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Comparing the Surface Behavior of Conventional and CAD-CAM Feldspathic Porcelains in the Face of Laser-Assisted Bleaching and Post-bleach Polishing

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Abstract

Introduction: The prevalence of using different esthetic methods increases the possibility of close contact between them with potential adverse interactions. This study aimed to compare the surface changes (microhardness and roughness) in two types of feldspathic porcelain after laser bleaching and post-bleach polishing.

Methods: 12 standardized rectangular specimens were prepared for each porcelain group (conventionally layered and CAD-CAM milled). Vickers microhardness and roughness were evaluated before and after the bleaching procedure and after polishing. Data were statistically analyzed using repeated measures ANOVA and *t* test ($P<0.05$).

Results: The surface roughness of both groups increased significantly after laser bleaching ($P<0.001$ for conventional and $P=0.004$ for CAD-CAM porcelains). The polishing process reduced the roughness of both groups; the reduction was significant in conventional specimens ($P=0.020$). The surface hardness values did not change significantly in the groups after bleaching and post-bleach polishing stages ($P=0.142$). Generally, the average surface roughness of CAD-CAM specimens was significantly lower ($P<0.001$), and the surface microhardness of the CAD-CAM group was significantly higher than conventional porcelains ($P=0.011$).

Conclusion: Laser bleaching significantly increased the surface roughness of feldspathic porcelains; however, it did not affect the surface microhardness significantly. Unlike CAD-CAM specimens, polishing significantly improved the surface smoothness of conventional porcelains.

Keywords: Dental porcelain; Lasers; Microhardness; Surface properties; Tooth bleaching

Introduction

Dental bleaching, as a non-destructive method, has received a lot of attention for improving tooth color with a success rate of over 79%.[1-3] The process of office-bleaching could be accelerated using light or heat sources,[4] with conflicting pieces of evidence about the effects and results.[1-5] The low-power laser is among the methods proposed for process acceleration. The semiconductor diode laser is the smallest, the most durable, and the newest generation of lasers with the lowest price.[1] This laser is made of semiconductor crystals using a combination of aluminum, gallium, and arsenic.[6] The available wavelengths of the diode laser for dentistry are between 800 to 980 nm that are absorbable by tooth pigments. A 940-nm wavelength produces more color correction with less increase in pulp temperature compared to 980 nm.[1] The advantage of process acceleration has put laser-bleaching among the most prevalent bleaching methods in dentistry. Meanwhile, other esthetic options like ceramic veneers have experienced exponential prevalence. Feldspathic porcelains are widely used in anterior tooth veneers for their remarkable aesthetic properties.[7,8] They could be fabricated by conventional layering or computer-assisted procedures, while CAD-CAM ceramics have more homogeneous structure with fewer defects for their standard production process at high temperature and pressure.[9,10]

The prevalence of using different esthetic methods increased the possibility of close contact between them with the potential possibility of adverse effects[11,12] that might influence the surface characteristics. Microhardness is an important surface characteristic that affects the polishability and scratchability of the restorative material, as well as the material resistance to the applied force.[13] Surface roughness is another property that affects material wearability, plaque accumulation, staining, and bacterial adhesion with the related risk of caries and periodontal diseases.[14,15] Different studies reported

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controversial results for the effect of bleaching materials on surface characteristics of dental ceramics.[14,16-24] Rodrigues et al found that bleaching agents could reduce the microhardness of the surface and increase the roughness of ceramics,[16] while Polydorou et al found that bleaching would not affect the porcelain microhardness,[24] and Ourique et al showed that carbamide peroxide (CP) did not change the ceramic surface roughness.[17] The controversial results could be attributed to the usage of different types of dental ceramics and bleaching materials with different times, techniques, or concentrations.

To the best of the present authors' knowledge, there is no study on comparing the reactions of different types of feldspathic porcelain to bleaching, and no research has evaluated the effect of subsequent post-bleach polishing or its compensating capability for surface modifications caused by bleaching. This study aimed to compare the effects of laser bleaching and post-bleach polishing on the roughness and microhardness of conventionally layered and CAD-CAM feldspathic porcelains. The null hypotheses proposed that bleaching and subsequent polishing will not affect surface properties and that there will be no significant differences between the conventional and CAD-CAM milled porcelains in this regard.

Materials and Methods

Two groups of conventionally and CAD-CAM feldspathic porcelains were prepared to investigate the effect of laser bleaching and polishing on their surface characteristics (Table 1). By using two-sample *t* test power analysis, 12 samples were required for each group (n = 12). Hydrogen peroxide (HP) 35% was used as a bleaching agent and a diode laser with a 940-nm wavelength and 7-watt power as the light accelerator (Table 2).

Preparation of Test Specimens

For the first group, an initial block of 12 × 14 × 2.5 mm^3 was formed by wax (Cavex Holland BV, Haarlem, Netherlands) and duplicated using a putty impression material (Panasil Fast Putty, Ketenbach Dental, Eschenburg, Germany) to make 12 identical wax samples. The refractory material (Nori-Vest, Kuraray Noritake, Hattersheim, Germany) was prepared with a ratio of 6 mL liquid to 30 g powder and used to prepare a mold over the wax samples. The mold was used for conventional layering (Vita VMK Master, Vita, Sackingen, Germany) according to the manufacturer's instructions (Figure 1). For the second group, blocks of feldspathic porcelain (VitaBlocs Mark II, Vita, Sackingen, Germany) were sectioned using a cutting machine (Mecatome, Presi, Eybens, France) to the desired similar size of 12 × 14 × 2.5 mm^3.

All the specimens were polished by a polishing kit (ZilMaster, Shofu Dental Corp, California, USA) containing coarse and medium discs for finishing and pre-polishing and fine discs for super polishing (using electric handpiece at 20 000 rpm with a total of 1.5 N pressure). Polishing paste (Renfert All in One, Hilzingen, Germany) was also applied using a prophylactic cup on an electric handpiece at 15 000 rpm for 10 seconds. The specimens were adjusted and measured by a gauge to confirm the uniform final thickness of 2 mm.

Laser Bleaching and Post-bleach Polishing

Bleaching material containing HP 35% (Laserwhite20, Biolase, San Clemente, California, USA) was applied to the specimens, and the diode laser system (Epic X diode laser system, Biolase, San Clemente, California, USA) was set on the bleaching program (7 W for 30 seconds). The whitening gel remained for 1 minute on the surface before the second laser cycle (30 seconds). After the second cycle, the gel stayed on the porcelains for at least 5 minutes and then was cleaned with water and gauze. The steps were performed twice according to the manufacturer's instructions (with a total time of 14 minutes). After laser bleaching, all the samples were polished following the same initial polishing procedure.

Surface Characteristic Measurement

Surface characteristics were measured in three steps: (*i*) after sample preparation (baseline), (*ii*) after laser bleaching, and (*iii*) after polishing. The surface roughness (Ra parameter) was measured by a profilometer (Tr210, Timegroup, USA) with needle speed of 0.05 mm/s; the Vickers test (Buehler LTB 60 044, Lake Bluff, USA) was used for microhardness measurement with 500 g of load

Table 2. Epic X Diode Laser System

Wavelength	940 nm
Power	0.1-10 W
Fiber tip diameter	200, 300 and 400 µm
Mode	CW or pulse
Pulse duration	0.01-20 ms
Pulse repetition rate	Up to 20 kHz
Spot size	
Surgical handpiece	Max in contact mode 400 µm
Deep tissue handpiece	30 mm diameter = 7.1 cm^2
Whitening handpiece	Rectangular 35*8 mm = 2.8 cm^2
Beam divergence	8-22′ per side angle
NODH	4.77 m

Table 1. The Physical Characteristics of CAD-CAM and Conventional Feldspathic Porcelains

Porcelains	Flexural Strength	Density	Transformation Temperature	Co-Efficient of Thermal Expansion
Conventional	90 MPa	2.4 g/cm^3	565 °C	13.2-13.7 × $10^{-6}K^{-1}$
CAD-CAM	136 ± 20 MPa	2.4 ± 0.5 g/cm^3	780-790 °C	9.4 ± 0.1 × $10^{-6}K^{-1}$

applied for 30 seconds. Three readings were performed in each step, and the average quantities were reported for each specimen.

Statistical Analysis

Changes in surface roughness and microhardness in CAD-CAM milled and conventional feldspathic porcelains were compared by repeated measures ANOVA. When the changes in the surface characteristic between the groups were not significant, repeated measures ANOVA using two porcelain types together was used to compare the mean surface characteristic ($P>0.05$). However, when the changes were significantly different ($P<0.05$), repeated measures ANOVA was used for each porcelain type to compare the difference between the stages in each porcelain group separately. Since the changes in surface roughness between the two porcelain groups were significantly different, a *t* test was used to compare the groups with each other in different stages, while repeated measures ANOVA was applied to compare the changes in microhardness.

Results

Roughness

The changes in surface roughness in the investigated groups were significantly different ($P=0.024$). Therefore, a *t* test was used to compare the mean values in different stages, and the results showed that the average surface roughness of CAD-CAM specimens was significantly lower than conventional porcelains in all the stages ($P<0.001$; Table 3 and Figure 2). Repeated measures ANOVA revealed a significant increase in the surface roughness of conventional porcelains after laser bleaching ($P<0.001$), which decreased significantly after second polishing ($P=0.020$); however, the primary smoothness was not reobtained. In CAD-CAM porcelains, the surface roughness increased significantly after laser bleaching ($P=0.004$); the polishing procedure reduced the surface roughness, but this reduction was not significant ($P=0.131$).

Microhardness

Repeated measures ANOVA showed a non-significant difference in microhardness changes between the porcelain groups ($P=0.369$). The surface microhardness of the CAD-CAM group was significantly higher than conventional porcelain based on repeated measures ANOVA ($P=0.011$, Table 4, Figure 3); microhardness did not change significantly regardless of the porcelain types and evaluation steps ($P=0.142$).

Discussion

The bleaching material has to be in close contact with the tooth surface during the whitening process. The possibility of potential adverse reactions caused much research to be done on the effect of bleaching agents on tooth structure. In Mirzaie and colleagues' study, laser-assisted bleaching (Biolase, San Clemente, California, USA) changed the surface roughness less than the conventional bleaching method.[25] Also, in the study by de Magalhaes et al, bleaching with a diode laser-activated substance had no effect on the surface microhardness of the enamel.[26] The introduction of new types of ceramics and bleaching methods and materials calls for further investigations on the impact of bleaching peroxides on restorative materials. Just like the contact with tooth structure, the contact between the bleaching and the restorative materials is also very important. [19]

Office-bleaching uses high concentrations of HP (25% to 50%) and the process can be accelerated using light or heat

Table 3. Descriptive Statistics of Surface Roughness

Material	Stage of Measurement	N	Minimum (µm)	Maximum (µm)	Mean (µm)	Std. Deviation
Conventional	Initial	12	0.121	0.614	0.33408	0.139994
Feldspathic	Laser bleaching	12	0.320	0.689	0.44542	0.113064
Porcelain	Polishing	12	0.192	0.601	0.40108	0.125484
CAD-CAM	Initial	12	0.038	0.272	0.14533	0.073367
Feldspathic	Laser bleaching	12	0.061	0.337	0.18992	0.079397
Porcelain	Polishing	12	0.051	0.224	0.16700	0.053501

Table 4. Descriptive Statistics of Surface Microhardness

Material	Stage of Measurement	N	Minimum (kgf/mm²)	Maximum (kgf/mm²)	Mean (kgf/mm²)	Std. Deviation
Conventional	Initial	12	500	637	573.17	45.966
Feldspathic	Laser bleaching	12	500	658	578.00	50.474
Porcelain	Polishing	12	526	616	567.42	31.859
CAD-CAM	Initial	12	548	719	623.75	60.441
Feldspathic	Laser bleaching	12	585	655	608.42	21.907
Porcelain	Polishing	12	546	650	589.33	28.108

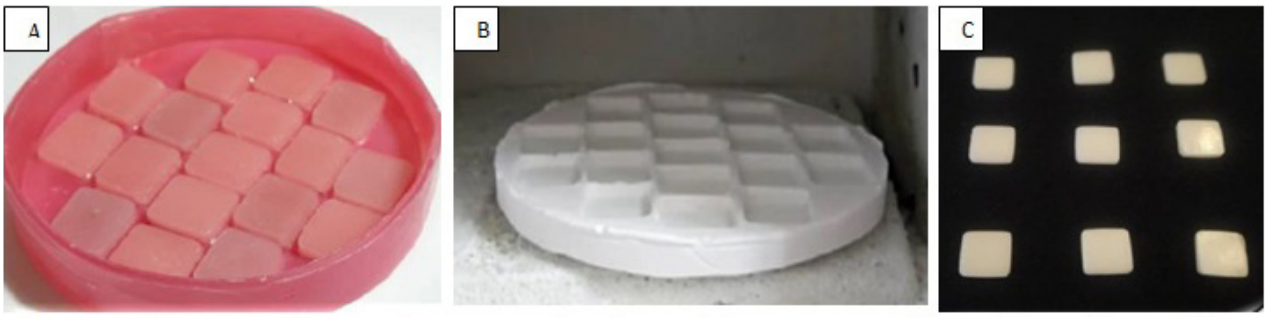

Figure 1. The steps of preparing conventional porcelain group. A, the mold was formed by wax models; B, refractory base was poured; C, porcelain tablets were prepard by conventional layering.

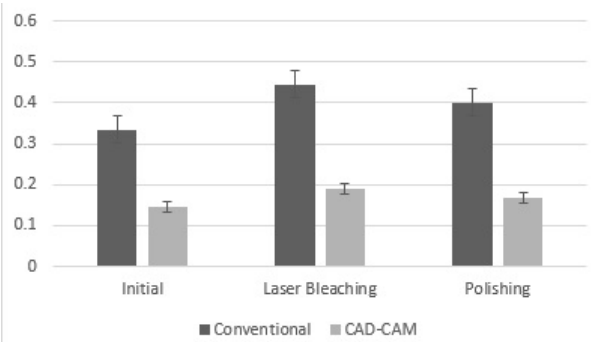

Figure 2. Mean surface roughness of porcelain group in three stages.

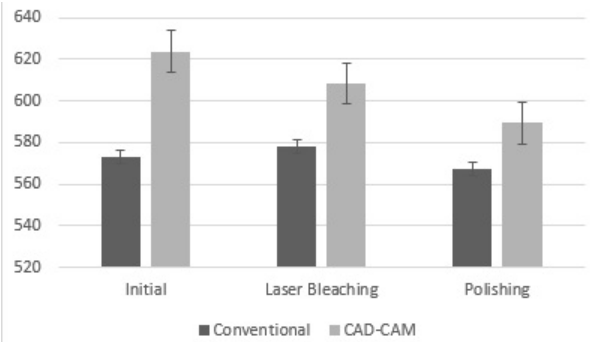

Figure 3. Mean surface microhardness of porcelain group in three stages.

sources. Some of the advantages of this type of bleaching are the supervision of the dentist, soft tissue protection, and shorter time.[27] In Dostalova and colleagues' study, the bleaching method without accelerating factors changed 2-3 shades in 15 minutes and a shorter time (5 minutes) was not effective in changing the color. Using a 970-nm diode laser as an accelerator in bleaching caused the same color change but in less time (2 minutes with a 2-W laser, and 5 minutes with a 1-W laser).[28] However, the shorter time may cause fewer adverse effects on surface characteristics that have made this process very prevalent. For using HP gel, lasers are more effective than LEDs and also have the advantage of reducing tooth contact with the whitening gel. The reduction in treatment time reduces the tooth sensitivity after treatment, gingival irritation, and enamel surface changes.[3,28,29]

In this study, two categories of feldspathic porcelains prepared by the conventional method and CAD-CAM milling were used to investigate the effect of laser bleaching and post-bleaching polishing on their surface properties. The porcelain surface could be polished or glazed with the same effectiveness and esthetic results. However, to control the surface luster of the restoration, polishing is preferred over glazing.[30,31] In this study, the bleaching agent containing 35% HP that has been reported to cause 9 shades of color change was used.[32] To accelerate the bleaching process, a laser system with a wavelength of 940 nm was used.

Feldspathic porcelains could be made by the conventional layering or milling method, and for remarkable esthetic properties, they have been widely used as veneers in anterior teeth.[7,8,33] The production method could affect the properties of these high-glass ceramics and their reactions to different environmental situations. The present study evaluated and compared the effect of the porcelain type on surface changes after laser bleaching. Based on the results, the null hypotheses were partially rejected as the roughness of both groups increased significantly after laser bleaching ($P < 0.001$ for conventional and $P = 0.004$ for CAD-CAM porcelains). Our results were in line with the results reported by Rodrigues et al,[16] Zaki and Fahmy,[18] Kamala and Annapurni,[20] and Butler et al[21] Furthermore, several studies reported that even home bleaching by CP could increase the surface roughness of ceramics.[14,18,20]

Leonard et al reported an increase in the pH of bleaching agents after 15 minutes. He concluded that prolonged contact with bleaching material might increase the surface roughness.[34] The laser accelerates the bleaching process and significantly reduces the contact time.[2,3,25,28] However, the increase in roughness in this study signified that the erosion of the porcelain matrix by peroxide could happen even in 14 minutes, regardless of the structural density or type differences of conventional and CAD-CAM feldspathic porcelain. Turker and Biskin reported

the content of SiO_2 and K_2O_2 (that forms the ceramic matrix and affects the surface characteristics), decreased from 4.82% to 1.89% in feldspathic porcelains after home bleaching.[35] However, there are other studies that reported no change in surface roughness after bleaching.[16,18]

The results of microhardness evaluation in the present study confirmed that in both groups and in all measurement periods, microhardness did not change significantly ($P=0.142$). These results were consistent with those reported in the studies by Malkondu et al[22] and Polydorou et al,[23,24] and they were different from some other studies.[16,19,22] The content of SiO_2 in ceramic structure affects the surface microhardness, and bleaching agents could reduce the surface hardness by decreasing SiO_2 content.[36] A part of the variation in the results of the studies might be related to the differences in the pH values of bleaching agents that range from 3.67 (acidic) to 11.13 (very basic).[37] Based on Malkondu and colleagues' study, even at similar pH, CP reduced surface microhardness significantly, while HP did not cause the same significant effect.[22] This result was attributed to the reaction process. During the bleaching process, CP breaks down into HP and urea, which are changed to carbon dioxide and ammonia. Ammonia increases the basic phase of the environment, and the increase in pH will cause more free radicals to be produced.[38] However, the microhardness of the ceramics did not change in Polydorou and colleagues' studies by either home (CP) or office bleaching agents (HP).[23,24]

These controversial results could return to the difference between the ceramic type and the concentration or time of bleaching agents used and reflect the technique sensitivity of the process. However, considering these results, in case of unavoidable contact between the bleaching agent and restorative material, it might be helpful to refine the surface of restoration by post-bleach polishing. Based on the results of the present study, post-bleach polishing is strongly suggested in feldspathic porcelains since the results confirmed that the surface roughness decreased after polishing in both groups and this reduction was significant in conventional specimens ($P=0.020$). The effect of polishing on surface characteristics depends on the materials and techniques.[39,40] Generally, CAD-CAM products, fabricated at high temperature and pressure, are more homogeneous and have fewer structural defects than conventional porcelains. In conventional porcelains, traditional porcelain layering could result in structural voids. The presence of these voids makes the polishing process more effective in conventional porcelains since removing them during polishing could improve surface smoothness significantly.[10,41]

The surface roughness of CAD-CAM porcelains was significantly lower ($P<0.001$), and their surface microhardness was significantly higher than conventional specimens in all the stages ($P=0.011$). More homogenous structure of CAD-CAM feldspathic porcelain with 4-micrometer particles improved the material's surface properties compared to conventionally layered specimens with 19-micrometer particles in a non-homogenous structure.[42,43]

The obvious inconsistencies in the literature results suggest that some restorative materials might be more susceptible to surface changes, and some bleaching agents are more likely to cause those changes. Based on the results of the present study, protecting the restorative material to prevent unintentional contact with bleaching peroxides is suggested, and in case of undesirable contact, polishing in a correct sequence is an acceptable solution to the prevention of further complications.

Experimental studies might not completely reflect the clinical situations; therefore, further long-term clinical studies are encouraged. The majority of microhardness and roughness studies focused on home bleaching agents and conventionally layered porcelains, and there is no study on the effect of different bleaching materials on CAD-CAM ceramics. With the improvements that happened in the field of dental materials and techniques, further research studies are necessary to evaluate and improve the newly introduced materials fabricated by computerized methods.

Conclusion

Based on the results of this study and considering the limitations, it can be concluded that:

1. The surface roughness of CAD-CAM porcelain was significantly lower, and its surface microhardness was significantly higher than conventionally layered porcelain.
2. The surface roughness of both groups increased significantly after laser bleaching.
3. Post-bleach polishing reduced the surface roughness of both groups. The reduction was significant in conventional specimens, but the primary smoothness was not reobtained.
4. The surface microhardness of conventional and CAD-CAM feldspathic porcelains did not change significantly after laser bleaching or post-bleach polishing.

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Conflict of Interests

The authors do not have any financial or conflicting interest in the companies whose materials are included in this article.

Ethical Considerations

Here is the ethical consideration part of the afticle: Due to the

experiments performed in the laboratory, no special consideration was required. Precautions regarding contact with chemicals and dangers during the process were carefully observed.

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