Lithium Disilicate Ceramic Roughness Evaluation After Different Finishing Methods and Comparison Before and After Surface Reduction and Intraoral Polishing Imitation

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Abstract

**Relevance of the problem:** Lithium disilicate ceramic restorations require efficient surface treatment after hot pressing technique and final occlusal adjustment and reduction. After these procedures surfaces become rough. Rough ceramic surface causes internal cracks, increased bacteria adhesion and wear of antagonist teeth.

**Aim of the work:** To determine which lithium disilicate ceramic surface finishing method develops smoother surface and to ascertain if it is possible to polish the surface sufficiently after surface reduction caused by grinding with diamond bur.

**Material and methods:** Twenty 10 mm x 4 mm disc-shaped lithium disilicate ceramic plates were made using hot pressing technique. Specimens were divided into two groups by surface treatment method. P group specimens (n=10) were polished while G group specimens (n=10) were glazed. Then surface reduction was made for all the specimens using 40μm diamond bur and the intraoral polishing imitation was performed using NTI CeraGlaze (NTI-Kahla GmbH, Germany) polishing system. After every procedure mean surface roughness (Ra) of all specimens was estimated with profilometer and analyzed with scanning electron microscope (SEM) and optical microscope. Statistical analysis was performed using SPSS 20.0. Roughness was compared using Student t, Mann-Whitney and Wilcoxon tests.

**Results:** P group Ra after polishing was 1,532±0.729μm, G group after glazing - 2,519±1,513μm. G group Ra after surface reduction was 2,585±0.529μm, P group - 2,685±0.538μm. G group Ra after intraoral polishing imitation was 1,983±1,220μm, P group - 1,611±0,685μm.

**Conclusions:** Lithium disilicate ceramic surface roughness after glazing was similar to polished surfaces. Lithium disilicate ceramic surface after occlusal reduction may be polished using intraoral polishing systems adequately to the previous surface roughness.

**Keywords:** Lithium disilicate, polishing, glazing, reduction, intraoral.

**INTRODUCTION**

The main prosthetic dentistry objective is the loss of tooth structure rehabilitation with the physical material similar to the natural tooth [1]. The use of dental ceramics has increased because of its positive qualities - biocompatibility and durability [2]. It is often preferred by the patients because of acceptable aesthetic characteristics. However, ceramic surface becomes rough due to mastication. This increases the chance of developing surface microcracks, which reduces the strength of restorations [3]. Ceramic materials and its production techniques have improved considerably over the last decade [4]. One of the most important goal of modern ceramic systems is to improve the physical properties [5]. Pressable lithium disilicate glass ceramic was created for this purpose and it features high strength and a wide range of shades, the ability to choose the correct prosthetic transparency and brightness [6]. Ceramic restorations require high quality final surface finishing, because after pressing surface remains rough [7]. Glazing and polishing are the most frequently used techniques for final ceramic preparation [8]. Rough occlusal surfaces of ceramic restorations weaken the strength of the prosthesis, causing increased antagonistic tooth wear as well as the biofilm formation, which leads to more favorable conditions for the development of periodontal inflammation [9, 10]. Without a high quality surface preparation or after the removal of glazed surface when the final occlusal adjustment is performed in the patient's mouth, lithium disilicate crystals remain exposed. The appearance of needle-like crystals results in surface roughness [11].
There is no consensus what is the most effective method to eliminate surface irregularities and how to process the reduced occlusal surface to be clinically acceptable.

**Aim of the work:** To assess the effect of different methods of lithium disilicate ceramic treatment on surface roughness and the possibility to polish the surface sufficiently after surface reduction.

**MATERIAL AND METHODS**

**Specimens**

Twenty 10 mm x 4 mm disc-shaped specimens were modeled (Fig. 1) and then milled from block of wax using CAD/CAM system (Zirkonzahn M5, South Tyrol, Italy). Samples were separated and prepared for lost-wax hot pressing technique (Fig. 2). Phosphate-bonded precision investment material (CS High Speed Investment, Feguramed GmbH, Buchen, Germany) and investment ring system (IPS Silicone Ring 100g, IvoclarVivadent AG, Schaan, Liechtenstein) were used for the press ceramic technique according to the manufacturer’s instructions. Pressing mold was heated for 60 minutes at 850°C. Wax modified lithium disilicate ceramic (IPS e.max Press MO 0; IvoclarVivadent AG, Schaan, Liechtenstein) using pressing device (Programat EP 3010, IvoclarVivadent AG, Schaan, Liechtenstein).

![Figure 1. Sample modeled using CAD/CAM system computer](image1)

![Figure 2. Wax specimens prepared for ceramic pressing](image2)
The samples (Fig. 3, 4) were randomly divided into two equal groups of 10 samples, depending on the final surface treatment method:

- **P Group** - ceramic surface was polished;
- **G Group** - ceramic surface was glazed.

**Figure 3. Lithium disilicate ceramic samples**

**Figure 4. Lithium disilicate specimens immediately after pressing**

**Polishing**

Surfaces of P group specimens (n=10) were polished to achieve smooth and glossy surface. Polishing procedure was carried out with three instruments in order of priority: silicone-based polishing instruments (NTI CeraGlaze P301, P3001, P30001, NTI-Kahla GmbH, Germany) (Fig. 5) having medium, mild and very mild abrasive diamond particles using laboratory micromotor (Qube, Schick Dental, Germany) at 5000 rpm speed without cooling water for 1 minute with each instrument.

**Figure 5. Polishing instruments**
The final polishing step was carried out with diamond particles containing paste (Zirkopol, Feguramed GmbH, Buchen, Germany) at first with polishing felt and then polishing brush using laboratory micromotor (Qube, Schick Dental, Germany) at 10000 rpm speed without cooling water for 1 minute with each instrument (Fig 6).

**Figure 6. Polishing paste, felt and brush**

**Glazing**

Surfaces of G group specimen (n=10) were prepared for glazing. Surfaces were planed with special ceramic stone at 10000 rpm speed and sandblasted 2 centimeters from the surface with 50μm sized aluminum oxide particles. Each sample had been sandblasted for 5 seconds. The surfaces were washed in high pressure steam device (120°C, 2,5 bar, Inkosteam, Hedent, Germany). Glazing powder (IPS e.max Ceram Glaze Powder, IvoclarVivadent AG, Schaan, Liechtenstein) and liquid (IPS e.max Ceram Glaze and Stain Liquid, IvoclarVivadent AG, Schaan, Liechtenstein) were mixed according to the manufacturer’s instructions. Glaze layer evenly distributed on the surfaces and heated in ceramic heating device (DEKEMA Austromat 624, Freilassing, Germany). Glazing was repeated until the sample surfaces were covered by two coating layers.

**Roughness**

Surface roughness of all lithium disilicate ceramic samples (n = 20) were evaluated using profilometer (Ambios Technology Inc., XP-Plus 200 Stylus, USA) after the primary polishing and glazing by dental technicians in the laboratory, the surface reduction and intraoral polishing imitation. During the measurement needle moved 3 mm through the surface of each sample at 0.12 mm/s speed and constant 3.9 mN force. Relief deviations from the median line of the absolute values (Ra) were calculated over the entire length.

**Reduction**

Lithium disilicate ceramic surfaces were reduced (Fig. 7) with conical 40μm grain diamond bur (NTI 845KR-F-G 018, NTI-Kahla GmbH, Germany) (Fig. 8) using high-speed handpiece (NSK NLX plus, Nakanishi, Japan) at 10000 rpm speed with cooling water. In order to simulate the clinical situation the procedure was carried out in two opposite directions. The bur was changed to new after using it for 10 specimens due to drilling efficiency decrease probability. Then samples had been washed with distilled water in an ultrasonic bath for 5 minutes.
Intraoral polishing simulation

This procedure mimics the intraoral surface polishing after the cementation of ceramic prosthesis and its occlusal adjustment. Intraoral polishing procedure was carried out with three instruments in order of priority: silicone-based polishing instruments (NTI CeraGlaze P336, P3036, P30036, NTI-Kahla GmbH, Germany) having medium, mild and very mild abrasive diamond particles using low-speed handpiece (NSK NLX plus, Nakanishi, Japan) at 5000 rpm speed without cooling water for 1 minute with each instrument. The final polishing stage was made with diamond particles containing pasta (pasta Griglia I Anaxdent, GmbH, Buchen, Germany) and the polishing brush at 10000 rpm speed without cooling water for 1 minute. Then samples had been washed with distilled water in an ultrasonic bath for 5 minutes.

Scanning electron microscope (SEM)

Two lithium disilicate ceramic samples were randomly chosen from both P and G groups. The samples were analyzed with scanning electron microscope (Hitachi S-3400N VP-SEM, Singapore) at 1000 times magnification after the primary polishing and glazing by dental technicians in the laboratory, reduction and surface intraoral polishing simulation in order to permit a qualitative visual assessment of the surface deformations.

Optical microscope

Two lithium disilicate ceramic samples were randomly chosen from both P and G groups. For added visual assessment samples were analyzed with optical microscope (Nikon Eclipse LV150, USA) at 100 times magnification after the primary polishing and glazing by dental technicians in the laboratory, surface reduction and intraoral polishing imitation.
Statistical analysis of the data

The collected data were collected in the database. Statistical analysis was performed using SPSS 22.0 software package (SPSS Inc., Chicago, Illinois, USA). Significance level selected p<0.05. Distributions of quantitative variables evaluated using Shapiro-Wilk test. To compare two independent groups of averages parametric Student t test and the nonparametric Mann-Whitney test were used. Quantitative comparison of dependent variables applied parametric and nonparametric paired Wilcoxon test.

RESULTS

Roughness

Lithium disilicate samples (two groups of n = 10) surface roughness were measured after the initial preparation, after reduction and after intraoral polishing imitation. The average roughness (Ra) data is presented in the Table 1. Statistically insignificant roughness difference was found after the initial preparation of the surface, after reduction and after intraoral polishing simulation between the P and G groups (Table 2).

Table 1. Average surface roughness

<table>
<thead>
<tr>
<th>Surface preparation</th>
<th>Group of samples</th>
<th>Average roughness Ra (SD), μm</th>
<th>Average roughness Ra Min*-max**, μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>After initial preparation</td>
<td>G</td>
<td>2,519 (±1,513)</td>
<td>0,875-3,591</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>1,532 (±0,729)</td>
<td>0,549-2,99</td>
</tr>
<tr>
<td>After surface reduction</td>
<td>G</td>
<td>2,585 (±0,529)</td>
<td>1,499-3,315</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>2,685 ±0,538</td>
<td>2,040-3,685</td>
</tr>
<tr>
<td>After intraoral polishing simulation</td>
<td>G</td>
<td>1,983 (±1,220)</td>
<td>0,614-3,563</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>1,611 (±0,685)</td>
<td>0,833-2,295</td>
</tr>
</tbody>
</table>

SD–standard deviation, *min – the minimum value, **max – the maximum value, G – glazed, P – polished

Table 2. Ra significance level (p) based on the Student t test

<table>
<thead>
<tr>
<th>P group</th>
<th>G group</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>After polishing</td>
<td>After glazing</td>
<td>1.857</td>
<td>0.08*</td>
</tr>
<tr>
<td>After surface reduction</td>
<td>After surface reduction</td>
<td>-0.419</td>
<td>0.68*</td>
</tr>
<tr>
<td>After intraoral polishing imitation</td>
<td>After intraoral polishing imitation</td>
<td>0.841</td>
<td>0.41*</td>
</tr>
</tbody>
</table>

*Statistically insignificant (p>0.05)
In the P group the lowest average roughness was after initial polishing (1,532 ± 0,729μm) and it statistically significant (p <0.05) differed from the average roughness of the surface after reduction. In the P group intraoral polishing simulation average roughness was statistically significant (p <0.05) lower than the surface after reduction. Based on non-parametric Wilcoxon test for dependent samples the P group the average roughness values distribution between surface preparation methods is showed graphically (Figure 9). The average surface roughness does not statistically differ after all surface preparation methods in the G group (Table 3).

Regardless of the initial sample preparation method, based on the Wilcoxon test, a statistically significant (p <0.05) greater surface roughness was found after reduction (2.635 ± 0,521μm) compared with the roughness after initial preparation (2,025 ± 1,261μm) and statistically significant (p <0.05) lower roughness after intraoral polishing simulation (1.797 ± 0,981μm) compared with the reduced surface (Figure 10).

**Table 3.** G group Ra significance level (p) based on the Wilcoxon test

<table>
<thead>
<tr>
<th>G group</th>
<th>Z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>After glazing</td>
<td>After intraoral polishing imitation</td>
<td>-0.968</td>
</tr>
<tr>
<td>After glazing</td>
<td>After reduction</td>
<td>-0.459</td>
</tr>
<tr>
<td>After reduction</td>
<td>After intraoral polishing imitation</td>
<td>-1.478</td>
</tr>
</tbody>
</table>

*Statistically insignificant (p>0.05)
Figure 10. Average roughness distribution

\(^a\)_{p=0.03}; \(^b\)_{p=0.003}

Scanning electron microscope (SEM)

Visually monitoring the obvious difference is seen in both P and G groups after initial treatment and after reduction (G1 and G2; P1 and P2). SEM analysis results are presented in Figure 11. In both cases rough, irregular surface is observed after the reduction. Comparing pictures after reduction with pictures taken after intraoral polishing imitation, obvious visible surface change is observed - surface after polishing simulation has become much smoother, and the observed lines reflect polishing instruments usage in one direction. P1 picture shows different directions of the lines which reflects polishing instruments usage in different directions by dental technicians. G1 picture shows a solid non-porous coating layer without any sharp protrusions. Dark areas do not reflect the surface roughness - it is caused by electron radiation captured by SEM.
Figure 11. G1 – G Group sample image after the initial preparation of the surface (glazing); G2 – G group sample surface image after reduction; G3 – G group sample image after intraoral polishing simulation; P1 – P group sample image after the initial preparation of the surface (polishing); P2 – P group sample surface image after reduction P3 – P group sample image after intraoral polishing simulation. 1000x magnification.

Optical microscope

In the picture, which is G Group surface immediately after glazing (G4), pores are visible, which was not apparent at SEM analysis under 1000 times magnification. In P4 picture surface unevenness is observed due to polishing instruments usage. In both cases obvious surface damage is observed after the surface reduction by grinding bur. Evident surface leveling after the reduction is visible in the G6 and P6 pictures. In comparison with the G4 and G6 images, it is clear that porous disappeared after intraoral polishing simulation.
**DISCUSSION**

Ceramic restorations require final occlusal adjustment and reduction. Diamond burs are used for this purpose, which damage the upper ceramic polished or glazed layer [31]. This procedure increases the surface roughness and, as a consequence, antagonistic tooth wear, reduces the strength of the ceramic prosthesis, promotes the accumulation of plaque [32]. It is necessary to use intraoral polishing kit to plane, smoothen the damaged surface caused by the occlusal correction. According to Wahadni et al. [30], ceramic restorations should be polished with diamond particles containing polishing pastes. This conclusion supports the Lohbauer et al. [33] arguing that it is important to use that kind of polishing paste for lithium disilicate ceramic surfaces in order to effectively polish sharp lithium disilicate crystals.

This study investigated glazed (n = 10) and polished (n = 10) lithium disilicate ceramic surface roughness after initial preparation, after the reduction and surface intraoral polishing imitation. RafatAmer [25] found that lithium disilicate polished surface roughness (0.247 ± 0.137μm) statistically similar to glazed (0.357 ± 0.648μm). Our study also concluded that similar roughness values (Ra) were in both P and G groups after the initial ceramic preparation (after polishing in P group 1.532 ± 0.729μm, after glazing in G group 2.519 ± 1.513μm). On the other hand, according to Haroon Rashid [28], the single layer glazed surfaces (21.60 ± R 15.54μm) are rougher than polished (7.62 ± 2.01μm).

**Figure 12.** G4 – G group sample image after the initial preparation of the surface (glazing); G5 – G group sample surface image after reduction; G6 – G group sample image after intraoral polishing simulation; P4 – P group sample image after the initial preparation of the surface (polishing); P5 – P group sample surface image after reduction P6 – P group sample image after intraoral polishing simulation. 100x magnification.
Alhanouf Alhabdan [31] states that after intraoral polishing surfaces may become softer than after glazing. Author found that lithium disilicate surface roughness is statistically less rough when using intraoral SofLex (0.195 ± 0.14μm), Optra Fine (0.459 ± 0.191μm) and Eve (0.448 ± 0.427μm) polishing systems compared with the original glazed surfaces (respectively 0.427 ± 0.278μm, 0.666 ± 0.541μm and 0.642 ± 0.312μm) [31]. In our study there was no significant roughness difference between glazing (2.519 ± 1.513μm) and intraoral polishing imitation (1.983 ±1,220μm).

Scanning electron microscope (SEM) and optical microscope pictures were used to combine qualitative analysis with surface quantitative results. Scurria et al. [31] argued that relying solely on large- raising SEM photographs is not appropriate because it is impossible from such a small surface area to describe in general on the entire surface of the research, and recommended to carry out at least 100 times magnification picture for comparisons. In the present study optical microscope (100x magnification) and SEM (1000x magnification) were used to show the generic and specific surface images. SEM showed the smooth sample surface after initial glazing in dental laboratory, but optical microscope revealed porous and uneven specimen surface.

Very often the glazing does not reduce the surface roughness to an acceptable value because the coating layer is insufficient thick to effectively complete the ceramic surface micro-cracks and grooves [34]. In this study, lithium disilicate ceramic samples were glazed with two layers, unlike in earlier discussed study [28]. This may have influenced the absence of difference between polished and glazed samples. Regardless of the initial surface preparation method, the intraoral polishing system effectively leveled sharp relief elevations caused by 40μm grain diamond bur.

One of the main study limitation was that all preparation procedures were performed in the disc-shaped sample surfaces which are not identical to the dental ceramic restorations. Surface roughness was also studied not through the entire surface length and both SEM and optical microscope analysis were performed on one randomly chosen sample from each group.

Direct extrapolation of the results is that during the intraoral polishing or surface reduction procedures the pressure of instruments varies depending on the dental practitioner. The average roughness average after intraoral polishing simulation could be different if the surface would be reduced by the different grain bur.

Nevertheless, the results of this study demonstrate additional training and standardization of methods to be able to determine the most suitable lithium disilicate ceramic surface preparation method in the dental laboratory and after the occlusal contact alignment in the patient’s mouth.

CONCLUSIONS

Using both the lithium disilicate ceramic final surface preparation methods, e.g. initial polishing and glazing, similar smoothness of ceramic surface is created. Regardless of the initial surface preparation, surface reduction with the diamond bur leads to greater roughness. Initial ceramic surface preparation technique had no influence on the intraoral polishing imitation results. Lithium disilicate ceramic has similar roughness values after finishing the surface in dental technician laboratory as well as after imitating intraoral polishing of grinded ceramic surface.

REFERENCES


• Silvia P. Amaya-Pajares. Effect of different finishing and polishing techniques on the surface roughness of four ceramic materials after surface adjustment [dissertation]. The University of North Carolina: Department of Operative Dentistry at the School of Dentistry; 2014.


