA etching, and the lowest was found after Er:YAG laser irradiation. The shear bond strength after laser irradiation can be increased by HFA etching	– –
da Silva Ferreira et al/ 2010[41]	Feldespatic	60, in 3 groups, 2 subgroups: 1. (Control group) Air abrasion 2. Al2O3+Er:YAG laser 3. Al2O3+Nd:YAG laser 2 subgroups: a RelyXTM ARC & self- adhesive resin	Nd:YAG Er:YAG	Frequency: 4 Hz; T: 20 s; pulse energy: 500 mJ; scanning motion; 0.5-mm focal distance, with no water spray, in order not to remove the hydroxyapatite paste. Power: 1 W; frequency: 20 Hz; pulse energy: 100 mJ; energy density: 141.54 J/cm Scanning motion with no water spray. 1mm distance	SBS	Surface treatment proposed with AA associated with the Er:YAG or Nd:YAG laser and using cementation with self-adhesive cement can be effective.	+ +

Table 1. Continued

Akyıl et al/ 2010[42]	Y-TZP	140, In 9 groups: the irradiated area coated with graphite before irradiation 1. C, no treatment; 2. AA air abrasion; 3. CJ silica coating; 4. ER, Er:YAG laser; 5. ND, Nd:YAG laser; 6.CO, CO2 laser; 7. AA+ER, air abrasion Er:YAG laser; 8. AA+ND, air abrasion Nd:YAG laser; 9. AA+CO, air abrasionCO2 laser. *The samples of AAER, AAND, and AACO groups were ultrasonically cleaned with 96% isopropanol for 3 min	Nd:YAG	Power: 2 W; pulse energy: 200 mJ/pulse; frequency: 10 Hz; T: for 10 s; adjustable air and water spray	SEM SBS	CO2 and Er:YAG laser irradiation alone or Nd:YAG laser irradiation after air abrasion may be used as an alternative treatment method to increase the bond strength between resin cement and Y-TZP material. The application of air abrasion before Er:YAG or CO2 laser irradiation created a rough surface texture on Y-TZP surfaces, but afterwards the application of lasers may destroy this structure	+
			Er:YAG	Power: 2 W; pulse energy: 200 mJ/pulse; frequency: 10 Hz; T: for 10 s; adjustable air and water spray			+
			Co_2	Power: 4 W; T: 50 s; adjustable air and water spray.			+
Osorio et al/ 2009[43]	In-Ceram alumina	In 4 groups: 1. No treatment; 2. Rocatec System sandblasting with silica powder; 3. Nd:YAG laser; 4. Nd:YAG laser plus Rocatec System	Nd:YAG	Power: 2 W; frequency: 20 Hz; pulse energy: 100 mJ, energy density: 141.54 J/cm^2; 1mm distance scanning	SEM	No differences in ceramic surfaces roughness occurred after any of the tested treatments.	–
Cavalcanti et al/2009[44]	Y-TZP Cercon porcera	30, In 5 groups: 1. Control; 2. Air abrasion 53 µm aluminum oxide for 15 s; 3-5. Irradiation with 3 different energy intensities	Er:YAG	Frequency: 10 Hz; T: 5 s; 200 mj, 25.48 J/cm^2; 400 mj, 50.96 J/cm^2; 600 mj, 76.43 J/cm^2; coated with graphite prior to laser irradiation	SEM	For both zirconia-based materials, irradiation with 400 mJ or 600 mJ increased surface roughness Procera surfaces irradiated with 200 mJ were rougher than the air-abraded ones.	+
Ersu et al/2009[45]	In-Veram spinell, In-Ceram alumina, In-Ceram zirconia	150, in 5 groups: 1. C—untreated; 2.SB—sandblasted 50-micron aluminum oxide, 5 s; 3. AB—airborne particle abrasion 27-micron aluminum oxide, 5 s; 4.HFA 9.5% for 60 s; 5.L—CO2 laser irradiation	CO_2	P: 3 W; F: 1000 Hz and pulse duration:160 ms	SEM SBS Surface roughness (Ra in mm)	CO_2 laser showed significantly higher BS for In-Ceram Spinell, both airborne particle AA and CO_2 laser irradiation showed higher BS for In-Ceram zirconia. AA demonstrated higher BS for In-Ceram alumina and In-Ceram zirconia. No significant relationship was determined between (*Ra*) and SBS	+
Spohr et al/2008[46]	In-Ceram zirconia	9, in 3 groups: 1. Sandblasting with Al2O3 50 µm, for 10 s; 2. Sandblasting as described for group 1, followed by sandblasting with silica powder 30 µm, for 10 s; 3. Sandblasting as described for group 1(application of graphite power) + Nd:YAG irradiation	Nd:YAG	Power: 2 W, 20 pps; T: 2 min; pulse energy: 100 mJ; pulse duration: 100 µs; energy density: 141.54 J/cm^2; with no water spray; scanning motion 1mm distance	SBS SEM	The highest BS: Nd:YAG laser treatment Nd:YAG laser irradiation is an effective surface treatment for bonding between In-Ceram zirconia and Panavia Fluoro Cement. Nd:YAG laser-irradiated surface showed a Smooth blister-like bubbles with voids were surrounded by a flat and porous layer with openings of various diameters.	+

Table 1. Continued

An et al/2008[47]	Feldespatic	90, in 9 groups: 1. orthophosphoric acid; 2. orthophosphoric acid + silane; 3. HF; 4. HF+ silane; 5. sandblasted; 6. sandblasted + silane; 7. laser; 8. laser + silane; 9. glazed surface served as a control group	CO_2	2 W super pulse; T: 20 s	SBS	The HFA + S group showed the highest SBS. 2-watt super pulse CO_2 laser etching can provide a satisfactory result (7.86 ± 0.96 MPa) for ceramic bracket bonding	+
Shiu et al/ 2007[48]	Feldespatic	100, in 10 groups: 1. control group; 2. HFA 10% for 2 min; 3. H3PO4 37% for 1 min; 4. APF 1.23% for 10 min; 5. diamond bur 30 µm; 6. Al2O3 air abrasion with 50 µm; 7. Al2O3 + HF; 8. CoJet-Sand; 9. Er:YAG laser; 10. Al2O3 + Er:YAG laser	Er:YAG	F: 4 Hz; T: 2 min; energy pulse: 500 mJ; focal distance: 0.5 mm; under water refrigeration; 480 pulses and 242 J of total energy	SBS (adhesive/ cohesive failure)	The lowest bond strengths were obtained with H3PO4, APF, Er:YAG , and the control group. Er:YAG laser showed low BS and seems to be inadequate for clinical use	–
Gökçe et al/ 2007[49]	IPS Empress 2	110, in 5 groups: 1.control group; 2. HF 9.5% for 30 s; 3-5: laser with different power	Er:YAG	Power: 4-10 W; frequency: 20 Hz; T: 20 s; pulse energy: 300, 600, 900 mj; power density: 191.08, 382.16, 573.25 W/cm2; Pulse duration: 250 µs; Sweeping motion The irradiated specimens were dried with an oil-free air source for 15 s	SBS SEM	The 300 mJ laser group exhibited the highest SBS values, indicating that laser etching could also be used for surface treatments.	+
Akova et al/ 2005[50]	Porcelain fused to metal	100, in 10 groups: 1. SB: 50-micron aluminum oxide; 2. SB+S; 3. OFA 37% for 2 min; 4. OFA+S; 5. HFA 9.6% for 20 s; 6. HFA+S; 7. laser etched (L); 8. laser etched with silane (L+S); 9. glazed (Control 1/C1); 10. deglazed (Control 2/C2).	CO_2	P: 15 W, 10 W, 5 W, 3 W, and 2 W in the super pulse mode (15 ms, 2 Hz); T: 20 s	SBS bond failure cohesive adhesive mixed SEM	The bond failure modes of HFA and silane groups, except L+S, were cohesive in porcelain. Only irradiation by 2 W for 20 s provided a porous surface texture without cracks.	+
Tengrungsuna et al/2004[51]	Porcelain fused to metal	64, in 4 groups: 1. control group (not treated); 2. sandblasting for 10 s; 3.Nd:YAG laser; 4. HF 9.6% for 1 min	Nd:YAG	T: 20 pps, 60 s; Pulse energy: 150 mJ/pulse; energy density: 375J/cm^2	SEM, SBS	No significant difference between 3 treated surfaces (laser, HF, SB)	+

effective on low strength porcelain.
- One research reported that Nd:YAP laser can condition ceramics surfaces effectively, it showed physical and chemical surface modification but they did not evaluate this conditioning on bond strength.
- In order to determine the effect of the Er,Cr:YSGG laser on surface conditioning, 2 studies were found; this laser can be effective on high and low strength dental ceramics in similar parameters. More studies are needed for more reliable results on the effects of this laser.

Discussion

The aim of this review article was to measure and evaluate results of previously conducted studies focused on the efficiency of porcelains etching by different types of lasers and also compare each method's efficacy with regular techniques.

The goal for each method was to achieve a surface with certain physical and chemical properties so that the adhesive material can flow easily and make proper bond strength; as it has been previously proven, adherence of brackets to teeth relies on the adhesive material, retention, and proper preparation of teeth surface.[18]

Although there are many routine techniques that clinicians have profited up to this date, there always were limitations such as damaging peripheral tissues, inability to create proper bond strength, damaging tooth structure itself or attached restorative material, and considerable clinical time. Using different types of lasers with different settings have been suggested due to these limitations.

Several studies conducted on Nd:YAG lasers made it clear that this type of laser is efficient for etching the surface of feldspathic porcelain; the level of etching equaled HF or were even higher in some cases; however some studies rejected such effects and the positive role due to different study designs.

In a study by Liu et al,[19] Nd:YAG laser (power: 1.05 W) was shown to be as effective as HF for etching the surface of feldspathic porcelain. In another study by Akpinar et al,[20] Nd:YAG laser (4 W, 40 Hz) achieved lower bond strength compared with HF and sandblast while in this study femtosecond laser (1 kHz) could make stronger bond strength.

Nd:YAG lasers exhibited different results at zirconia-based porcelains, as Spohr et al showed that Nd:YAG laser at a 2 W power and 2-minute irradiation time can bring acceptable modified surface.[46] Usumez et al gained acceptable results by increasing pulse energy and pulse duration at 1-minute irradiation as well.[32] In the reviewed studies, time of irradiation was between 5 seconds to 2 minutes and it needs to be further studied as it seems an important factor in the final result.

To summarize, effects of Nd:YAG laser differ based on output power, pulse duration, pulse energy, irradiation time and surface characteristics, nonetheless it still had better effects on feldspathic porcelains.

Er:YAG lasers had conflicting results on feldspathic porcelains. Kara et al[35] and Dilber et al[38] demonstrated the efficacy of this laser at 10 W power and 20 Hz frequency for surface etching; the results showed the same level of surface modification as HF. Erdur et al[23] used Er:YAG with an output power of 1-6 W and frequency of 20 Hz and reported non-acceptable SBS; the surface roughness evaluated by electronic microscope was not acceptable as well. While in this study Er:YAG was not beneficial, titanium sapphire laser could deliver efficient changes at 0.45 W power. Overall this laser seems to be useful at powers higher than 10 W. It seems that due to different settings and techniques used in the studies that evaluated Er:YAG lasers, reaching a certain conclusion is rather difficult and more studies with standard parameters and protocols are needed to have a realistic conclusion; however it seems the laser will do well at an energy between 250 to 300 mJ. The lack of one important factor in most studies was the distance of laser head from the surface of the samples which seems to play an important role in final results.

Er:YAG lasers are capable of bringing more significant changes on zirconia porcelains. Cavalcanti et al[44] reported acceptable surface roughness by this laser at 400 and 600 mJ pulse energy. Akyil et al[40] showed that Er:YAG can be beneficial at 2 W power and 200 mJ pulse energy as well; the irradiation time for this setting was 10 seconds.

CO_2 laser at 10 and 15 W power was used in the study of Ahrari et al and provided stronger bond strength than HF in feldspathic porcelains.[39] Ersu et al[45] used CO_2 laser on 3 types of zirconia-based porcelains; the bond strength was highest in In-Ceram Spinell, and in other types, in spite of delivering surface changes, bond strength could not be increased.

Akhavan Zanjani et al[28] used Er,Cr:YSGG at 3 W power for 50 seconds and could make an acceptable surface roughness in zirconia porcelain. Kursoglu et al[34] also supported usage of this laser at 1.5-2 W power due to the significant difference with the control group in feldspathic porcelains.

Although there are several studies considering efficiency and potential of each laser for surface etching and therefore resulting bond strength, but due to different approaches and techniques the results were almost different and reaching certain settings for the definite optimum efficacy was not possible.

Conflict of Interests

None.

Ethical Considerations

Not applicable.

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