

THE EFFECT OF DIFFERENT SURFACE TREATMENT TECHNIQUES ON THE SURFACE ROUGHNESS OF FELDSPATHIC PORCELAIN

Farklı Yüzey Tedavi Tekniklerinin Feldspatik Porselenlerin Yüzey Pürüzlülüğü Üzerindeki Etkileri

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ABSTRACT

Purpose: This *in vitro* study compared the effect of five different techniques on the surface roughness of feldspathic porcelain. **Materials and Methods:** 100 feldspathic porcelain disk samples mounted in acrylic resin blocks were divided into five groups (n=20) according to type of surface treatment: I, hydrofluoric acid (HFA); II, Deglazed surface porcelain treated with Neodymium:yttrium-aluminum-garnet (Nd:YAG) laser; III, Deglazed porcelain surface treated with Erbium:yttrium-aluminum-garnet (Er:YAG) laser; IV, Glazed porcelain surface treated with Neodymium:yttrium-aluminum-garnet (Nd:YAG) laser; V, Glazed porcelain surface treated with Erbium:yttrium-aluminum-garnet (Er:YAG) laser. The surface roughness of porcelain was measured with a noncontact optical profilometer. For each porcelain sample, two readings were taken across the sample, before porcelain surface treatment (T1) and after porcelain surface treatment (T2). The roughness parameter analyzed was the average roughness (Ra). Statistical analysis was performed using Kolmogorov-Smirnov and Wilcoxon signed rank test. **Results:** Mean Ra values for each group were as follows: I, 12.64±0.73; II, 11.91±0.74; III, 11.76±0.59; IV, 3.82±0.65; V, 2.77±0.57. For all porcelain groups, the lowest Ra values were observed in Group V. The highest Ra values were observed for Group I, with a significant difference with the other groups. Kolmogorov-Smirnov showed significant differences among groups (p<0.001). **Conclusion:** Surface treatment of porcelain with HFA resulted in significantly higher Ra than laser groups. Both Er:YAG laser or Nd:YAG laser on the deglaze porcelain surface can be recommended as viable treatment alternatives to acid etching.

Keywords: Porcelain roughness; hydrofluoric acid; Er-YAG laser; Nd:YAG laser; surface treatment

ÖZ

Amaç: Bu *in vitro* çalışmada, beş farklı tekniğin feldspatik porselenin yüzey pürüzlülüğüne etkisinin karşılaştırılması amaçlanmıştır.

Gereç ve Yöntem: Akrilik rezin bloklara gömülen 100 feldspatik porselen disk işlem tipine göre beş gruba (n=20) ayrıldı. (I, Hidroflorik asit (HFA); II, Neodymium:yttrium-aluminum-garnet (Nd:YAG) lazer uygulanan deglaze porselen yüzey; III, Erbium:yttrium-aluminum-garnet (Er:YAG) lazer uygulanan deglaze porselen yüzey; IV, Nd:YAG lazer uygulanan glaze porselen yüzey; Er:YAG lazer uygulanan glaze porselen yüzey). Porselen yüzeylerin pürüzlülüğü temassız optik profilometre ile ölçüldü. Her bir porselen örnek, porselen yüzey tedavisinden önce (T1) ve porselen yüzey tedavisinden sonra (T2) iki kez değerlendirildi. Pürüzlülük parametre analizi ortalama pürüzlülük olarak belirlendi (Ra). İstatistiksel analiz Kolmogorov-Smirnov ve Wilcoxon işaretli sıralar testi kullanılarak yapıldı.

Bulgular: Her bir grubun ortalama Ra değeri sırası ile : I, 12.64±0.73; II, 11.91±0.74; III, 11.76±0.59; IV, 3.82±0.65; V, 2.77±0.57 olarak saptandı. Tüm porselen grupları içinde en düşük Ra Grup V de gözlemlendi. Diğer gruplarla istatistiksel olarak anlamlı farklılık olmakla beraber birlikte en yüksek Ra, Grup I'de gözlemlendi. Kolmogorov-Smirnov testinde gruplar arasında anlamlı farklılık olduğu saptandı (p<0.001).

Sonuç: HFA ile yapılan porselen yüzey tedavilerinde diğer lazer gruplardan istatistiksel olarak daha yüksek Ra ile sonuçlandı. Deglaze porselen yüzeyinde hem Er:YAG hemde Nd:YAG lazer uygulaması asitleme tedavisine alternatif tedavi olarak tavsiye edilebilir.

Anahtar kelimeler: Porselen yüzeyi; hidroflorik asit; Er-YAG lazer; Nd:YAG lazer; yüzey işleme

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Introduction

Roughness is defined as the set of irregularities, i.e., small saliencies and re-entries, that characterize a surface and can be evaluated by means of electronic appliances, such as roughness meter. When considering that etching transforms the smooth and even surface of the porcelain into an irregular surface that allows for penetration of the resinous monomers into the irregularities, (1) one must bear in mind that porcelain surface roughness may influence the bond strength of brackets. A more demanding sense of esthetics has led to an increase in adults requesting orthodontic treatment. Thus, the orthodontist frequently encounters all porcelain restorations, which are gaining popularity because of their superior biocompatibility and distinct esthetic appeal (2).

The conventional orthodontic bonding system does not guarantee enough roughness to porcelain to withstand orthodontic forces. Thus, to increase roughness of porcelain restorations, several options that are generally combinations of various mechanical and chemical conditioning methods are available (3, 4). These methods are bonding to deglazing the porcelain by roughening the surface with diamond burs and chemical preparation of the porcelain with acids (hydrofluoric acid, HFA) (5, 6). The use of different lasers as replacement option in these treatments has been proposed, and has showed acceptable results. Er:YAG (Erbium:yttrium-aluminum-garnet), Nd:YAG (Neodymium-Doped Yttrium Aluminium Garnet), lasers have been used for this purpose (7, 8). Li *et al.* (8) conditioned porcelain with application of Nd:YAG in 0.6, 0.9 and 1.2W powers and demonstrated that this type of laser in combination with light curing composite promotes acceptable roughness and bond strength to porcelain.

Given the scarcity of roughness data related to surface treatment methods, the present study aimed to comparatively evaluate the difference in porcelain roughness changes after porcelain conditioning using HFA, glaze/deglazed surface porcelain treated with Nd:YAG laser and glaze/deglazed surface porcelain treated with Er:YAG laser etching by means of a non-contact optical profilometer. The null hypothesis was that there would be no difference in surface roughness after the 5 conditioning techniques.

Materials and Methods

Specimen preparation

100 feldspathic porcelain discs (Noritake super porcelain EX-3, Noritake Co., Inc., Nagoya, Japan) 6 mm in diameter and 3 mm in thickness were fabricated and glazed/deglazed according to the manufacturer's recommendations. Discs were viewed under a stereomicroscope (EMZ-TR, Meiji Techno Co. Ltd., Japan) at 20X magnifications to ensure that the flattened surfaces were free from defects such as cracks, pits and fissures. A 2x4 mm window was cut in an acrylic resin plate that was used to limit the area of porcelain. This plate also enabled the clinician to standardize the area and one operator held the acrylic plate over the porcelain surface while a second operator applied the surface conditioning to the area within the window. The porcelain surface, preventing micro cracks, was made uniform by abrasion with a diamond bur (30 m, Brasseler, Lemgo, Germany) prior to surface treatment. Discs were randomly divided into five groups (n=20) according to surface conditioning methods as follows:

Group I (HFA acid etching): Mechanical roughening and deglazing were performed with a cylindrical diamond bur (30 m, Brasseler, Lemgo, Germany) rotated at 40,000 rpm for 3 seconds with the shaft parallel to the sample. Samples were then etched for 60 sec. with 9.6% hydrofluoric acid gel (HFA, Vita Ceram Etch, Bad Sackingen, Germany) washed under water for 15 seconds and air-dried.

Group II (Nd:YAG laser on the deglaze porcelain surface): An Nd:YAG laser device (2970- nm wavelength; LightWalker, Fotona, Ljubljana, Slovenia) with an output of 1.5 W was used in medium-short pulse mode (MSP; 100 ms, 120 mj, 10 Hz, 1.5 W). The device uses a fiber-optic system to deliver laser energy to a sapphire tip that is bathed in an adjustable air/water spray. The laser beam was directed perpendicular to the deglaze porcelain surface (deglazing was performed with a cylindrical diamond bur, as described in Group I) from a distance of 1 mm from the porcelain surface and applied for 15 s, with air and water levels set at 90% and 80%, respectively.

Group III (Er:YAG laser on the deglaze porcelain surface): An Er:YAG laser device (2940- nm wavelength; LightWalker, Fotona, Slovenia) with an output of 1.5W was used in medium- short pulse mode

(MSP; 100 ms, 120 mj, 10 Hz, 1.5 W). The device uses a fiber-optic system to deliver laser energy to a sapphire tip that is bathed in an adjustable air/water spray. The laser beam was directed perpendicular to the porcelain at a distance of 1 mm from the deglaze porcelain surface (deglazing was performed with a cylindrical diamond bur, as described above) and applied for 15 s, with air and water levels set at 90% and 80%, respectively.

Group IV (Nd:YAG laser on the glaze porcelain surface): An Nd:YAG laser device (2970-nm wavelength; LightWalker, Fotona, Slovenia) with an output of 1.5 W was used to the glaze porcelain surface (deglazing was not performed), in medium-short pulse mode (MSP; 100 ms, 120 mj, 10 Hz, 1.5 W) as described Group II.

Group V (Er:YAG laser on the glaze porcelain surface): An Er:YAG laser device (2970-nm wavelength; LightWalker, Fotona, Slovenia) with an output of 1.5 W was used to the glaze porcelain surface (deglazing was not performed), in medium-short pulse mode (MSP; 100 ms, 120 mj, 10 Hz, 1.5 W) as described Group III. After laser ablation, to clear porcelain particles and dust, the surface of laser-treated specimens in all group II,III,IV and V was cleaned with running water without brushing and dried in air.

The surface profile was analyzed at the center of the delimited area (A 2x4 mm window) using a noncontact optical profilometry (Contour Elite, Bruker Nano Surfaces Division, Tucson, AZ, USA). For each porcelain sample, two readings were taken across the sample—before porcelain conditioning (T1) and after porcelain conditioning (T2). Although perfect repositioning accuracy is impossible at the micron level, the sample was roughly in the same position for every measurement. The roughness

parameter analyzed was the average roughness (Ra), which is the arithmetic mean of the height of peaks and depth of valleys from a mean line in the measuring length.

Statistical analysis

Descriptive statistics including mean and standard deviation were calculated for each group using a statistical software package (SPSS 15.0; Chicago, Illinois: SPSS Inc. 2006). A Kolmogorov-Smirnov normality test was applied to identify differences in Ra among groups. Comparison between repeated tests (T1-T2) was implemented with Wilcoxon Signed Ranks test. Statistical significance was set at the $p<0.05$ level.

Results

Mean Ra values for each group were as follows: I, 12.64 ± 0.73 ; II, 11.91 ± 0.74 ; III, 11.76 ± 0.59 ; IV, 3.82 ± 0.65 ; V, 2.77 ± 0.57 (Table 1). The highest Ra values were observed for Group I. Ra values for the glazed porcelain surface treated with Er:YAG laser (Group V) were significantly lower than all other groups. Kolmogorov-Smirnov showed significant differences among groups ($p<0.001$) (Table 1).

When compared to the values at T1, Ra values at T2 were significantly higher for all experimental groups ($p<0.001$). Significant differences were observed among mean Ra values of the experimental groups at T2. The 3D profilometric images of the HFA porcelain surfaces showed rougher surfaces than those of Er:YAG laser- and Nd:YAG laser treated porcelain surfaces (Figure 1).

Table 1. Mean Ra values for all groups.

Groups	T1	T2	Mean difference	p ¹
I	10.31 ± 0.45	12.64±0.73	2.32±0.90	p<0.001
II	10.06±0.29	11.91±0.74	1.85±0.77	
III	10.34±0.60	11.76±0.59	1.42±0.72	
IV	1.52±0.55	3.82±0.65	2.30±0.97	
V	1.17±0.23	2.77±0.57	1.60±0.72	
			p ² <0.001	

p¹: Wilcoxon signed rank test, p²: Kolmogorov-Smirnov.

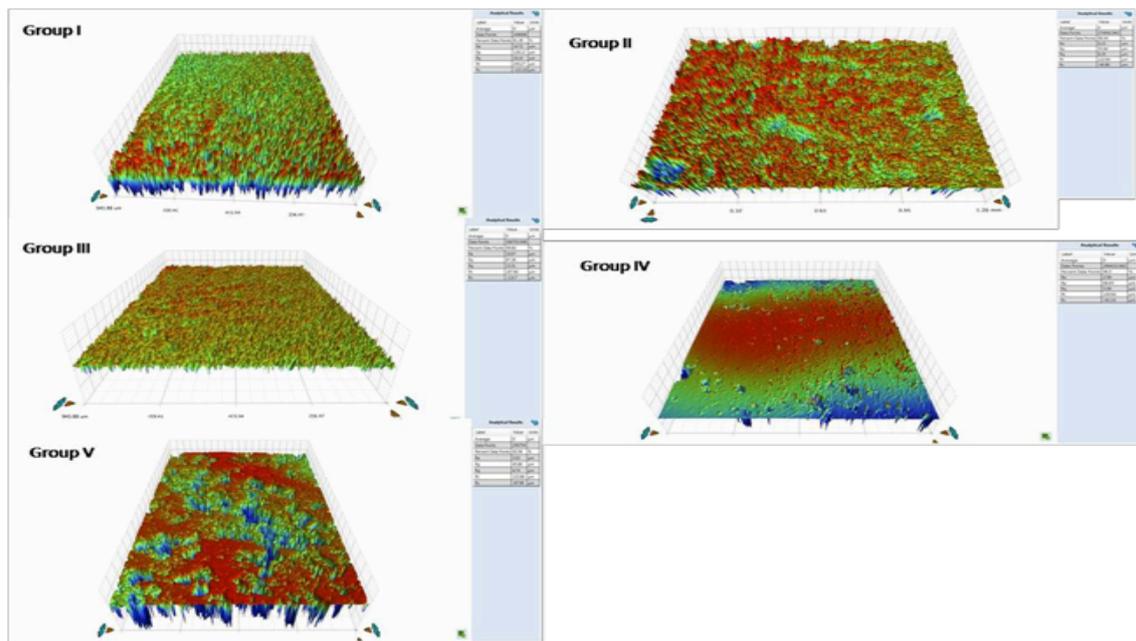


Figure 1. Profilometric image of all group porcelain surface.

Discussion

Surface treatments roughen the porcelain and enhance the formation of optimal micromechanical bond between the porcelain and resin. Thus, porcelain surface preparation (by etching or laser) is a critical part for clinical success of bonding of orthodontic brackets to porcelain surfaces. The current study is the first to compare the effect of five popular orthodontic surface conditioning techniques on porcelain roughness by using a non-contact optical profilometer. This study presented an alternative combination of an Nd:YAG laser with deglaze /glaze porcelain surface and Er:YAG laser with deglaze /glaze porcelain surface. Our results showed significant differences in the surface roughness data among the groups tested. Therefore, the null hypothesis that there are no differences in surface roughness among the groups must be rejected.

In the present study, HFA porcelain specimens showed the highest surface roughness (Ra) and optical profilometry images had more distinct sharp peaks than those of the other groups. (Figure) This is due to the acid's ability to react with the silica phase, which creates micromechanical retention through microchannels (9, 10). This finding is in accord with the results of studies by Borges *et al.* (11), Bottino *et al.* (12) and Kukiattrakoon and Thammasitboon (13). There is

no doubt that conventional acid etching with HFA is an appropriate technique for porcelain bonding to composite but because of risks of burning and irritating oral tissues, a lot of precision is required (2). For this reason many orthodontists have some considerations regarding its use. Although the use of lasers in etching enamel surfaces has been previously reported (14), the effect of laser etching on porcelain surfaces has been less extensively examined. Er:YAG and Nd:YAG lasers have been suggested as possible alternatives to HFA application for porcelain treatment for a number of reasons (15-17). Advantages of Nd:YAG laser irradiation in conditioning of porcelain surfaces were reported by Poosti *et al.* (18), and Kim and Cho (7) study revealed improvement of bond strength of regions between porcelain and titanium. Poosti *et al.* (18) proved that laser irradiation by Nd:YAG laser is an acceptable substitute for HFA; however, the Er:YAG laser is not an acceptable option. In contrast, Yassae *et al.* (19) found Er:YAG laser (1.6 W, 7.88 MPa) was an appropriate choice for bonding brackets to porcelain surfaces, with acceptable bond strength and minimal surface damage when compared to other conditioning methods such as 9.6% HFA, and Er:YAG lasers of 2 and 3.2 W, respectively. Er:YAG laser irradiation of a porcelain surface can remove the glass phase of the porcelain and create a rough surface.

Furthermore, Er:YAG laser irradiation increases the micromechanical retention of resin. However, Subasi and Inan (20) used 400 mJ pulse energy and found significantly lower surface roughness values than air abrasion. Gokce *et al.* (21) reported that the shear bond strength of Empress specimens after Er:YAG laser irradiation at 300 mJ was higher than that of surfaces irradiated with 600 and 900 mJ. Kara *et al.* (17) reported that treatment of low fusing porcelains with 5% HFA etching produced same roughness values with Er:YAG laser. Akova *et al.* (22) also demonstrated that increase in bond strength in samples under laser irradiation is related to creation of micromechanical retention on the surface. Uşümez *et al.* (23) also showed that laser irradiation with 2W power resulted in creation of shear bond strength like with acid etching mechanism; although laser irradiation with 1W power created significantly less amount of bond strength compared to the application of acid. Comparison of different studies in this field shows some conflicts. It appears that the difference in study method is the reason for occurrence of different findings and sometimes contradictory ones. It has been reported that porcelain structural changes resulting from laser irradiation depends on laser energy, duration of irradiation and distance between radiation sources to porcelain surface. In the present study, both Nd:YAG and Er:YAG laser treatment on the deglaze porcelain surface (Groups II,III) resulted in roughness values that were acceptable for clinical usage, and no cracks were observed in the porcelain surfaces, most likely because of the relatively low output power used (1.5W).

In generally, past studies showed that the roughness values achieved on deglazed porcelain was greater than that on glazed porcelain (24-28). In this study support past studies. This study concluded that a deglazed porcelain surface would yield the Ra. The low Ra values of glaze porcelain surface specimens treated by Nd:YAG and Er:YAG laser may also be attributed to the laser etching's less effect on the glaze porcelain surface than effect on the deglaze porcelain surface. In addition to producing rougher porcelain surfaces, laser systems have advantages of saving chair time. Two studies evaluated the bond strengths of metallic brackets to porcelain surfaces with different etching times (29, 30). The results proved that the specimens that were etched for 60 seconds showed significantly higher bond strengths than the specimens etched for 20

seconds. Fifteen seconds of water spraying and 15 seconds of air drying are also necessary in HFA etching. A total of 90 seconds for each tooth is needed with HFA. The required time is shorter with laser systems, only 15 seconds, than that required for HFA. Laser systems are 75 seconds faster than HFA etching. From a clinical standpoint, saving chair time also improves adhesion because it reduces the risk of salivary contamination.

Surface roughness measurements are performed using Vickers diamond testing machine, contact (or stylus) profilometer, non-contact optical profilometer, or scanning electron microscopes. The conventional contact profilometers is a linear measurement tool that has often been used to measure roughness, but it produces lower Ra values than does the optical profilometer because of the limitations of the spatial dimensions of its tip in detecting microcracks (31). Moreover, the conventional profilometer may affect the reading or even damage hard dental tissues because of its contact with the specimen (32). Non-contact profilometers generally use some type of laser to scan the surface to create the profile and offer quick measurement of surface features without surface contact. In addition, non-contact profilometers usually generate a surface plane (three-dimensional surface mapping) rather than just simple line profiles, which allows volumetric loss analysis (33). In comparison to contact profilometry, the optical method does not risk damage to the sample surface, which could provide higher reliability for repeated measurements (34). SEM assesses porcelain roughness qualitatively with visual analysis using electron microscopy and therefore the evaluation of roughness of porcelain surfaces from scanning electron microscope photomicrographs can be unreliable and subjective (35). Non-contact profilometry has the advantage of measuring the absolute depth of the defects over the electron microscopy (36). Lee *et al.* (37) used both methods (profilometer and scanning electron microscope) and observed that despite the differences in the appearance of surface samples with various treatments observed using an electron microscope, profilometry allowed reliable quantitative assessment of significance. To measure the surface roughness in the present study, a non-contact optical profilometer was chosen because this device gives repeatable, quantitative metrology data and also 3D color image of the specimens to reveal microscopic details.

Conclusion

Within the limitations of this *in vitro* study, it may be concluded that HFA operated according to the parameters used here significantly increases porcelain surface roughness and Nd:YAG laser and Er:YAG laser produces more roughness effect on the deglaze porcelain surface than effect on the glaze porcelain surface. Therefore, both Nd:YAG laser and Er:YAG laser on the deglaze porcelain surface may be a reasonable alternative to HFA treatment. However, further studies are required to evaluate the effects of different power settings and different laser applications on porcelain surfaces to obtain optimum roughness values.

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Conflict of interest

None declared

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