



The effects of different polishing techniques on the staining resistance of CAD/CAM resin-ceramics

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PURPOSE. The purposes of this study were to evaluate the staining resistance of CAD/CAM resin-ceramics polished with different techniques and to determine the effectiveness of the polishing techniques on resin-ceramics, comparing it with that of a glazed glass-ceramic. **MATERIALS AND METHODS.** Four different CAD/CAM ceramics (feldspathic ceramic: C-CEREC Blocs, (SIRONA) and three resin-ceramics: L-Lava Ultimate, (3M ESPE), E-Enamic, (VITA) and CS-CeraSmart, (GC)) and one light cure composite resin: ME-Clearfil Majesty Esthetic (Kuraray) were used. Only C samples were glazed (gl). Other restorations were divided into four groups according to the polishing technique: nonpolished control group (c), a group polished with light cure liquid polish (Biscover LV BISCO) (bb), a group polished with ceramic polishing kit (Diapol, EVE) (cd), and a group polished with composite polishing kit (Clearfil Twist Dia, Kuraray) (kc). Glazed C samples and the polished samples were further divided into four subgroups and immersed into different solutions: distilled water, tea, coffee, and fermented black carrot juice. Eight samples (8 × 8 × 1 mm) were prepared for each subgroup. According to CIELab system, four color measurements were made: before immersion, immersion after 1 day, after 1 week, and after 1 month. Data were analyzed with repeated measures of ANOVA ($\alpha=.05$). **RESULTS.** The highest staining resistance was found in gl samples. There was no difference among gl, kc and cd ($P>.05$). Staining resistance of gl was significantly higher than that of bb ($P<.05$). Staining resistances of E and CS were significantly higher than those of L and ME ($P<.05$). **CONCLUSION.** Ceramic and composite polishing kits can be used for resin ceramics as a counterpart of glazing procedure used for full ceramic materials. Liquid polish has limited indications for resin ceramics. [J Adv Prosthodont 2016;8:417-22]

KEYWORDS. CAD/CAM; Polishing techniques; Resin-ceramics; Staining resistance

INTRODUCTION

Dental CAD/CAM technology has been on the market for 30 years and has been becoming increasingly popular for

esthetic restorations. This technology was developed to solve some challenges, such as working with high strength materials in one appointment and creating restorations with the best natural appearance, and it integrates dental clinic and dental laboratory in a single center.¹ CAD/CAM blocks, when fabricated under optimal conditions, increases the intrinsic strength of restorations compared with that of laboratory processed restorations.² Ensuring the best natural appearance could be handled by using all-ceramic materials.^{3,4} However, all-ceramic materials may display some disadvantages.⁵ The brittle nature of conventional ceramic materials potentially leads to catastrophic fractures.⁶ This phenomenon directly affects the restoration's lifetime. Reinforced glass ceramics were introduced to the market with higher fracture resistance of ceramic restorations. These materials still do not show satisfying mechanical

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Received February 25, 2016 / Last Revision July 26, 2016 / Accepted October 14, 2016

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properties after fatigue, under cycling loading.⁷ Recently, resin-ceramic hybrid materials were developed for CAD/CAM systems as a substitute for machinable ceramics and they were intended to eliminate the brittle behavior of all-ceramics under loading. The resin-ceramic hybrid materials existing in the market are: a resin-infused hybrid ceramic (Enamic, VITA), a resin nano ceramic (Lava Ultimate, 3M ESPE), and a hybrid nano ceramic (Cerasmart, GC Dental Products). Indeed, these materials have been made of resin and ceramic together and have properties close to each other.

The staining resistance of a restoration is as crucial as the fracture resistance and other mechanical properties.⁸ After a long time, inadequate color stability and staining may create a reason for a clinician to renew the restoration. It has been stated that color stability of a material is effected from these factors: 1) intrinsic factors (*via* aging), 2) extrinsic factors (plaque accumulation and surface staining from diet), and 3) surface degradation and absorption of staining agents.⁹ After material selection, a suitable surface finishing procedure could be used to minimize the effects of extrinsic factors. Ceramic materials could be glazed or polished with pastes, rubbers, and discs containing diamond micro-particles.¹⁰ Rubbers and discs have 2- or 3-step procedure and polishing could be accomplished using pastes.¹¹ Rubbers, discs, and pastes can also be used for polishing composite resins. In addition, there are light cured liquid polishers for composite resins to achieve smoother polished surfaces. All these polishing materials improve surface smoothness,¹² which is desirable for bacterial reduction and shiny appearance.¹³

Glazing is one of the most popular surface finishing procedures for ceramic restorations. It was shown that glazing is the best way for decreasing surface roughness of ceramic materials, compared with mechanical surface polishing systems.¹⁰ Moreover, Motro *et al.*¹⁴ found that glazed ceramic materials have shown less staining than mechanically polished materials. However, it is not possible to glaze the resin-ceramic hybrid materials under heat treatment because of their resin content.¹⁵ For this reason, other surface fin-

ishing procedures gain importance for resin-ceramic hybrid materials to recreate a surface similar to glazed ceramic surface. However, the effects of different finishing procedures applied to CAD/CAM resin-ceramic materials on staining resistance and staining resistance differences between a glazed CAD/CAM ceramic and CAD/CAM resin-ceramic materials finished with other procedures were unclear. Thus, the aim of this study was to evaluate the effect of different polishing procedures on the staining resistance of CAD/CAM resin-ceramic materials immersed into different staining solutions at 1 day, 1 week, and 1 month after polishing. The null hypothesis was that different polishing techniques would not affect the staining resistance of CAD/CAM resin-ceramic materials.

MATERIALS AND METHODS

Four different types of CAD/CAM ceramic blocks and a paste-like composite resin (ME-Clearfil Majesty Esthetic, Kuraray, Tokyo, Japan) were used in this study. The ceramics were a feldspathic ceramic (C-Cerec Blocs, Sirona Dental Systems, Bensheim, Germany) and three resin-ceramics (L-Lava Ultimate, 3M ESPE, St. Paul, MN, USA; E-Enamic, VITA Zahnfabrik, Bad Säckingen, Germany; CS-CeraSmart, GC, Tokyo, Japan) (Table 1). The surfaces of the C sample group were glazed and resin-ceramic samples were divided into four groups according to following polishing materials: Eve Diapol ceramic polishing kit (ed), Bisco Biscover liquid polish (bb), Kuraray Clearfil Twist Dia composite polishing kit (kc), and the control group (c) without any surface treatment. Each of the ceramic groups was then divided into subgroups to be stored in different solutions for staining resistance study: tea (St), turkish coffee (Scf), fermented black carrot juice (Sbc), and distilled water (Sdw). The effects of four different polishing techniques and four different solutions on the color changes of four different ceramic materials and a composite resin material were evaluated. Each of the 24 subgroups consisted of eight specimens ($n = 8$, $N = 192$).

Table 1. Restorative materials

Material	Abbreviation	Manufacturer	Composition
CAD/CAM ceramic block Cerec Blocs, Sirona	C	VITA Zahnfabrik	Feldspathic crystalline particles in glassy matrix
CAD/CAM resin-ceramic Enamic	E	VITA Zahnfabrik	UDMA, TEGDMA, feldspar ceramic enriched with aluminum oxide
CAD/CAM resin-ceramic LAVA Ultimate	L	3M ESPE	Bis-GMA, UDMA, Bis-EMA, TEGDMA, SiO ₂ (20 nm), ZrO ₂ (4 - 11 nm), aggregated ZrO ₂ /SiO ₂ cluster
CAD/CAM resin-ceramic CeraSmart	CS	GC	Bis-MEPP, UDMA, DMA, silica (20 nm), barium glass (300 nm)
Composite Resin Clearfil Majesty Esthetic	ME	Kuraray Noritake Dental	Bis-GMA, Silanated barium glass filler (average: 0.7 μm)

All of the specimens were prepared in A2 shade and cut from CAD/CAM blocks in 1 mm thickness by a low speed diamond saw (Isomet 1000) and the final thicknesses of the specimens were confirmed with a digital caliper for standardization.

The polishing procedures were applied in the following order:

- For Bisco Biscover LV:
 - The ceramic surfaces were etched for 15 seconds. Etching material was then rinsed and removed with air. Then, Bisco biscover LV was applied as a thin layer to the surface. All specimens surfaces were polymerized by a LED (Light-Emitting-Diodes) curing device with a light intensity of 1250 mW/cm for 20 seconds (Elipar S10, 3M ESPE, St. Paul, MN, USA).
- For EVE Diapol:
 - 1st Step: Blue polishing discs, removing and shaping
 - 2nd Step: Pink polishing material, smoothing
 - 3rd Step: Gray polishing material, polishing
- For Kuraray Clearfil Twist Dia:
 - 1st Step: Rubber disc for smoothing
 - 2nd Step: Rubber disc for polishing

In ED and KC groups, sample surfaces were polished for 30 seconds at each step. After the surface treatments, specimens were cleaned for 5 minutes with an ultrasonic bath.

In this study, each of the subgroups was stored in four different solutions that could cause discoloration and followed up after 1 day, 1 week, and 1 month. The specimens immersed in solutions were kept in oven at 37°C. The solutions were used without being diluted. The specimens were stored in opaque plastic containers and enumeration was performed in order to prevent confusion of containers. Solutions were renewed in three-day intervals in order to prevent bacterial contamination.

Measurements of surface discoloration before immersion and after immersion in different time intervals were performed by one researcher three times for each specimen in three different surfaces under the same environmental conditions. Each of the sample surfaces was washed under the running tap water before color measurement and dried with a sterile gauze. Color measurements were made using a white background with spectrophotometer (Shade pilot Degudent Inc., Hanau, Germany).

Color change (ΔE) for each sample was evaluated using the formula below:

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

$$\Delta L = L^*_o - L^*_t$$

$$\Delta a^* = a^*_o - a^*_t$$

$$\Delta b^* = b^*_o - b^*_t$$

L^*_t, a^*_t, b^*_t : Before storage

L^*_o, a^*_o, b^*_o : After storage

The Commission Internationale de l'Eclairage (CIE) measurements make it possible to evaluate the degree of color change based on three coordinates L^* , a^* , and b^* . The L^* value measures the lightness of an object; a^* , a measure of redness (positive) or greenness (negative); and b^* , a

measure of yellowness (positive) or blueness (negative).

The Repeated Measures Analysis of Variance (ANOVA) between the time intervals and one-way ANOVA and Tukey's post hoc tests were performed for statistical analysis using IBM SPSS 20.0 software (SPSS Inc., Chicago, IL, USA).

RESULTS

ΔE values of the ceramics polished with different techniques are presented in Fig. 1 and Table 2.

At all time intervals, the highest staining resistance was acquired with composite polishing kit for all the restorations except for Majesty Esthetic. Also, the control group's ΔE values were higher than those of other polishing techniques.

At all time intervals, the repeated measures of ANOVA results showed that there was no difference among CEREC Bloc samples ($P > .05$). For LAVA Ultimate, there was no difference among composite polishing kit, ceramic polishing kit, and liquid polish ($P > .05$). ΔE values of these three groups were significantly lower than those of the control group ($P < .05$). For CeraSmart, there was no difference between control and liquid polish, and between composite polishing kit and ceramic polishing kit ($P > .05$). ΔE values of control and liquid polish were significantly higher than those of composite polishing kit and ceramic polishing kit ($P < .05$). For Majesty Esthetic, ΔE values of liquid polish were significantly lower than those of other groups except for composite polishing kit. ΔE values of control group were significantly higher than those of other groups ($P < .05$). There was no difference between composite polishing kit and ceramic polishing kit ($P > .05$).

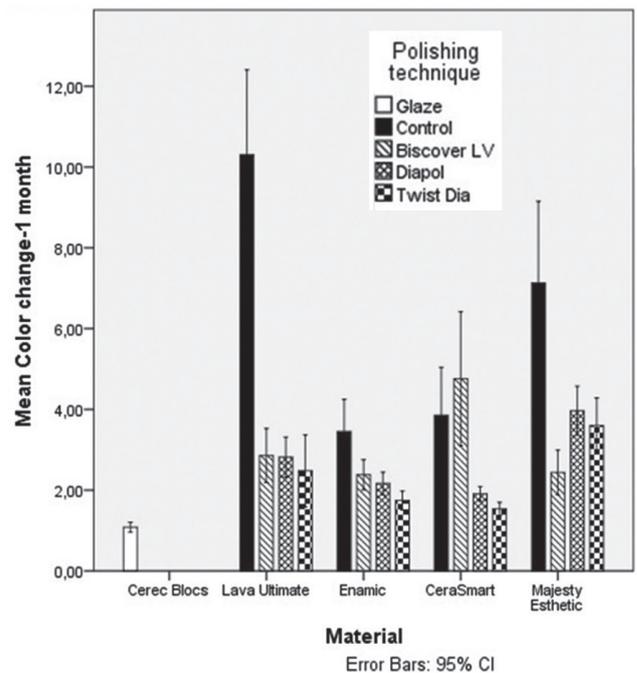


Fig. 1. Color change graph 1 month after the immersion.

Table 2. Color change values 1 month after the immersion

Restorative material	Glaze	Control	Polishing technique		
			Biscover LV	Diapol	Twist Dia
Cerec Blocs	1.08	—	—	—	—
Lava Ultimate	—	10.3	2.86	2.82	2.48
Enamic	—	3.45	2.38	2.17	1.74
CeraSmart	—	3.85	4.76	1.91	1.54
Majesty Esthetic	—	4.93	2.44	3.97	3.6

For Enamic, at all time intervals, ΔE values of the control group were significantly higher than those of composite polishing kit ($P < .05$). There was no difference between composite polishing kit and ceramic polishing kit ($P > .05$). At 1 day after immersion, ΔE values of composite polishing kit and ceramic polishing kit were significantly lower than those of liquid polish. However, there was no significant difference between 1 week after immersion and 1 month after immersion.

For restorative materials, separate one-way ANOVA and Tukey analysis of the mechanically polished samples showed that there was no difference between Enamic and CeraSmart, and between Lava Ultimate and Majesty Esthetic ($P > .05$). The staining resistances of Enamic and CeraSmart were significantly higher than those of Lava Ultimate and Majesty Esthetic ($P < .05$). For polishing kits, the staining resistances of ceramic polishing kit and composite polishing kit were similar with that of glaze ($P > .05$), and significantly higher than those of liquid polish and control groups ($P < .05$).

DISCUSSION

The null hypotheses tested in this study were partially rejected; the stain resistances of the samples polished with composite polishing kit and ceramic polishing kit were significantly higher than those of the samples polished with liquid polish. Also, glazed ceramic samples showed higher stain resistance than the samples finished with liquid polish ($P < .05$), and no difference was found between composite polishing kit and ceramic polishing kit ($P > .05$).

There are varying factors causing color changes in restorations: plaque accumulation, pigmentation effect of staining solutions, dehydration, water absorption, surface roughness, and chemical degradation. In the present study, the efficacy of different polishing techniques against staining was evaluated and compared with that of glaze.

Several studies reported that glaze was superior to other polishing techniques in terms of surface properties and staining resistance.^{14,16-19} Since it is not possible to glaze hybrid resin-ceramics, the main objective of this study was

to evaluate some commercially available materials on their effectiveness with comparison to glaze. Due to mixed compositions of resin-ceramics that are neither pure ceramic nor pure composite resin, there is no conventional polishing material existing in the market. Thus, it is aimed to test effectiveness of a composite polishing kit, a ceramic polishing kit, and a liquid polish. Recently, the staining resistance of resin-ceramics polished with silicon carbide abrasive papers was evaluated in a few studies.²⁰⁻²² However, this technique is not useful in clinical practice. The polishing materials used in this study were applicable to all restoration surfaces and gave immediate results, which gave them real clinical usability.

In this study, staining resistances were evaluated by immersion of samples to solutions that are consumed frequently in daily life. Distilled water was chosen for control. Throughout the study, the samples were immersed in different solutions for 1 month, similar with the study of Ertas *et al.*, which should be equivalent to about 2.5 years of clinical ageing.

Based on the previous studies, ΔE values greater than 3.3 are considered to be clinically unacceptable.²³⁻²⁵ A month after the immersion, unpolished Lava Ultimate and Majesty Esthetic groups showed dramatically higher ΔE values than 3.3. ΔE values were close to 4 in unpolished Enamic and CeraSmart groups. These results could be attributed to water absorption properties of monomers. Monomers may also have absorbed the pigments from the staining solutions. Both Lava Ultimate and Majesty Esthetic contain Bis-GMA, distinct from Enamic and CeraSmart. Water absorption potential of Bis-GMA was shown to be higher than those of UDMA, TEGDMA, and Bis-EMA.^{23,26,27} According to previous studies,^{21,28} ceramic materials exhibited better color stability than composite resins. Also, Acar *et al.*²¹ found that discoloration of Lava Ultimate was more than that of Enamic, which is in agreement with the results of the present study. However, they claimed that the color change of Lava Ultimate was clinically unacceptable, which is different from our results. This may be caused by the polishing techniques (silicon carbide papers 600, 800, 1200 grit) different from those used by the other researchers.

Further, for the results of the unpolished control groups,

the highest staining resistance was found for glazed ceramic group. Also, all of the finishing procedures for Lava Ultimate and Enamic were acceptable. Liquid polish for CeraSmart, and composite polishing kit and ceramic polishing kit for Majesty Esthetic showed higher discoloration than the clinically acceptable value. Unlike CeraSmart, liquid polish performed well with Majesty Esthetic. Also, the highest staining resistance values were obtained with composite polishing kit and ceramic polishing kit for CeraSmart groups. The staining resistance of the control group was better than that of liquid polish for CeraSmart. This may be related to porosities on the surface of the liquid polish caused by insufficient coherence with the underlying ceramic. This can be explained by steric hindrance: The central oxygen atoms, existing in the organic matrix of both liquid polish and CeraSmart, push each other and may affect the molecule's preferred shape. Unlike CeraSmart, dipole-dipole force between central carbon atoms in PMMA (organic matrix of Enamic) and central oxygen atoms in the organic matrix of liquid polish may strengthen the bonding. Further studies with different liquid polish materials are required to better understand the staining resistance of resin-ceramics.

CONCLUSION

In this study, it can be concluded that, polishing is crucial for all materials as dramatical changes were observed between polished and unpolished groups. Ceramic polishing kit and composite polishing kit ensure satisfactory results in resin-ceramics. Liquid polish best performs when used on composite resin. Also, liquid polish may have unsatisfactory results on some resin-ceramics; as unexpected color changes occurred in CeraSmart.

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REFERENCES

- Davidowitz G, Kotick PG. The use of CAD/CAM in dentistry. *Dent Clin North Am* 2011;55:559-70.
- El Zohairy AA, De Gee AJ, Mohsen MM, Feilzer AJ. Microtensile bond strength testing of luting cements to pre-fabricated CAD/CAM ceramic and composite blocks. *Dent Mater* 2003;19:575-83.
- Oh SH, Kim SG. Effect of abutment shade, ceramic thickness, and coping type on the final shade of zirconia all-ceramic restorations: in vitro study of color masking ability. *J Adv Prosthodont* 2015;7:368-74.
- Lee WS, Kim SY, Kim JH, Kim WC, Kim HY. The effect of powder A2/powder A3 mixing ratio on color and translucency parameters of dental porcelain. *J Adv Prosthodont* 2015;7:400-5.
- Attia A, Kern M. Influence of cyclic loading and luting agents on the fracture load of two all-ceramic crown systems. *J Prosthet Dent* 2004;92:551-6.
- Dalpino PH, Francischone CE, Ishikiriama A, Franco EB. Fracture resistance of teeth directly and indirectly restored with composite resin and indirectly restored with ceramic materials. *Am J Dent* 2002;15:389-94.
- El-Damanhoury HM, Haj-Ali RN, Platt JA. Fracture resistance and microleakage of endocrowns utilizing three CAD-CAM blocks. *Oper Dent* 2015;40:201-10.
- Acar O, Yilmaz B, Altintas SH, Chandrasekaran I, Johnston WM. Color stainability of CAD/CAM and nanocomposite resin materials. *J Prosthet Dent* 2016;115:71-5.
- Dietschi D, Campanile G, Holz J, Meyer JM. Comparison of the color stability of ten new-generation composites: an in vitro study. *Dent Mater* 1994;10:353-62.
- Imirzalioglu P, Karacaer O, Yilmaz B, Ozmen Msc I. Color stability of denture acrylic resins and a soft lining material against tea, coffee, and nicotine. *J Prosthodont* 2010;19:118-24.
- Preis V, Grumser K, Schneider-Feyrer S, Behr M, Rosentritt M. The effectiveness of polishing kits: influence on surface roughness of zirconia. *Int J Prosthodont* 2015;28:149-51.
- Steiner R, Beier US, Heiss-Kisielewsky I, Engelmeier R, Dumfahrt H, Dhima M. Adjusting dental ceramics: An in vitro evaluation of the ability of various ceramic polishing kits to mimic glazed dental ceramic surface. *J Prosthet Dent* 2015;113:616-22.
- Sarikaya I, Güler AU. Effects of different polishing techniques on the surface roughness of dental porcelains. *J Appl Oral Sci* 2010;18:10-6.
- Motro PF, Kursoglu P, Kazazoglu E. Effects of different surface treatments on stainability of ceramics. *J Prosthet Dent* 2012;108:231-7.
- Fasbinder DJ, Neiva GF. Surface evaluation of polishing techniques for new resilient CAD/CAM restorative materials. *J Esthet Restor Dent* 2016;28:56-66.
- Raimondo RL Jr, Richardson JT, Wiedner B. Polished versus autoglazed dental porcelain. *J Prosthet Dent* 1990;64:553-7.
- Fuzzi M, Zaccheroni Z, Vallania G. Scanning electron microscopy and profilometer evaluation of glazed and polished dental porcelain. *Int J Prosthodont* 1996;9:452-8.
- Yilmaz C, Korkmaz T, Demirköprülü H, Ergün G, Ozkan Y. Color stability of glazed and polished dental porcelains. *J Prosthodont* 2008;17:20-4.
- Esquivel JF, Chai J, Wozniak WT. Color stability of low-fusing porcelains for titanium. *Int J Prosthodont* 1995;8:479-85.
- Lawson NC, Burgess JO. Gloss and stain resistance of ceramic-polymer CAD/CAM restorative blocks. *J Esthet Restor Dent* 2016;28:S40-5.
- Acar O, Yilmaz B, Altintas SH, Chandrasekaran I, Johnston WM. Color stainability of CAD/CAM and nanocomposite resin materials. *J Prosthet Dent* 2016;115:71-5.
- Stawarczyk B, Liebermann A, Eichberger M, Güth JF. Evaluation of mechanical and optical behavior of current esthetic dental restorative CAD/CAM composites. *J Mech Behav Biomed Mater* 2015;55:1-11.
- Stawarczyk B, Sener B, Trottmann A, Roos M, Ozcan M, Hämmerle CH. Discoloration of manually fabricated resins and industrially fabricated CAD/CAM blocks versus glass-ce-

- ramic: effect of storage media, duration, and subsequent polishing. *Dent Mater J* 2012;31:377-83.
24. Robinson FG, Haywood VB, Myers M. Effect of 10 percent carbamide peroxide on color of provisional restoration materials. *J Am Dent Assoc* 1997;128:727-31.
 25. Patel SB, Gordan VV, Barrett AA, Shen C. The effect of surface finishing and storage solutions on the color stability of resin-based composites. *J Am Dent Assoc* 2004;135:587-94.
 26. Gajewski VE, Pfeifer CS, Fróes-Salgado NR, Boaro LC, Braga RR. Monomers used in resin composites: degree of conversion, mechanical properties and water sorption/solubility. *Braz Dent J* 2012;23:508-14.
 27. Khokhar ZA, Razzoog ME, Yaman P. Color stability of restorative resins. *Quintessence Int* 1991;22:733-7.
 28. Gawriolek M, Sikorska E, Ferreira LF, Costa AI, Khmelinskii I, Krawczyk A, Sikorski M, Koczorowski PR. Color and luminance stability of selected dental materials in vitro. *J Prosthodont* 2012;21:112-22.