©Operative Dentistry, 2018, **43-1**, 90-100

Effect of Finishing and Polishing on Roughness and Gloss of Lithium Disilicate and Lithium Silicate Zirconia Reinforced Glass Ceramic for CAD/CAM Systems

A Vichi • R Fabian Fonzar • C Goracci • M Carrabba • M Ferrari

Clinical Relevance

Silica-based glass ceramics restorations achieve clinically acceptable, enamel-like roughness and gloss by either glazing or manual finishing and polishing. The latter can be considered an adequate procedure, comparable to furnace-based restorations, and this is noteworthy for chairside monolithic restorations.

SUMMARY

Objective: To assess the efficacy of dedicated finishing/polishing systems on roughness and gloss of VITA Suprinity and IPS e.max CAD.

Method: A total of 24 blocks of Suprinity and 24 of e.max were cut into a wedge shape using an InLab MC-XL milling unit. After crystallization, the 24 Suprinity wedges were divided into four subgroups: group A.1: Suprinity Polishing Set Clinical used for 30 seconds and group A.2: for 60 seconds; group A.3: VITA Akzent Plus Paste; and group A.4: spray. The 24 e.max wedges (group B) were divided into four subgroups according to the finishing procedure: group B.1: Optrafine Ceramic Polishing System for 30 seconds and group B.2: for 60 seconds; group B.3: IPS e.max CAD Crystall/Glaze paste; and group B.4: spray. After finishing/polishing, gloss was assessed with a glossmeter and roughness evaluated with a profilometer. Results were analyzed by applying a two-way analysis of variance for gloss and another for roughness (α=0.05). One specimen per each subgroup was observed with a scanning electron microscope.

*Alessandro Vichi, DDS, PhD, Department of Medical Biotechnologies, University of Siena, Siena, Italy. Faculty of Medical Sciences, LUdeS HEI Foundation, Lugano, Switzerland – La Valletta, Malta

Riccardo Fabian Fonzar, DDS, PhD, Department of Medical Biotechnologies, University of Siena, Siena, Italy

Cecilia Goracci, DDS, PhD, Department of Medical Biotechnologies, University of Siena, Siena, Italy

Michele Carrabba, DDS, PhD, Department of Medical Biotechnologies, University of Siena, Siena, Italy

Marco Ferrari, MD, DMD, PhD, Department of Medical Biotechnologies, University of Siena, Siena, Italy and Department of Restorative Dentistry, University of Leeds, UK

*Policlinico Le Scotte, viale Bracci Siena, 53100, Italy; email: alessandrovichi1@gmail.com

DOI: 10.2341/16-381-L

Results: For roughness, materials and surface were significant factors (*p*<0.001). Suprinity exhibited significantly lower roughness than e.max. Also the Material-Surface Treatment interaction was statistically significant (*p*=0.026). For gloss, both material and surface treatment were significant factors (*p*<0.001). VITA Suprinity showed significantly higher gloss than e.max. Also the Material-Surface Treatment interaction was statistically significant (*p*<0.001).

Conclusions: Manual finishing/polishing for 60 seconds and glazing paste are the most effective procedures in lowering the roughness of CAD/CAM silica-based glass ceramics. Manual finishing/polishing for 60 seconds allows milled silica-based glass ceramics to yield a higher gloss. VITA Suprinity displayed higher polishability than IPS e.max CAD.

INTRODUCTION

Computer-aided design and computer-aided manufacturing (CAD/CAM) technology represents an important part of contemporary prosthetic dentistry.[1] CAD/CAM or "digital" dentistry developed following two main streams. The digital procedure can in fact be carried out by the technicians in their laboratories, with a workflow that can somehow resemble the traditional one, or, alternatively, it can be performed entirely in dental offices. In the so-called chairside procedure, a single-unit restoration can be fabricated in the dental office and delivered in a one-session appointment of reasonable time. Since its launch in 1985, the CEREC system, the first and currently leading system for chairside restorations, has developed hardware, software, and material options.[2,3] Among the several materials available for milling,[4-6] lithium silica-based glass ceramics are relevant for esthetic, physical, and mechanical properties. Despite the different chemistry, both IPS e.max CAD (Ivoclar Vivadent, Schaan, Liechtenstein) and VITA Suprinity (VITA Zahnfabrik, Bad Sackingen, Germany) are particularly indicated for monolithic restorations.[7,8] Once milled, the restorations are coarse in texture,[1,9,10] so polishing and finishing are mandatory before delivery.[11] These procedures render the surfaces smoother[1] and more lustrous[12] as well as improve the restoration biocompatibility,[13-15] minimizing the incidence of biological complications such as plaque retention and antagonist-tooth wearing. In addition, well-finished surfaces lead to less technical and esthetic problems because the material becomes tougher,[16,17] glossy,[18] and stable in translucency[19] and color.[20]

Glass ceramics can be finished by handpiece burs, with or without glossy paste, or by furnace-based glazing materials. Because manual polishing and glazing affect differently the surface smoothness and aspect of dental ceramics,[1,11,18,21,22] it appeared of interest to evaluate whether roughness and gloss vary according to the finishing procedures.

To assess *in vitro* the effect of the dedicated manual and furnace-based finishing systems on the surface properties of VITA Suprinity and IPS e.max CAD, a study with a twofold objective was conducted. The first objective was to verify whether differences exist between the two materials in the ability to decrease roughness and increase gloss. The tested null hypothesis was that VITA Suprinity and IPS e.max CAD achieve the same roughness and gloss after finishing with their respective dedicated systems. The second objective was to assess whether for each of the two materials, the manual and the furnace-based recommended systems perform similarly. The tested null hypothesis was that no statistically significant difference in roughness and gloss exist among the different proprietary finishing and polishing systems tested on VITA Suprinity and IPS e.max CAD.

METHODS AND MATERIALS

Specimen Preparation

Blocks of zirconia-reinforced lithium silicate (VITA Suprinity, HT A3, VITA Zahnfabrik) and lithium disilicate (IPS e.max CAD, HT A3, Ivoclar Vivadent AG) for the CEREC CAD/CAM system (Sirona Dental, Bernsheim, Germany) were selected for this study. Twenty-four blocks were used for each of the two tested materials.

A model for a 30° wedge-shaped specimen was designed with CEREC InLab software v3.88 (Sirona Dental; Figure 1). Specimens were milled in an InLab MC-XL milling machine (Sirona Dental). In order to standardize the milling procedure, the diamond burs of the milling unit (Step Bur 12S and Cylinder Pointed Bur 12S, both Sirona Dental) were replaced before starting the milling procedure and then every 10 milling cycles. Each milled wedge was finally separated from the block base by means of a low-speed, water-cooled diamond disc.

Final crystallization was performed following manufacturer's instructions in their respective recommended furnaces: VITA Vacumat 6000 (VITA

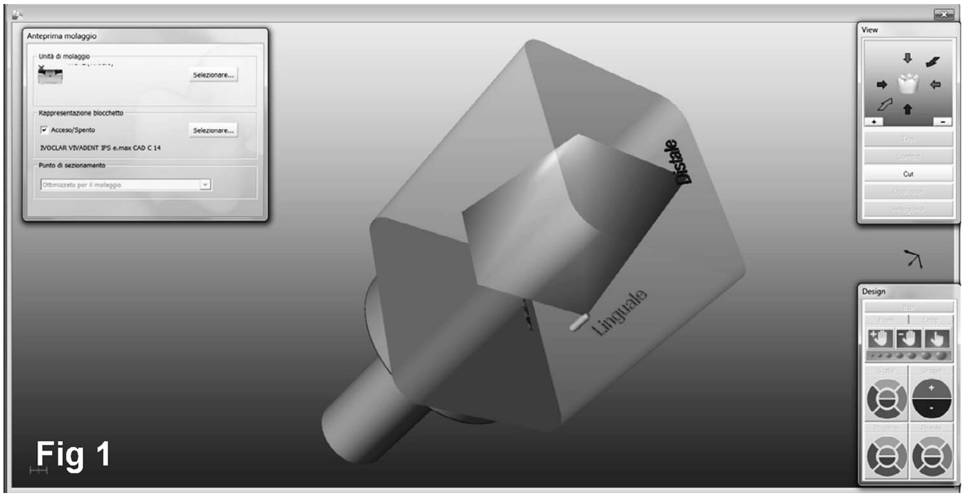

Figure 1. *Software image of the 30° wedges milled from VITA Suprinity and IPS e.max CAD blocks.*

Zahnfabrik) for VITA Suprinity and EP 600 Combi (Ivoclar Vivadent) for IPS e.max CAD.

After crystallization, the 24 VITA Suprinity wedges (group A) were randomly divided into four subgroups according to the finishing procedure (Table 1): group A.1 = VITA Suprinity Polishing Set Clinical used for 30 seconds (VITA Zahnfabrik); group A.2 = VITA Suprinity Polishing Set Clinical used for 60 seconds; group A.3 = VITA Akzent Plus Paste (VITA Zahnfabrik); group A.4 = VITA Akzent Plus Spray (VITA Zahnfabrik). The 24 e.max CAD wedges (group B) were also randomly divided into four subgroups according to the finishing procedure: group B.1 = Optrafine Ceramic Polishing System (Ivoclar Vivadent) used for 30 seconds; group B.2 =

Table 1: *Tested Groups, Materials, and Treatments*

Groups	Blocks	Finishing and Polishing Systems	Treatments and Abbreviations	
A1	VITA Suprinity (ZLS)	SUPRINITY Polishing Set Clinical	Manual finishing and polishing with contra-angle handpiece First tip: 30 seconds, 10,000 rpm; second tip: 30 seconds, 6,000 rpm.	30MFP
B1	IPS e.max CAD (LD)	Optrafine Ceramic Polishing System	Manual finishing and polishing with contra-angle handpiece First tip: 30 seconds, 10,000 rpm; second tip: 30 seconds, 6,000 rpm.	
A2	VITA Suprinity (ZLS)	SUPRINITY Polishing Set Clinical	Manual finishing and polishing with contra-angle handpiece First tip: 60 seconds, 10,000 rpm; second tip: 60 seconds, 6,000 rpm.	60MFP
B2	IPS e.max CAD (LD)	Optrafine Ceramic Polishing System	Manual finishing and polishing with contra-angle handpiece First tip: 60 seconds, 10,000 rpm; second tip: 60 seconds, 6,000 rpm.	
A3	VITA Suprinity (ZLS)	VITA Akzent Plus Paste	Laboratory finishing Smoothly applied on the surface with a brush and fired	GP
B3	IPS e.max CAD (LD)	IPS e.max CAD Crystall/Glaze paste	Laboratory finishing Smoothly applied on the surface with a brush and fired	
A4	VITA Suprinity (ZLS)	VITA Akzent Plus Spray	Laboratory finishing Smoothly sprayed on the surface and fired	GS
B4	IPS e.max CAD (LD)	IPS e.max CAD Crystall/Glaze spray	Laboratory finishing Smoothly sprayed on the surface and fired	

Abbreviations: GP, glazing paste; GS, glazing spray; MFP, manual finishing and polishing; rpm, revolutions per minute.

Optrafine Ceramic Polishing System used for 60 seconds; group B.3 = IPS e.max CAD Crystall/Glaze paste (Ivoclar Vivadent); group B.4 = IPS e.max CAD Crystall/Glaze spray (Ivoclar Vivadent). For each group, five wedges were used for roughness and gloss measurements. Given that both sides of each wedge received the surface treatment, a total of 10 surfaces per group were assessed (n=10). One extra specimen per subgroup was prepared for scanning electron microscopy (SEM) observations.

For the manual finishing procedure (subgroups A.1, A.2, B.1, B.2), rubber cups were used and replaced every two specimens. Finishing was carried out following the manufacturers' instructions with a contra-angle handpiece (Kavo INTRAmatic 20CN, Kavo, Biberach, Germany) under water-cooling. All the manual finishing and polishing procedures were performed by the same operator. The operator was calibrated using a precision scale before and during the procedure, considering a 40*g* force as a reference for light pressure. The calibration was repeated for every subgroup (10 specimens).[23]

For the furnace-based finishing procedure of subgroup A.3, the glazing material was applied and then fired in a VITA Vacumat 6000 furnace (VITA Zahnfabrik, Bad Sackingen, Germany) with the following firing cycle: pre-dry at 400°C for 6 minutes, heat 80°C/minute until 800°C followed by opening after 1 minute of holding time with no vacuum.

For subgroup A.4, the glazing material was applied and then fired in a VITA Vacumat 6000 furnace with the following firing cycle: pre-dry at 400°C for 4 minutes, heat 80°C/minute until 800°C followed by opening after 1 minute of holding time with no vacuum.

For subgroups B.3 and B.4, after the application of the glazing material (paste and spray, respectively), the following firing cycle was performed with EP 600 Combi (Ivoclar, Schaan, Liechtenstein): pre-dry at 403°C for 6 minutes, heat 90°/minute until 820°C, heat 30°C/minute until 840°C, followed by opening after 3 minutes of holding time; vacuum on at 550°C and vacuum off at 820°C.

Roughness and Gloss Measurement

Before testing, specimens were ultrasonically cleaned in a 95% alcohol solution for three minutes. A profilometer (Mitutoyo SJ-201P, Mitutoyo Corp., Kanagawa, Japan) set with a cutoff value of 0.8 mm, a stylus speed of 0.5 mm/s, and a tracking length of 5.0 mm was used[24] to assess the surface roughness (Ra). The setup was standardized by means of a custom mold for both instrument and specimen. Mean Ra (μm) was recorded.

A glossmeter (Novo-Curve, Rhopoint Instruments Ltd, Bexhill-on-Sea, UK) with a 60° angle was used for the gloss evaluation. ISO 2813 specifications for ceramic materials were followed[25] and gloss units (GU) were recorded. To avoid any ambient light and to control the specimen position during measuring, a custom-made opaque silicone mold was used.

In order to test the formulated null hypothesis, the ability of the material to be finished (group A; group B), and the efficacy of the recommended finishing systems (subgroups A.1-A.4; subgroups B.1-B.4) were compared for roughness and gloss, respectively, using a two-way analysis of variance (ANOVA), having verified that the groups' data distribution was normal (p=0.077; Kolmogorov-Smirnov test) and variances were homogeneous (p=0.545; Levene test). In all the analyses, the level of significance was set at $\alpha = 0.05$ and PASW Statistic 18.0 software (SPSS, Chicago, IL, USA) was used.

SEM Evaluation

Specimen preparation for SEM observations involved ultrasonic cleaning in a 95% alcohol solution for three minutes and air drying with an oil-free air spray. Specimens were then secured onto SEM (JSM-6060LV, JEOL, Tokyo, Japan) slabs with gold-conducting tape, and were gold coated in a vacuum sputter coater (SC7620 Sputter Coater, Polaron Range, Quorum Technologies, Newhaven, UK). The treated surfaces were then observed at 500× magnification (Figure 2).

RESULTS

Roughness (Ra)

The results of superficial roughness measurements are reported in Table 2. The two-way ANOVA demonstrated that material and surface treatment were significant factors for roughness (p<0.001). In particular, regardless of the surface treatment, VITA Suprinity exhibited significantly lower roughness than IPS e.max CAD. When assessing the influence of the polishing system, the two-way ANOVA disclosed that 60 seconds of manual finishing and polishing and glazing paste resulted in significantly lower roughness than glazing spray. Also 60 seconds of manual finishing and polishing yielded significantly lower roughness than 30 seconds of manual finishing and polishing. Also

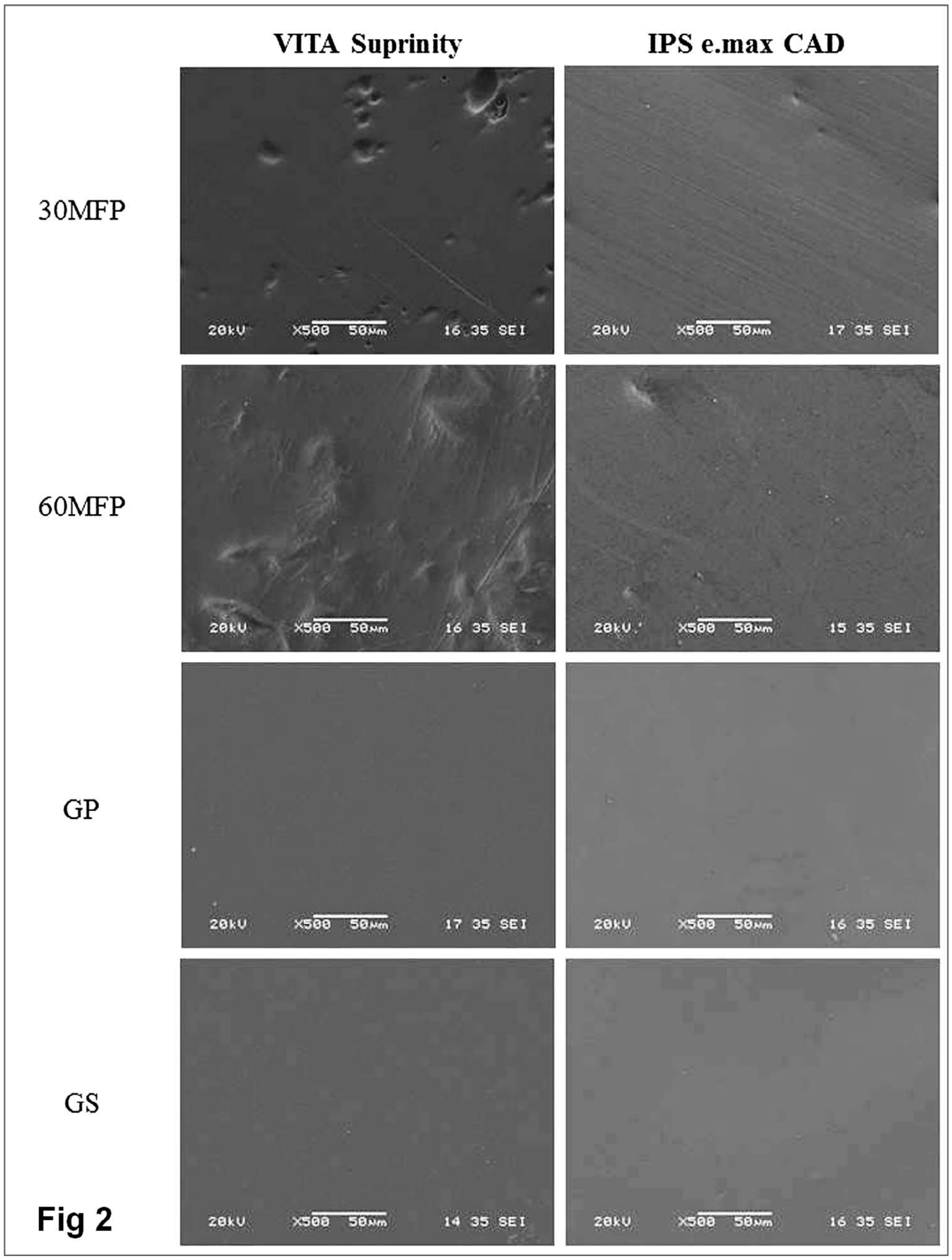

Figure 2. *SEM analysis of VITA Suprinity and IPS e.max CAD at 500 × after 30 and 60 seconds of manual finishing and polishing (30MFP and 60MFP, respectively), glazing paste (GP), and glazing spray (GS).*

the Material × Surface Treatment interaction was statistically significant ($p=0.026$). Specifically, with Suprinity 30 seconds of manual finishing and polishing and glazing spray resulted in significantly lower roughness than 60 seconds of manual finishing and polishing and glazing paste, whereas with IPS e.max CAD, glazing spray produced significantly higher roughness than the other treatments ($p<0.05$). In addition, IPS e.max CAD was significantly rougher than Suprinity following all the treatments except 30 seconds of manual finishing and polishing ($p<0.05$).

Gloss (GU)

The results of the gloss measurements are presented in Table 3. The outcome of the two-way ANOVA pointed out that both material and surface treatment were significant factors for gloss ($p<0.001$). In particular, regardless of the surface treatment, VITA Suprinity exhibited significantly higher gloss than IPS e.max CAD. Considering the effect of the polishing system, it emerged that 60 seconds of manual finishing and polishing produced significantly higher gloss than the other investigated treatments. Also the Material × Surface Treatment interaction

Table 2: *Mean (SD) for Surface Roughness of VITA Suprinity and IPS e.max CAD After 30 and 60 Seconds of Manual Finishing and Polishing (30MFP and 60MFP, Respectively), Glazing Paste (GP), and Glazing Spray (GS) and Statistical Significance (Sign.)**

Treatment	Roughness (μm)						Sign.
	VITA Suprinity			IPS e.max CAD			
	Mean	SD	Sign.	Mean	SD	Sign.	
30MFP	0.69^{α}	0.15	*b*	0.62^{α}	0.21	a	BC
60MFP	0.37^{α}	0.08	*a*	0.53^{β}	0.13	a	A
GP	0.42^{α}	0.12	*a*	0.66^{β}	0.15	a	AB
GS	0.64^{α}	0.31	*b*	0.91^{β}	0.21	b	C
Sign.	*A*			*B*			

** Italic upper case letters indicate substrate statistical groups. Upper case letters indicate treatment statistical groups. Italic lower case letters indicate statistical groups among treatments within VITA Suprinity. Lower case letters indicate statistical groups among treatments within IPS e.max CAD. Superscript Greek letters indicate statistical groups among the two materials within each treatment.*

Table 3: *Mean (SD) for Surface Gloss of VITA Suprinity and IPS e.max CAD After 30 and 60 Seconds of Manual Finishing and Polishing (30MFP and 60MFP, Respectively), Glazing Paste (GP) and Glazing Spray (GS) and Statistical Significance (Sign.)**

Treatment	Gloss (GU)						Sign.
	VITA Suprinity			IPS e.max CAD			
	Mean	SD	Sign.	Mean	SD	Sign.	
30MFP	49.05^{β}	6.17	*c*	63.14^{α}	12.13	a	B
60MFP	85.02^{α}	12.94	*a*	65.77^{β}	12.36	a	A
GP	72.24^{α}	10.60	*a*	48.28^{β}	9.53	b	B
GS	69.86^{α}	9.0	*b*	54.89^{β}	13.91	ab	B
Sign.	*A*			*B*			

** Italic upper case letters indicate substrate statistical groups. Upper case letters indicate treatment statistical groups. Italic lower case letters indicate statistical groups among treatments within VITA Suprinity. Lower case letters indicate statistical groups among treatments within IPS e.max CAD. Superscript Greek letters indicate statistical groups among the two materials within each treatment.*

was statistically significant ($p<0.001$). Specifically, with Suprinity, 30 seconds of manual finishing and polishing produced the lowest gloss. However, by increasing the polishing time to 60 seconds, a gloss significantly higher than with either glazing procedure was obtained ($p<0.05$). On IPS e.max CAD using gloss paste, a gloss significantly lower than with either manual polishing procedure was achieved ($p<0.005$). In addition, following 30 seconds of manual finishing and polishing, IPS e.max exhibited significantly higher gloss than Suprinity ($p<0.005$). Conversely, with all the other surface treatments it was Suprinity that achieved superior gloss ($p<0.05$).

SEM Evaluation

Different surface topographies were observed for the manual and heat-mediated polishing systems (Figure 1). For VITA Suprinity, some irregularities were still present after the 30 seconds of manual polishing. The 60-second polishing group resulted in a more homogeneous surface with few isolated minor defects and scratches. For IPS e.max CAD, scratches resulting from the abrasive action of the polishing rubber cups were particularly evident after 30 seconds of manual polishing. However, no substantial superficial defects were visible. Conversely, a more uniform surface was found for the 60-seconds manual polishing group. For both materials, more extensive defect-free surfaces were observed after paste and spray glazing.

DISCUSSION

Given that statistically significant differences were detected between IPS e.max CAD and VITA Suprinity in roughness and gloss, the first null hypothesis was rejected. Statistically significant differences were also found in roughness and gloss among the different subgroups, both for IPS e.max CAD and VITA Suprinity. Thus, the second null hypothesis was rejected as well.

Roughness and gloss evaluation allows glass ceramics to be superficially analyzed and screened with regard to their surface characteristic after finishing.[18] Roughness can be described by several linear (Ra, Rq, Rz) or three-dimensional (Sa, Sq, Sz) parameters.[1,22,26] For the present investigation, Ra, which is defined as the mean arithmetical value of all the absolute distances of the profile inside of the measuring length,[11] was assessed because it is the most commonly used parameter for evaluating the effect of finishing protocols on dental ceramics.[27-31]

Gloss (GU) represents the amount of specular reflection from a surface,[12,32] and it is calculated by comparing the magnitude of incident light traveling toward a surface at a 60° angle to the magnitude traveling away from the surface at an equal and opposite angle. Optical properties (refraction index) and surface topography[12] characterize the gloss to the extent that the coarser the texture, the lower the reflectivity.[18,33-36]

The first aim of the present study was to compare finishing systems that are marketed for the proprietary silica-based glass ceramics. The variability observed in roughness and gloss for VITA Suprinity and IPS e.max CAD may be ascribed to the differences in ceramic microstructure as well as to the peculiar properties of the polishing and glazing

Table 4: *Polishing Systems Specifications as Declared by the Manufacturer*

Instrument	Grit	Contents	Manufacturer
VITA Suprinity Polishing Set clinical (pink)	Diamond powder 500/600	Polyurethane-rubber/caoutchouc Diamond grains Pigments	VITA Zahnfabrik Bad Sackingen Germany
OptraFine F (coarse)	NR	Synthetic rubber Diamond granulate Titanium dioxide	Ivoclar Vivadent AG Schaan Liechtenstein
VITA Suprinity Polishing Set Clinical (gray)	Diamond powder 3000	Polyurethane-rubber/caoutchouc Diamond grains Pigments	VITA Zahnfabrik Bad Sackingen Germany
OptraFine P (fine)	NR	Synthetic rubber Diamond granulate Titanium dioxide	Ivoclar Vivadent AG Schaan Liechtenstein

Abbreviation: NR, not reported by the manufacturer.

systems. At present no data are available in the literature concerning VITA Suprinity finishing and polishing. The information available for IPS e.max CAD indicates similar results of the various manual finishing and polishing systems, suggesting that the ability to obtain smooth surfaces mainly depends on the material, rather than on the finishing/polishing system used.[37,38]

Polishing and glazing yielded similar results with regard to roughness. IPS e.max CAD polished with OptraFine for 30 or 60 seconds and finished using glazing paste showed, in fact, comparable roughness. Although Lawson and others[38] reported less efficacy of the glazing paste when compared with 60-second manual polishing, most of the studies agree on the comparability of the two procedures,[39-41] even if different final Ra values are reported. These differences in final Ra might be explained by the baseline roughness of the specimens. Because roughness is conventionally measured with a profilometer on flat surfaces, the after-milling roughness is usually replicated by grinding and polishing the specimens with silicon carbide papers of increasing grit.[42,43] Given that the combination of carbide papers differs among the studies, baseline surfaces might vary and mismatch the effective after-milling roughness. For the present study, the flat specimens were directly milled with the CEREC MC-XL milling unit, with the twofold objective of high repeatability of the specimens and test of the real after-milling surface.

Polishing time played an important role in the final smoothness and luster, as previously reported.[18] Despite the minor differences in composition between the VITA Suprinity Polishing set and Optrafine manual sets (Table 4), polishing time affected roughness and gloss of VITA Suprinity differently than it did IPS e.max CAD. Whereas for VITA Suprinity the obtained values indicated a smoother and glossier surface after 60 seconds of polishing, for IPS e.max CAD, the values did not change. This might be explained by the differences in the microstructure of the two materials.[28,44,45] VITA Suprinity is a zirconia-reinforced, silica-based glass ceramic with a mean crystal size of approximately 0.5 μm, whereas IPS e.max CAD is a lithium disilicate–based glass ceramic with a mean crystal size of 1.5 μm. Because ceramic crystals removed from the surface during polishing might become part of the abrasive system and contribute to characteristics of the surface topography,[46] the finer microstructure of VITA Suprinity might account for its smoother surface compared to IPS e.max CAD after 60 seconds of polishing.[29] In addition, silicon dioxide concentration varies between IPS e.max CAD (57.0-80.0) and VITA Suprinity (56.0-64.0). Because the higher the concentration of silicon dioxide, the greater the crystalline phase,[47] the superior crystalline content of IPS e.max CAD might explain its lower capability to be smoothed after 60 seconds of polishing. Furthermore, the higher content of zirconium dioxide in VITA Suprinity might contribute to its lower superficial roughness after 60 seconds of polishing, because zirconia allows the material to be more efficaciously polished.[48]

The times tested in the present study refer to manufacturers' instructions and are in the range of common clinical use. It could be supposed that either material would display higher superficial smoothness and gloss after longer polishing times.[18] However, longer polishing times might also cause greater substance loss, given that polishing is a subtractive procedure. This occurrence should be given due consideration clinically.

Concerning the efficacy of the furnace-based glazing systems, VITA Suprinity showed lower roughness and higher gloss after paste glazing than spray glazing. Different trends were observed for IPS e.max CAD, given that roughness and gloss were lower for paste than for spray glazing. The differences in composition and characteristic density between IPS e.max CAD Crystall/Glaze Paste and VITA AKZENT Plus Paste resulted in a different glaze spread ability on the ceramic surface. This occurrence might explain the lower gloss of IPS e.max CAD compared with VITA Suprinity, because the less smooth glaze coat might have caused a variation in the superficial refraction index and, therefore, in the gloss.

As reported by Vo and others,[49] IPS e.max CAD treated with glazing spray obtained the highest superficial roughness among the tested finishing systems. Owing to the rougher baseline surfaces of the milled wedges, glazing spray was not able to uniformly coat all the irregularities, thus demonstrating less efficacy at smoothing.[50-51] Monaco and others[52] found Ra values (0.58±0.5 μm) for this procedure lower than the values reported in the present study. A possible explanation might again be found in the baseline roughness of the material. This assumption is supported by other studies indicating that a lower surface roughness can be obtained when the specimens are polished prior to glazing.[1,53]

When assessing the efficacy of the furnace-based systems on the two tested materials, it was observed that glazing paste and spray were more effective on VITA Suprinity than on IPS e.max CAD in terms of both roughness and gloss. As previously reported, a possible reason for this finding may be the differences in microstructure of these glass ceramics. Due to the lower crystalline volume and the smaller crystal size, VITA Suprinity might have exhibited a lower baseline roughness that would have led to lower roughness after glazing.[1,28,53,54] As roughness and gloss have an inverse proportional trend,[12] the lower roughness of VITA Suprinity surfaces may account for their higher gloss.

To better understand the outcome of the present study, the collected data have to be related to clinical requirements. Some *in vivo* studies[55] have suggested an ideal threshold surface roughness of 0.2 μm, above which bacterial retention is facilitated and the incidence of biological complications increased. In addition, superficial roughness greater than 0.5 μm can be detected by the sensorial fibers of the tongue, resulting in discomfort for the patient.[56] Nevertheless, natural enamel roughness is reported to range between 0.64 and 0.90 μm with regard to the tooth type, location, and patient age.[41,57] When referring to the clinical acceptability of the finished surfaces, all the Ra values measured in the present study were far below the abrasive wearing threshold (1.5 μm).[38] Furthermore, 60 seconds of polishing (0.37±0.08 μm) and glazing paste (0.42±0.12 μm) allowed VITA Suprinity to be imperceptible by the tongue. All the other groups fell within the enamel roughness range (0.64-0.90 μm), with the exception of IPS e.max CAD after glazing spray (0.91±0.21 μm).

Unlike for roughness, a clinically accepted threshold for gloss has not been established. However, natural enamel gloss is reported to range between 40 and 52 GU.[58] VITA Suprinity polished for 30 seconds (49±6 GU) and IPS e.max CAD finished with glazing paste (48±10 GU) displayed similar gloss to that of enamel, whereas all the other procedures gave higher values for both materials. The most efficient system was 60 seconds of manual polishing for either VITA Suprinity (85±13 GU) or IPS e.max CAD (66±12 GU). Similar results (57 GU) were observed for IPS e.max CAD finished with 4000-grit silicon carbide paper polishing,[59] whereas the combination of 1200-grit silicon carbide paper polishing and alumina slurry extrapolishing allowed lithium disilicate to become more lustrous (96 GU).[12]

From a clinical perspective it should also be noted that manual polishing systems have the main advantage of completing the in-office restoration in a single session, still ensuring comparable or better performance than glazing systems.[28,60] By manual polishing, the clinician finishes the in-office restoration without any thermal treatment, speeding up and simplifying the overall workflow; this is particularly relevant considering the increasing use of monolithic restorations.

CONCLUSION

Within the limitations of the present study, the following conclusions can be drawn:

- Manual finishing and polishing for 60 seconds and glazing paste were the most effective procedures at lowering the roughness of CAD-CAM silica-based glass ceramics.
- Manual finishing and polishing for 60 seconds allowed milled silica-based glass ceramics to yield the highest gloss.
- VITA Suprinity displayed higher polishability than IPS e.max CAD.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

(Accepted 14 March 2017)

REFERENCES

1. Fasbinder DJ, & Neiva GF (2016) Surface evaluation of polishing techniques for new resilient CAD/CAM restorative materials *Journal of Esthetic and Restorative Dentistry* **28(1)** 56-66.
2. Mörmann WH (2006) The evolution of the CEREC system *Journal of the American Dental Association* **137(Supplement 1)** 7S-13S.
3. Sadowsky SJ (2006) An overview of treatment considerations for esthetic restorations: A review of the literature. *Journal of Prosthetic Dentistry* **96(6)** 433-442.
4. Wittneben JG, Wright RF, Weber HP, & Gallucci GO (2009) A systematic review of the clinical performance of CAD/CAM single-tooth restorations *International Journal of Prosthodontics* **22(5)** 466-471.
5. Vichi A, Sedda M, Del Siena F, Louca C, & Ferrari M (2013) Flexural resistance of CEREC CAD/CAM system ceramic blocks. Part 1: Chairside materials *American Journal of Dentistry* **26(5)** 255-259.
6. Sedda M, Vichi A, Del Siena F, Louca C, & Ferrari M (2014) Flexural resistance of CEREC CAD/CAM system ceramic blocks. Part 2: Outsourcing materials *American Journal of Dentistry* **27(1)** 17-22.
7. Stawarczyk B, Liebermann A, Eichberger M, & Güth JF (2015) Evaluation of mechanical and optical behavior of current esthetic dental restorative CAD/CAM composites *Journal of the Mechanical Behavior of Biomedical Materials* **55(March)** 1-11.
8. Magne P, Carvalho AO, Bruzi G, & Giannini M (2015) Fatigue resistance of ultrathin CAD/CAM complete crowns with a simplified cementation process *Journal of Prosthetic Dentistry* **114(4)** 574-579.
9. Song XF, Ren HT, & Yin L (2015) Machinability of lithium disilicate glass ceramic in *in vitro* dental diamond bur adjusting process *Journal of the Mechanical Behavior of Biomedical Materials* **53(January)** 78-92.
10. Corazza PH, de Castro HL, Feitosa SA, Kimpara ET, & Della Bona A (2015) Influence of CAD-CAM diamond bur deterioration on surface roughness and maximum failure load of Y-TZP-based restorations *American Journal of Dentistry* **28(2)** 95-99.
11. Silva TM, Salvia AC, Carvalho RF, Pagani C, Rocha DM, & Silva EG (2014) Polishing for glass ceramics: Which protocol? *Journal of Prosthodontic Research* **58(3)** 160-170.
12. Lawson NC, & Burgess JO (2015) Gloss and stain resistance of ceramic-polymer CAD/CAM restorative blocks *Journal of Esthetic and Restorative Dentistry* **28(Supplement 1)** S40-S45.
13. Quirynen M, Van der Mei HC, Bollen CML, Schotte A, Marechal M, Doornbusch GI, Naret I, Busscher HJ, & Van Steenberghe D (1993) An *in vivo* study of the influence of surface roughness of implants on the microbiology of supra- and subgingival plaque *Journal of Dental Research* **72(9)** 1304-1309.
14. Bollen CM, Papaioanno W, Van Eldere J, Schepers E, Quirynen M, & van Steenberghe D (1996) The influence of abutment surface roughness on plaque accumulation and peri-implant mucositis *Clinical Oral Implants Research* **7(3)** 201-211.
15. Oh WS, Delong R, &Anusavice KJ (2002) Factors affecting enamel and ceramic wear: A literature review *Journal of Prosthetic Dentistry* **87(4)** 451-459.
16. de Jager N, Feilzer AJ, & Davidson CL (2000) The influence of surface roughness on porcelain strength *Dental Materials* **16(6)** 381-388.
17. Lohbauer U, Müller FA, & Petschelt A (2008) Influence of surface roughness on mechanical strength of resin composite versus glass ceramic materials *Dental Materials* **24(2)** 250-256.
18. Heintze SD, Forjanic M, & Rousson V (2006) Surface roughness and gloss of dental materials as a function of force and polishing time *in vitro Dental Materials* **22(2)** 146-165.
19. Awad D, Stawarczyk B, Liebermann A, & Ilie N (2015) Translucency of esthetic dental restorative CAD/CAM materials and composite resins with respect to thickness and surface roughness *Journal of Prosthetic Dentistry* **113(6)** 534-540.
20. Motro PF, Kursoglu P, & Kazazoglu E (2012) Effects of different surface treatments on stainability of ceramics *Journal of Prosthetic Dentistry* **108(4)** 231-237.
21. Brunot-Gohin C, Duval JL, Azogui EE, Jannetta R, Pezron I, Laurent-Maquin D, Gangloff SC, & Egles C (2013) Soft tissue adhesion of polished versus glazed lithium disilicate ceramic for dental applications *Dental Materials* **29(9)** e205-e212.
22. Odatsu T, Jimbo R, Wennerberg A, Watanabe I, & Sawase T (2013) Effect of polishing and finishing procedures on the surface integrity of restorative ceramics *American Journal of Dentistry* **26(1)** 51-55.
23. Antonson SA, Yazici AR, Kilinc E, Antonson DE, & Hardigan PC (2001) Comparison of different finishing/polishing systems on surface roughness and gloss of resin composites *Journal of Dentistry* **39(Supplement 1)** e9-e17.
24. The European Standard (2004) EN 623-624 Advanced technical ceramics. Monolithic ceramics. General and textures properties. Part 4: Determination of surface roughness. Brussels (B): *European Committee for Standardization*.
25. ISO-Standards (1999) EN ISO 2813 Specular gloss *Geneve: International Organization for Standardization*.
26. Zinelis S, Thomas A, Syres K, Silikas N, & Eliades G (2010). Surface characterization of zirconia dental implants *Dental Materials* **26(4)** 295-305.
27. Wang F, Chen JH, & Wang H (2009) Surface roughness of a novel dental porcelain following different polishing

procedures *International Journal of Prosthodontics* 2009 **22(2)** 178-180.

28. Sasahara RM, Ribeiro Fda C, Cesar PF, & Yoshimura HN (2006) Influence of the finishing technique on surface roughness of dental porcelains with different microstructures *Operative Dentistry* **31(5)** 577-583.

29. Yilmaz K, & Ozkan P (2010) Profilometer evaluation of the effect of various polishing methods on the surface roughness in dental ceramics of different structures subjected to repeated firings *Quintessence International* 2010 **41(7)** e125-e131.

30. Flury S, Lussi A, & Zimmerli B (2010) Performance of different polishing techniques for direct CAD/CAM ceramic restorations *Operative Dentistry* **35(4)** 470-481.

31. Whitehead SA, Shearer AC, Watts DC, & Wilson NH (1995) Comparison of methods for measuring surface roughness of ceramic *Journal of Oral Rehabilitation* **22(6)** 421-427.

32. Vichi A, Louca C, Corciolani G, & Ferrari M (2011) Color related to ceramic and zirconia restorations: A review *Dental Materials* **27(1)** 97-108.

33. Ohara N, Koizumi H, Matsumoto Y, Nakayama D, Ogino T, & Matsumura H (2009) Surface roughness and gloss of indirect composites etched with acidulated phosphate fluoride solution *Acta Odontologica Scandinavica* **67(5)** 313-320.

34. Covey DA, Barnes C, Watanabe H, & Johnson WW (2011) Effects of a paste-free prophylaxis polishing cup and various prophylaxis polishing pastes on tooth enamel and restorative materials *General Dentistry* **59(6)** 466-473.

35. Kakaboura A, Fragouli M, Rahiotis C, & Silikas N (2007) Evaluation of surface characteristics of dental composites using profilometry, scanning electron, atomic force microscopy and gloss-meter *Journal of Materials Science: Materials in Medicine* **18(1)** 155-163.

36. O'Brien WJ, Johnston WM, Fanian F, & Lambert S (1984) The surface roughness and gloss of composites *Journal of Dental Research* **63(5)** 685-688.

37. Tholt de Vasconcellos B, Miranda-Júnior WG, Prioli R, Thompson J, & Oda M (2006) Surface roughness in ceramics with different finishing techniques using atomic force microscope and profilometer *Operative Dentistry* **31(4)** 442-449.

38. Lawson NC, Janyavula S, Syklawer S, McLaren EA, & Burgess JO (2014) Wear of enamel opposing zirconia and lithium disilicate after adjustment, polishing and glazing *Journal of Dentistry* **42(12)** 1586-1591.

39. Akar GC, Pekkan G, Çal E, Eskitaşçıoğlu G, & Özcan M (2014) Effects of surface-finishing protocols on the roughness, color change, and translucency of different ceramic systems *Journal of Prosthetic Dentistry* **112(2)** 314-321.

40. Amer R, Kürklü D, & Johnston W (2015) Effect of simulated mastication on the surface roughness of three ceramic systems *Journal of Prosthetic Dentistry* **114(2)** 260-265.

41. Preis V, Weiser F, Handel G, & Rosentritt M (2013) Wear performance of monolithic dental ceramics with different surface treatments *Quintessence International* **44(5)** 393-405.

42. Kawai K, Urano M, & Ebisu S (2000) Effect of surface roughness of porcelain on adhesion of bacteria and their synthesizing glucans *Journal of Prosthetic Dentistry* **83(6)** 664-667.

43. Fraga S, Valandro LF, Bottino MA, & May LG (2015) Hard machining, glaze firing and hydrofluoric acid etching: Do these procedures affect the flexural strength of a leucite glass-ceramic? *Dental Materials* **31(7)** e131-e140.

44. Kelly JR, Nishimura I, & Campbell SD (1996) Ceramics in dentistry: Historical roots and current perspectives *Journal of Prosthetic Dentistry* **75(1)** 18-32.

45. Silva TM, Salvia AC, Carvalho RF, Pagani C, Rocha DM, & Silva EG (2014) Polishing for glass ceramics: Which protocol? *Journal of Prosthodontic Research* **58(3)** 160-170.

46. Al-Wahadni AM, & Martin DM (1999) An *in vitro* investigation into the wear effects of glazed, unglazed and refinished dental porcelain on an opposing material *Journal of Oral Rehabilitation* **26(6)** 538-546.

47. Goharian P, Nemati A, Shabanian M & Afshar A (2010) Properties, crystallization mechanism and microstructure of lithium disilicate glass-ceramic *Journal of Non-Crystalline Solids* **365(4-5)** 208-214.

48. Kou W, Molin M, & Sjögren G (2006) Surface roughness of five different dental ceramic core materials after grinding and polishing *Journal of Oral Rehabilitation* **33(2)** 117-124.

49. Vo DT, Arola D, Romberg E, Driscoll CF, Jabra-Rizk MA, & Masri R (2015) Adherence of *Streptococcus mutans* on lithium disilicate porcelain specimens *Journal of Prosthetic Dentistry* **114(5)** 696-701.

50. Asai T, Kazama R, Fukushima M, & Okiji T (2010) Effect of overglazed and polished surface finishes on the compressive fracture strength of machinable ceramic materials *Dental Materials Journal* **29(6)** 661-667.

51. Addison O, Cao X, Sunnar P, & Fleming GJ (2012) Machining variability impacts on the strength of a "chair-side" CAD-CAM ceramic *Dental Materials* **28(8)** 880-887.

52. Monaco C, Arena A, & Özcan M (2014) Effect of prophylactic polishing pastes on roughness and translucency of lithium disilicate ceramic *International Journal of Periodontics & Restorative Dentistry* **34(1)** e26-e29.

53. Dalkiz M, Sipahi C, & Beydemir B (2009) Effects of six surface treatment methods on the surface roughness of a low-fusing and an ultra low-fusing feldspathic ceramic material *Journal of Prosthodontics* **18(3)** 217-222.

54. Al-Shammery HA, Bubb NL, Youngson CC, Fasbinder DJ, & Wood DJ (2007) The use of confocal microscopy to assess surface roughness of two milled CAD-CAM ceramics following two polishing techniques *Dental Materials* **23(6)** 36-41.

55. Bollen CM, Papaioanno W, Van Eldere J, Schepers E, Quirynen M, & van Steenberghe D (1996) The influence of abutment surface roughness on plaque accumulation

and peri-implant mucositis *Clinical Oral Implants Research* **7(3)** 201-211.

56. Jones CS, Billington RW, & Pearson GJ (2004) The *in vivo* perception of roughness of restorations *British Dental Journal* **196(1)** 42-45.

57. Willems G, Lambrechts P, Braem M, Vuylsteke-Wauters M, & Vanherle G (1991) The surface roughness of enamel-to-enamel contact areas compared with the intrinsic roughness of dental resin composites *Journal of Dental Research* **70(9)** 1299-1305.

58. Barucci-Pfister N, & Göhring TN (2009) Subjective and objective perceptions of specular gloss and surface roughness of esthetic resin composites before and after artificial aging *American Journal of Dentistry* **22(2)** 102-110.

59. Mörmann WH, Stawarczyk B, Ender A, Sener B, Attin T, & Mehl A (2013) Wear characteristics of current aesthetic dental restorative CAD/CAM materials: Two-body wear, gloss retention, roughness and Martens hardness *Journal of the Mechanical Behavior of Biomedical Materials* **20(Apr)** 113-125.

60. Haywood VB, Heymann HO, & Scurria MS (1989) Effects of water, speed, and experimental instrumentation on finishing and polishing porcelain intra-orally *Dental Materials* **5(3)** 185-188.