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ORIGINAL ARTICLE

Effects of Different Finishing Procedures on Surface Roughness of Hybrid CAD/CAM Materials

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ABSTRACT

Hybrid ceramics combine the beneficial properties of resin with the advantage of glass ceramics. However, there are limited study about on roughness properties of hybrid materials. **Objective:** To investigate of the effects of surface finishing methods on roughness of dental restorations made from hybrid CAD/CAM blocks. **Methods:** A total of 60 samples were produced (n=20) for three main material groups, two different hybrid ceramic (LAVA Ultimate and VITA Enamic) and a conventional glass ceramic (IPS e.max CAD). Each material group was divided into two subgroups (n=10). Ten samples were polished and 10 were glazed according to related manufacturer instructions. Surface roughness was measured with a surface profilometer. Data were statistically analysed using two-way ANOVA ($p<0.05$). **Results:** This study revealed that glazed surfaces were exhibited higher surface roughness values than polished surfaces in all materials ($p<0.001$). Minimum Ra values were belonged to Lava Ultimate polished group ($Ra=0,07\ \mu m$) and maximum values were belonged to IPS e.max CAD glazed group ($Ra=0,38\ \mu m$). **Conclusion:** Within the limitations of the present study, it may be suggested that finishing the hybrid ceramic restorations by mechanical polishing instead of glaze gives better clinical performance in regard to surface roughness.

Key words: hybrid ceramic; surface finishing method; surface roughness

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INTRODUCTION

One of the most important purposes of prosthetic dentistry is to restore missing teeth or dental tissues with materials with physical properties similar to natural teeth. For this purpose, new technologies and materials are constantly being developed for use in dentistry. In few decades, with the increasing the pace of life, interest in CAD/CAM (computer aided design/ computer aided manufacture) restorations made in a single session in the clinic has increased.¹ The most important advantages of the system are that the rapid production of the restoration and as well as the designed restoration can be seen by the both physician and the patient beforehand production.²

Ceramics are one of the most preferred materials by clinicians due to their chemical stability, good mechanical and optical properties, as well as superior

biocompatibility. However, repairing the fractures that occur after the porcelain restoration is placed in the mouth poses a problem. A broken restoration needs to be replaced. In many cases, renewal of the restoration requires a complex and challenging process. Repair is the most conservative and the least invasive method that prevents the restoration from changing and can be solve the problem. However, in order to be achieve successful repair, there must be a good bonding between the existing restoration material and the repair material. Repairing and applicable of the resin composites are easier than porcelain, but their mechanical properties and biocompatibility are not as good as porcelains.³ For this reason, some researchers have tried to create ideal restorative materials by combining composites with dentin-like elastic modulus and feldspathic ceramics with enamel-like properties

in order to create the ideal material.⁴ For this purpose, hybrid ceramic materials are developed in accordance with the CAD/CAM system. These materials combine the beneficial properties of resin with the advantage of glass ceramics. Usage of hybrid ceramics in dentistry offers various advantages. Hybrid materials can be easily milled and no sintering is required. This has shortened the workflow. Characterization and grinding/polishing of the restoration can be done even after permanent cementation. The modulus of elasticity of hybrid ceramics is lower than porcelain and is closer to dentin. Therefore, it does not cause wear on the opposing teeth. According to literature,⁵ the polymer infiltrated ceramic networks (hybrid materials) have similar elasticity modulus with dentine, whereas ceramic based materials such as lithium disilicate glass ceramics and feldspar glass ceramic have higher elasticity modulus than dentine.

In 2012, resin nanoceramic was the first introduced hybrid ceramic CAD/CAM material in dentistry. Structure of this material consists of dispersed zirconia and silica nanoparticles and zirconia-silica clusters in the polymer matrix. In 2013, hybrid ceramic block composed of the polymer infiltrated ceramic networks were introduced to the dental market. In this material, feldspathic ceramic crystal network structure is supported by an acrylate-based polymer mesh. The fracture rate of this material compared to ceramics is significantly lower, in addition the wear resistance of it is higher than conventional composites. Less brittle material so that the edges do not break during milling and that provides a good marginal adaptation.⁶

The microstructure of the material has an effect on the surface properties. The surface roughness is one of the most important properties for dental restorations that affects many clinical features such as the longevity of the restoration, its esthetic appearance and plaque retention.⁷ Different surface finishing methods such as glaze or polish have been described in literature for CAD/CAM materials. Many previous studies focused on optical and surface properties of hybrid CAD/CAM materials have been stated that the optic and surface properties can be affected by the material type and the applied surface finishing procedure.^{8,9} In a previous study¹⁰ has been reported that polished hybrid ceramic material exhibited higher staining than glazed one and other glazed non-hybrid ceramics. It was reported that glazed CAD/CAM surfaces are more advanced and smoother compared with non-glazed surfaces.⁹ Another study about hybrid ceramic has reported that higher surface roughness and staining in glazed surface than polished surface.¹¹ However, some studies have reported different results stated similar roughness between glazed and polished surfaces.^{12,13} In order that there are limited studies and conflicting results about the effects of these methods on roughness properties of hybrid ceramic materials, future studies are required.

The aim of this study was to investigate the effect of different finishing methods on surface roughness of the hybrid CAD/CAM materials such as resin nanoceramic and interpenetrating network hybrid ceramic.

METHODS

In this study; A total of 60 specimens were prepared using two different CAD-CAM hybrid block and one glass ceramic block. Materials used, chemical ingredients, brand name/manufacturer companies, the names of experimental groups, applied surface finishing methods and number of the specimens for each group are presented in Table-1. To ensure standardization, monochromatic blocks had same shade and translucency (A1/HT for group LU, A1/HT for group EM, 1M1/HT for group VE) were used in all materials. All blocks were cut into 2 mm slices using precision cutting machine (IsoMet 1000 Low Speed Saw, Buehler, USA) with diamond cutting disc (Isomet Diamond Wafering Blades 127x0.4 mm, Buehler, USA). After cutting process, half of the samples of each material were divided into two subgroups (n=10), one was the mechanical polishing group, the other was the glaze group for each material.

Lithium disilicate reinforced glass ceramic specimens of EM-G and EM-P groups were crystallized according to the manufacturer's instructions and reached its final color. In accordance with the manufacturer's instructions, pre-polishing with silicone polishing rubbers were applied on the surface of the EM-G group specimens. After that, surfaces were cleaned in an ultrasonic bath (Ultrasonic Cleaner, 28UT ProD, Medisson, İstanbul, Turkey) and after drying, glaze material consisting of composition powder/liquid (IPS e,max Ceram Glaze Powder+Glaze and Stain Liquid, Ivoclar Vivadent, Schaan, Liechtenstein) was applied on sample surfaces with help of a brush and the glaze layer was sintered by firing according to the manufacturer's instructions. In the E.max-P group, after ultrasonic cleaning, mechanical polishing process was performed with a mechanical polishing set (Dialite LD K0240 Extra-Oral Lithium Disilicate Polishing System, Brasseler, USA) suitable for the lithium disilicate material until a gloss surface was obtained.

In hybrid CAD-CAM materials, glazing process was carried out using a resin-based light cure glaze material (Vita Enamic glaze, VITA Zahnfabrik, Bad Sackingen, Germany).

In the Vita Enamic glaze group (VE-G), one surface of the samples was sandblasted with 50µm Al₂O₃ particles at 1 bar pressure. Then 5% hydrofluoric acid gel (Vita Ceramics Etch, VITA Zahnfabrik, Bad Sackingen, Germany) was applied on the specimen surfaces for 60 seconds and then specimens were ultrasonically

Table 1. Experimental groups and used materials in the study

Group Code	n	Surface Finishing Method	Material	Brand Name/Manufacturer	Chemical Composition
LU-G	10	Glaze			
LU-P	10	Mechanical polishing	Hybrid Ceramic (Rezin nanoceramic)	Lava Ultimate/3M Espe, Seefeld, Germany	Contains about 80% (mass fraction) nanoceramic particles (20 nm Silika, 4-11 nm Zirconia and zirconia/silica combined nanoparticles), bound in the resin matrix. The ceramic particles consist of three different ceramic fillers which reinforce a highly cross-linked polymeric matrix.
VE-G	10	Glaze			
VE-P	10	Mechanical polishing	Hybrid Ceramic (Polymer infiltrated network ceramic)	Vita Enamic/ Vita Zahnfabrik, Bad Sackingen, Germany	Ceramic part (%86): 58 – 63%SiO ₂ , 20 – 23% Al ₂ O ₃ , 9 – 11% Na ₂ O, 4 – 6%K ₂ O, 0,5 – 2%B ₂ O ₃ , < 1% ZrO ₂ , < 1%K ₂ O Polymer part (%14): Uretan Dimethacrylate, Tri-etilen glicol dimethacrylate
EM-G	10	Glaze			
EM-P	10	Mechanical polishing	Glass Ceramic (Lithium disilicate reinforced ceramic)	IPS E Max CAD. Ivoclar Vivadent, Schaan, Liechtenstein	Crystal part (%70): Lithium disilicate crystals Ceramic part: 57-80%SiO ₂ , 11-19%Li ₂ O, 0-13% K ₂ O, 0-11P ₂ O ₅ , 0-8%, ZrO ₂ , 0-8%ZnO, 0-12% other colouring oxides

LU-G: Glazed Lava Ultimate, **VE-G:** Glazed Vita Enamic, **EM-G:** Glazed IPS Emax CAD, **LU-P:** Polished Lava Ultimate, **VE-P:** Polished Vita Enamic, **EM-P:** Polished IPS Emax CAD

cleaned. Glaze material was applied with disposable applicator brush (Vita Enamic Microbrush, VITA Zahnfabrik, Bad Sackingen, Germany) on all sample surfaces as a thin single layer without folds, and then dental led light source (Valo LED, Ultradent, Utah, USA) for 30 seconds was applied for polymerisation. After the polymerization, the surface is checked to ensure that there is no stickiness and thus the polymerization is completely ensured.

In the Lava Ultimate glaze (LU-G) group, one surface of the samples was sandblasted with 50µm Al₂O₃ particles at 1 bar pressure, then ultrasonically cleaned. With the disposable applicator brush (Vita Enamic Microbrush, VITA Zahnfabrik, Bad Sackingen, Germany) The glaze layer, which was applied to the sample surfaces as a thin single layer without folding, was polymerized with a dental LED light source (Valo LED, Ultradent, Utah, USA) by applying light for 30 seconds in accordance with the company's recommendation. After the polymerization, the surface was checked and it was observed that there was no stickiness and thus the polymerization was fully achieved.

In the Lava Ultimate polishing group (LU-P), mechanical polishing process was applied using the recommended polishing set by manufacturer and performed in accordance with the manufacturer's instructions. Firstly, pre-polishing was applied with medium and fine-grained rubbers at low speed onto the surfaces, then polishing paste was applied using bristle, felt and cotton brushes to the entire surfaces at high speed until a shiny surface is obtained.

In the Vita Enamic polishing group (VE-P), mechanical polishing was applied in two stages using the recommended polishing set (Vita Enamic polishing set technical, VITA Zahnfabrik, Bad Sackingen, Germany) until a shiny surface was obtained.

Surface Roughness measurements (Roughness average, Ra) were made on a profilometer (Mitutoyo Surftest SJ-310, Mitutoyo Corporation, Tokyo, Japan) at a speed rate of 0.5 mm/s and a cut-off value of 0.8 mm. After ultrasonic cleaning, the arithmetic mean of the measurements taken from three different region from each sample surface was accepted as the roughness value of the sample. Before each group measurement, the profilometer was calibrated with a reference block (Mitutoyo precision reference specimen code no:178-601, Mitutoyo, Japan) with a Ra value of 3.00 µm.

When evaluating the roughness change in hybrid CAD/CAM materials, lithium disilicate reinforced glass ceramic material was used as control, because of that it is the most commonly used CAD/CAM ceramic block in current dentistry due to its mechanical and esthetic properties. Group EM-G was accepted as the control group for the glazed groups and EM-P was accepted as the control value for the polished groups.

Statistical analysis of the data was performed using SPSS version 26 software (IBM SPSS, Inc., Chicago, IL). Normality of the experimental data obtained from each group were explored for using Shapiro-Wilk test. The data were analysed using two-way ANOVA (factor 1: Finishing method, factor 2: Material) and Tukey's post-hoc comparison. The significance level was set at $\alpha=0.05$.

Table 2. Means (standard deviations in parentheses) and statistical differences of surface roughness values (Ra values- μm)

Finishing Method	Group Code	Surface Roughness Mean (SD)	Significance p-value					
			LU-G	VE-G	EM-G	LU-P	VE-P	EM-P
GLAZE	LU-G	0,37 (0,02) ^a		<0.001	0.490	<0.001	<0.001	<0.001
	VE-G	0,22 (0,01) ^b	<0.001		<0.001	<0.001	<0.001	<0.001
	EM-G	0,38 (0,03) ^a	0.490	<0.001		<0.001	<0.001	<0.001
POLISHING	LU-P	0,07 (0,01) ^c	<0.001	<0.001	<0.001		<0.001	<0.001
	VE-P	0,12 (0,01) ^d	<0.001	<0.001	<0.001	<0.001		<0.001
	EM-P	0,18 (0,01) ^e	<0.001	<0.001	<0.001	<0.001	<0.001	

Note: Different superscript letters indicate the statistical differences among the all groups. p-value indicated statistical significance at $\alpha=0.05$. (LU-G: Glazed Lava Ultimate, VE-G: Glazed Vita Enamic, EM-G: Glazed IPS Emax CAD, LU-P: Polished Lava Ultimate, VE-P: Polished Vita Enamic, EM-P: Polished IPS Emax CAD)

Figure 1. Graphical representation of experimental data of the surface roughness. Error bars indicated the standart error at 95% confidence interval. (LU-G: Glazed Lava Ultimate, VE-G: Glazed Vita Enamic, EM-G: Glazed IPS Emax CAD, LU-P: Polished Lava Ultimate, VE-P: Polished Vita Enamic, EM-P: Polished IPS Emax CAD)

RESULTS

The mean surface roughness values and statistical test results are presented in Table 2 and graphical representation of experimental data is shown in Fig. 1. The results of 2-way ANOVA indicated that the surface roughness values varied significantly, depending on the finishing methods and materials ($p<0.001$). Glazed surfaces were exhibited higher surface roughness values than polished surfaces in all materials ($p<0.001$). The highest roughness value was seen in EM-G control group exhibited similar roughness with LU-G group ($p=0.490$). VE-G group had lower roughness (Mean $R_a=0.22$) than other glazed hybrid group (LU-G) and control group (EM-G) ($p<0.001$). In polished groups, VE-P and LU-P groups exhibited significantly lower mean roughness values when compared control group (EM-P). In addition, LU-P group has lower roughness when compared VE-P

group ($p<0.001$). EM-P control group showed higher roughness (Mean $R_a=0.18 \mu\text{m}$) values than polished hybrid groups ($p<0.001$). The most prominent changing (nearly 80%) in roughness depending to surface finishing technique was occurred in Lava Ultimate hybrid CAD/CAM material. Glazed Lava Ultimate material exhibited significantly higher roughness than polished one.

DISCUSSION

In this study, the surface roughness of hybrid CAD/CAM materials combining the advantages of ceramic and composite materials was investigated after two different surface finishing processes (polishing and glaze) and compared with the surface roughness of commonly used glass ceramic (Lithium disilicate reinforced glass ceramic) CAD/CAM material.

Surface finishing processes improve the mechanical and physical properties of the material.¹⁴ The glossy restoration surface better imitates the natural dental appearance and provides a more esthetic result. Dental plaque accumulation is less on the smooth surface, and cleaning of the plaque is easier. Glaze or polishing processes are applied to the restoration surface to obtain a smoother and glossier surface.

The glaze used for ceramics is a colorless glass powder. It is applied to the surface of the restoration and fired to obtain a glossy surface. The molten glass fills and closes the pores on the surface.¹⁵ There are different produced sets for the polishing process. In general, polishing is done by following a sequence from coarse to fine-grained abrasives. Glossy and smooth surfaces are obtained by using rubber and/or polishing pastes containing aluminum oxide. Wiley reported that with the polishing process, the surface can reach a gloss like a glazed surface.¹⁶ Rosenstiel et al. reported that the polished porcelain showed the same discoloration as the glazed group and the fracture toughness of the polished group was higher.¹⁷ According to Bollen et al., the surface roughness value of dental materials should be less than $0.2\mu\text{m}$ in order to minimize the amount of bacterial retention.¹⁸ However, when the findings of some studies in the literature were examined, it was seen that this value could not be reached.¹⁹⁻²¹ In all glazed groups in our study, the mean surface roughness was measured above $0.2\mu\text{m}$ (EM-G = $0.38\mu\text{m}$, LU-G = $0.37\mu\text{m}$, VE-G = $0.22\mu\text{m}$). On the other hand, the surface roughness values obtained by polished groups were measured as less than $0.2\mu\text{m}$. Ozarslan et al.¹¹ found that higher roughness values than $0.2\mu\text{m}$ in both polished and glazed VE material. The polishing time required to achieve lower roughness and the polish set used may have led to this result. But they stated that polished VE group had lower roughness than glazed one. In this respect, the results are similar to our study. Flurry et al.²² reported that polished LU showed the lowest surface roughness values than polished VE in accordance with our results.

Glaze material is applied to the surface as a layer. It is applied to the surface with the help of a brush, mostly by mixing powder-liquid. Glaze increases the gloss of the surface, but depending on the applicator, not being able to distribute it homogeneously on the surface during its application with a brush and not mixing the powder-liquid ratio as recommended may result in a high roughness value, although a glossy appearance can be obtained. The polishing process is carried out without applying any layer to the surface. The low Ra values reached by polishing is due to this reason. According to our results, glazed hybrid materials were exhibited higher roughness values than polished ones. This result is in accordance with the literature.^{9,11} Tekçe et al.⁹ reported that similar roughness values between glazed LU and glazed VE material. However,

glazed LU had higher roughness than glazed VE in our study. Dogheim et al.²³ reported that similar roughness between LU and EM material. In our result, roughnesses of LU and EM control group were similar in glazed group, but in polished group LU material had superior than EM material. This difference in results may be due to the difference in the production method of the EM material (Press or CAD). Pressed EM might lead inhomogeneous distribution of the lithium disilicate crystals and this might lead rougher surface. Although the surface roughness of dental materials can be evaluated by several different methods, profilometry is widely used in the literature. The most common method of calculating the average roughness value is the Ra value obtained by measuring the roughness values of all absolute surfaces and averaging them.²⁴ Tholt et al.²⁰ measured the roughness of ceramic surfaces finished with different surface techniques with a profilometer and atomic force microscope. As a result of the study, they stated that with the polishing process, a surface at least as glazed or even smoother can be obtained, similarly our results.

The Ra value offers important information about the surface roughness. However, it does not mean that there will be no defect in a local area of the surface. Glazing is an effective method for filling the surface defects.²¹ However, glazed surfaces were found to be significantly rougher than polished surfaces in our study. For this reason, when using hybrid materials in clinics, mechanical polishing can be preferred as it is a surface finishing method without applying any layer to the surface. When polishing is preferred, processes that may cause defects should be avoided during the production of the material. The blocks produced for use in CAD/CAM systems are pre-fabricated and homogeneous. Therefore, restorations produced using a hybrid ceramic block with a CAD/CAM system can be finished with polishing.

Another factor that determines the roughness in surface finishing processes is the microstructure of the material. In materials with interpenetrating network structure, it is beneficial that the physical and mechanical properties of the materials used for filler and network structure are close to each other. Otherwise, while the fillers wear away and move away from the structure, the network can maintain its existence in the structure as it is more durable and in the form of a mesh. In this case, it increases the surface roughness and has an abrasive effect on the opposing tooth. In our study, the smoothest surface was obtained in the LU-P group. LU material contains polymer matrix. The network structure is polymer and the filler is harder zirconia and silica. Therefore, if the filler is removed by abrasion, the polymer network is affected by the same factor and it becomes flattened by abrasion. For this reason, it is thought that a smoother surface is obtained with the polishing process in the

LU material. However, it is unclear how the initially obtained surface roughness will be affected by wear in the long term and whether it will preserve its initial values. Therefore, future clinical studies are needed on this subject.

CONCLUSION

It is concluded that the Lava Ultimate and Vita Enamic hybrid ceramic materials exhibit a smoother surface after polishing than the lithium disilicate glass ceramic material. Lower level of roughness can be achieved with polishing in Lava Ultimate material than Vita Enamic material, but Vita Enamic material is more advantageous in terms of roughness if glaze application is required.

CONFLICT OF INTEREST

Authors declare that there is no conflict of interest for this study.

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