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A new modified laser pretreatment for porcelain zirconia bonding

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ABSTRACT

Objectives. The aim of this study was to compare the effects of three different surface treatments in enhancing porcelain zirconia bonding.
Methods. Totally, 160 densely sintered zirconia specimens were prepared and randomly divided into four study groups: control (no treatment, Group C), sandblasting (Group S), sandblasting followed by regeneration firing (Group SH), and laser irradiation (pulse mode) on a CO_2 laser system (Group L). After surface treatment, porcelain powders were veneered on zirconia surface. Half of the specimens in each group were evaluated without aging (initial shear bond strength – initial SBS), and the other half was tested after being stored in water for one month (aging SBS). X-ray diffractometry (XRD) was used to observe any crystallographic transformation at zirconia surface. Results were statistically analyzed using analysis of variance (ANOVA) and Turkey test (=0.05).
Results. The initial average SBS values of Group S, Group SH, and Group L were 31.3 ± 5.7 MPa, 29.2 ± 7.0 MPa and 32.1 ± 7.5 MPa, respectively. The differences among these three groups were not significant. The control group had significantly lower value, 24.8 ± 6.7 MPa, than those of Group S and Group L. Furthermore, there was no significant difference between initial and aging values in each group. XRD analysis showed that sandblasting caused tetragonal to monoclinic phase transformation. Regeneration firing reversed such a transformation. However, crystallographic transformation could not be detected in laser treated specimens.
Significance. Both sandblasting and laser irradiation increased porcelain zirconia bond strength. The presented new modified laser pre-treatment might be an alternative way to sandblasting for improving zirconia/porcelain integration.

1. Introduction

Although zirconia, especially yttria-stabilized tetragonal zirconia polycrystal (Y-TZP), has been widely used in the production of all-ceramic restorations nowadays, the relatively higher failure rate of zirconia-based prostheses compared with porcelain-fused-to-metal (PFM) restoration is still concerned [1]. The bonding between zirconia and porcelain was also reported to be inferior to that between metal and

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porcelain [2]. Such weak bonding might be due to some factors, e.g. a mismatch in the coefficients of thermal expansion, surface treatment, lack of chemical bonding, unintentional formation of microporosities at the interface, etc. [3].

Several in vitro studies on zirconia surface treatment have been carried out aiming at improving the quality of porcelain to zirconia bonding. Since zirconia is chemically inert, it cannot be etched by some commonly used mineral acids, such as HF, H_3PO_4, under normal atmospheric conditions [4]. Thus, acid etching may not be an effective and convenient method. It has been reported that the application of sandblasting would help to produce a durable bonding at zirconia/porcelain interface [5]. However, such a finding has not been supported by all published studies. One study found that, although sandblasting could significantly increase the surface roughness of zirconia, it did not result in improving the zirconia/porcelain porcelain integration [6]. Furthermore, during the process of sandblasting, surface flaws may also be produced which might be detrimental to the clinical survival of zirconia-based restorations [7].

Light Amplification by Stimulated Emission of Radiation (laser) technology has been utilized as one of the industrial surface treatment methods for more than forty years. Laser beam has some advanced properties, includes high and precise monochromaticity, coherence, collimation, great brightness and output efficiency [8]. The use of laser energy in zirconia surface treatment has now been of interest and reported in several studies. It was found that the values of zirconia surface roughness had been significantly increased after being processed with Nd:YAG laser (pulse mode) as well as the surface wettability [9]. Another study compared the shear bond strengths of resin zirconia bonding among four different pre-treatment groups (untreated, HF etching, sandblasting and laser irradiation) and claimed that CO_2 laser irradiation (pulse mode) at the 3 W power induced higher bond strength. Such improvement in bond strength was ascribed to the generation of micro-cracks on zirconia superficial layer induced by laser treatment. Thus, the author proposed the laser irradiation as an alternative way to surface pre-treatment of zirconia [10]. Nevertheless, the application of laser irradiation as a method of zirconia surface conditioning is still lack of investigation. Since the same effects generated in resin zirconia bonding may not work in the same way in porcelain zirconia bonding, the final word of the influence of laser treatment on porcelain to zirconia bonding still remains questionable.

The aim of this study was to investigate the effects of laser irradiation on zirconia before veneering procedure on the shear bond strength between zirconia and veneering porcelain. The hypothesis of the study was that laser irradiation would improve bonding at zirconia/veneering porcelain interface compared to sandblasting.

2. Materials and methods

2.1. *Preparation of zirconia specimens*

One hundred and sixty Y-TZP (Cercon base, DeguDent GmbH, Hanau, Germany) planar specimens with a half moon shape and initial dimensions of 25 mm in diameter and 6 mm in thickness were sectioned from pre-sintered zirconia blocks (containing 3 mol% yttria) using a cutting machine (Microslice, Metal Research limited company, England) under running water. These pre-sintered discs were then polished with SiC paper (1000-grit) under running water on a polishing device (Lumn Major, Struers, Denmark). All the specimens were then densely sintered in a furnace (Cercon heat, DeguDent GmbH, Hanau, Germany) under the conditions (1350 °C for 6 h) according to the manufacturer's instructions. After the sintering procedure, dimensional change occurred (about 24 vol%) in each disc and the size of each slice was finally determined as: 19.2 mm in diameter, and 4.5 mm in thickness. Subsequently, all the zirconia specimens were divided into four experimental study groups ($n = 40$) using the method of randomization, according to the surface treatments as follows:

Group C (control): no special treatment was carried out to modify the zirconia specimen surfaces in this control group.

Group S (sandblasting): in this group, the bonding areas on zirconia specimens were sandblasted with 50 μm alumina particles (Vacumat 300, Vita zahnfabrik, Germany) for 15 s at the pressure level of 3.5 bar and the working distance was set as 10 mm. The direction of this air abrasion process was perpendicular to the specimen surface.

Group SH (sandblasting followed by regeneration firing): the specimens were sandblasted using the same settings as described above and the particles used as those in Group S. Then, after being ultrasonically cleaned in a 70% ethanol solution (Ethanol 70% Technisolv® Pure, VWR International, USA) for 10 min and air dried, they were further heated in a porcelain furnace (Cobra 15941205, Renfert GmbH, Germany) at the temperature of 1000 °C for 15 min with a 500 °C pre-drying temperature and 100 °C/min increasing firing rate.

Group L (laser irradiation): laser surface treatment of zirconia surface was adjusted according to authors' design and conducted using a commercial scale CO_2 laser system (GFK Marcatex Flexi-150, Eurotrend Group, Spain). This CO_2 laser was operated using a pulse mode and a wavelength of 10,600 nm. The output laser light was set as 60 dpi in resolution and 300 μs in pixel time. The actual output power was 15.1 W/cm^2. The entire surface of each zirconia disc was modified with laser beam directly without any coating for three times. After each period of laser irradiation, the specimens were rotated at 90° clockwise. The interval time between two irradiations was 20 s.

2.2. *Analysis of surface roughness*

The surface roughness of all groups was analyzed with a profilometer (Surtronic 3+, Taylor Hobson Ltd, UK). Arithmetical mean roughness, R_a, was determined as the indication of surface roughness. The higher R_a value is the rougher surface. Before each test, the profilometer was calibrated with a standard sample (6.02 μm) provided by the manufacturer and the cut off length was 0.80 mm. The tests were performed on a flat surface. Twenty randomly selected zirconia samples in each group were measured after surface modification. For each sample, the measurement of surface roughness was performed three times and the mean value of the three readings was adopted.