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Color Stability of Glazed and Polished Dental Porcelains

Caner Yılmaz, DDS, PhD,[1] Turan Korkmaz, DDS, PhD,[1] Hişam Demirköprülü, DDS, PhD,[1] Gülfem Ergün, DDS, PhD,[2] & Yalçın Özkan, DDS, PhD[3]

[1] Associate Professor, Department of Prosthodontics, Faculty of Dentistry, Gazi University, Ankara, Turkey
[2] Department of Prosthodontics, Faculty of Dentistry, Gazi University, Ankara, Turkey
[3] Assistant Professor, Department of Pharmaceutical Technology, Gülhane Military Medical Academy, Ankara, Turkey

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Correspondence
Caner Yilmaz, 70 sokak 21/ 7, Emek/Ankara 06510, Turkey. E-mail: cyilmaz@gazi.edu.tr

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Abstract

Purpose: The purpose of this study was to compare the visual and colorimetric color stability of two ultra low-fusing and three conventional low-fusing porcelains on both glazed and polished surfaces.
Materials and Methods: Twelve disks, 10 mm in diameter and 3 mm in thickness, were fabricated for each porcelain. Specimens were glazed using their specific glaze materials. For each type of porcelain, the specimens were divided into two groups: one group was immersed in methylene blue and the other group in distilled water as a control. The surfaces were visually examined for staining without magnification. Objective color measurement was performed for each sample using a Tristimulus colorimeter. After examining the color of the glazed specimens, glazed layers were removed from the surface of the specimens to simulate an intraoral environment. Then, porcelain polishing points and diamond polishing paste were applied. The samples were immersed again in methylene blue and distilled water, and after removing from the staining solution and distilled water, visual and objective measurements were performed again.
Results: Visually discernible stain was present on the polished groups of all five porcelains immersed in methylene blue, whereas the glazed group immersed in methylene blue showed no staining. No staining was observed with glazed and polished samples immersed in distilled water. The objective evaluation showed that the polished porcelain surface of all five porcelain products had statistically significant color deviation than the glazed surface in the same group after immersion in methylene blue. The results of this study show a statistically significant difference in color stability between the polished and glazed specimens.
Conclusion: It may be concluded that the glazed specimens showed a better color stability, although the staining observed in the polished specimens was not clinically noticeable.

New esthetic restorative materials are regularly introduced, yet porcelain remains the material of choice for most dentists. The selection of porcelain restorations is based on biocompatibility, strength, surface texture, and esthetic capability.[1,2]

The demand for highly biocompatible restorative materials has led to the recent development of ultra low-fusing porcelain. Ultra low-fusing porcelains can be fired at lower temperatures ($<850^{\circ}C$) than conventional porcelains (850 to $1100^{\circ}C$).[3]

Porcelain surfaces are smooth, and a final surface finish is achieved by glazing. Nevertheless, an occlusal adjustment is sometimes needed when the adaptation of the restoration is not perfect. In such a case, refinishing of the adjusted porcelain surfaces is performed intraorally.[4] Intraoral porcelain polishing is an important consideration in many restorative and esthetic procedures. While it is generally agreed that glazed porcelain provides the optimum surface finish, there are a number of clinical situations where some chairside adjustment is necessary, and it is impractical to reglaze the restoration. Various techniques have been described for refinishing porcelain surfaces in the mouth.[5,6]

Resistance to staining is considered an important clinical criterion in the evaluation of a new porcelain. A method of subjective evaluation is included in American Dental Association (ADA) specification No. 69 for all-ceramic restorations.[7] Visual evaluation is used in this method. Although this method is simple, errors may occur due to personal differences in color perception.[8]

The purpose of this study was to visually and colorimetrically compare the color stability of five types of feldspathic porcelains with both glazed and polished surfaces.

Materials and methods

Two ultra low-fusing porcelains and three conventional low-fusing porcelains were used for this study (Table 1). All specimens were prepared by the same operator to maintain standardization. Twelve disks, 10 mm in diameter and 3 mm in thickness, in shade A3 were fabricated for each porcelain. Porcelain specimens were prepared using a round split mold. Modeling fluid specific to each porcelain was used according to each manufacturer's instructions. The mold was vibrated to eliminate air bubbles, and excess moisture was removed. All specimens were fired in one furnace (Programmat P 90, Ivoclar, Schaan, Liechtenstein). The porcelain was fired once, according to the manufacturer's recommendations. The specimens were then glazed using the specific glaze medium for each.

For each type of porcelain, the specimens were divided into two groups. Six specimens were immersed for 24 hours in a saturated solution of methylene blue in ethanol [ethanol 95%(V/V)]. These samples were removed from the staining solution after 24 hours and cleaned with methylated spirit in an ultrasonic cleaner for 15 seconds. The other glazed samples were immersed in distilled water for 24 hours as control. The outer surfaces of all specimens were visually examined without magnification for staining. These procedures were based on ADA specification No. 69 (ANSI/ADA, 1991). Objective color measurement was performed by the same operator for each sample using a Gardner XL 20 Tristimulus colorimeter (Gardner Lab, Inc., Bethesda, MD) with a 10 mm head.

Values were recorded in accordance with the Commision Internationale de l'Eclairage $L^*a^*b^*$ (CIELAB) system. This system represents a 3D space having components of lightness (L), red-green (a), and yellow-blue (b). Color deviation (ΔE^*_{ab}) was calculated from the mean ΔL^*, Δa^*, and Δb^* values for each specimen using Hunter's equation:

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

After examining the color stability of the glazed specimens, the glazed layers were removed from the surface of the specimens using a 40-μm diamond bur (837L016 red ring, Edenta AG, Hauptstrasse, Switzerland) to simulate an intraoral adjustment. Then, porcelain polishing points (Cerapol gray-white at a speed of 20,000 rpm; Cerapol pink at a speed of 10,000 rpm; Cerapol plus at a speed of 5000 rpm; Edenta AG) and diamond polishing paste (Vita Karat diamond polishing set, VITA Zahnfabrik) were applied consecutively. The samples were immersed again in methylene blue or distilled water for 24 hours, as appropriate. After removing the samples from the staining solution and distilled water, visual and objective measurements were performed again.

To relate the amount of color change (ΔE) recorded by the colorimeter to a clinical environment, the data were converted to National Bureau of Standards (NBS) units.[9] NBS critical remarks of color difference are used for color comparison and quality control functions, because only the allowable ΔE^*_{ab} needs specification rather than a range of allowed L^*, a^*, and b^* values. It is possible to determine what an observer might report regarding the color change that occurs with the porcelains using these values. With NBS units, ΔE values can be described through the equation, NBS units $= \Delta E^*_{ab} \times 0.92$.

A one-way ANOVA with a Neuman–Keuls multiple comparison test was used to evaluate the glazed and polished specimens immersed in the methylene blue. For the identification of differences between the groups (glazed and polished), a two-way ANOVA test was used.

Results

Visual examination

The polished groups showed slight staining for all five porcelains studied, whereas the glazed group showed no staining when immersed in methylene blue. In the control group no staining was observed with glazed and polished samples immersed in distilled water.

Colorimetric examination

The mean $\Delta E_{ab}{}^*$ values along with the standard deviation and standard error of each porcelain are shown in Table 2. Figure 1 shows mean color differences for both glazed and polished samples in methylene blue and distilled water. When variations in the color changes of glazed specimens were compared with each other (by using one-way ANOVA and Neuman–Keuls post hoc test, $p < 0.01$), the result of specimen D ($\Delta E*_{ab} = 0.2051$, $p < 0.05$) was significantly different from the results of specimens B and E. Specimen E revealed statistically significant difference ($\Delta E_{ab} = 0.2663$, $p < 0.01$) from specimens A, B, C, and D. When comparing the control group with the glazed specimens immersed in methylene blue, A, B, C, D, and E showed various degrees of staining, which were found to be significantly different.

Table 1 Tested materials

Trade name	Code	Type	Dentin firing temperature (°C)	Glaze firing temperature (°C)	Manufacturer
Ceramco II	A	Conventional low-fusing	918	920	Ceramco, Inc., Center Conway, NH
Ceramco II low-fusing	B	Conventional low-fusing	865	870	Ceramco, Inc.
Finesse	C	Ultra low-fusing	760	755	Ceramco, Inc.
Microbond 700	D	Ultra low-fusing	710	680	Austenal, Inc., York, PA
Vita Omega	E	Conventional low-fusing	920	900	VITA Zahnfabrik, Bad Sackingen, Germany

Table 2 ΔE^*_{ab} Color differences for all tested materials

ΔE^*_{ab}	A	B	C	D	E
Glazed specimens	0.1413	0.1040	0.1677	0.2051*	0.2663**
SD	4.51×10^{-2}	5.49×10^{-2}	4.76×10^{-2}	3.92×10^{-2}	5.40×10^{-2}
SE	1.84×10^{-2}	2.24×10^{-2}	1.94×10^{-2}	1.60×10^{-2}	2.21×10^{-2}
Glazed control	0.0241	0.0133	0.0128	0.0211	0.0174
SD	3.29×10^{-2}	2.12×10^{-2}	3.33×10^{-2}	2.75×10^{-2}	3.88×10^{-2}
SE	1.28×10^{-2}	1.33×10^{-2}	1.82×10^{-2}	1.66×10^{-2}	1.71×10^{-2}
Polished specimens	0.6947**	0.6015**	0.5373**	0.5374**	0.4813**
SD	5.25×10^{-2}	4.30×10^{-2}	4.01×10^{-2}	3.87×10^{-2}	4.46×10^{-2}
SE	2.14×10^{-2}	1.76×10^{-2}	1.64×10^{-2}	1.58×10^{-2}	1.82×10^{-2}
Polished control	0.0333	0.0833	0.0166	0.0666	0.0500
SD	5.16×10^{-2}	4.08×10^{-2}	4.06×10^{-2}	5.28×10^{-2}	5.48×10^{-2}
SE	2.11×10^{-2}	1.66×10^{-2}	1.67×10^{-2}	2.60×10^{-2}	2.23×10^{-2}

SD = standard deviation; SE = standard error.
*Significant difference $p < 0.05$.
**Significant difference $p < 0.01$.

Among polished specimens immersed in methylene blue, specimens C, D, and E showed different results from A ($\Delta E_{ab} = 0.6947$, $p < 0.01$); and B ($\Delta E_{ab} = 0.6015$, $p < 0.01$) showed a difference from A, E, C, and D with both results being statistically significant. The control group was found to be statistically significantly different from the glazed specimens that were immersed in methylene blue ($p < 0.01$).

Comparing the glazed and polished specimens (which were both immersed in methylene blue), there was a significant difference between A, B, C, D, and E ($F = 7.56$, $p < 0.01$). Another significantly different result was found when the two techniques, glazing and polishing, were compared ($F = 3.83$, $p < 0.01$).

Among the glazed specimens immersed in the methylene blue, specimen E showed higher staining compared with the others. Among the polished specimens, specimen A showed the highest staining, and specimen E showed the least staining in the methylene blue. When the color stability of polished and glazed specimens in the methylene blue were compared and evaluated, the glazed specimens revealed better results. Critical remarks of color differences as expressed in NBS units are shown in Table 3. The data for color change of tested materials to NBS units are presented in Table 4.

With the glazed specimens, trace staining was noticed. In the evaluation of the polished specimens, specimens A and B demonstrated slight staining while C, D, and E demonstrated trace staining. These results did not lead to a clinically noticeable color change.

Discussion

Today, there are many all-ceramic systems available, but the metal ceramic-based porcelains continue to be the most commonly used restorations when both esthetics and strength are considered.[1] Two of the main requirements for a successful porcelain–metal restoration are good porcelain–metal bond and color stability.[3]

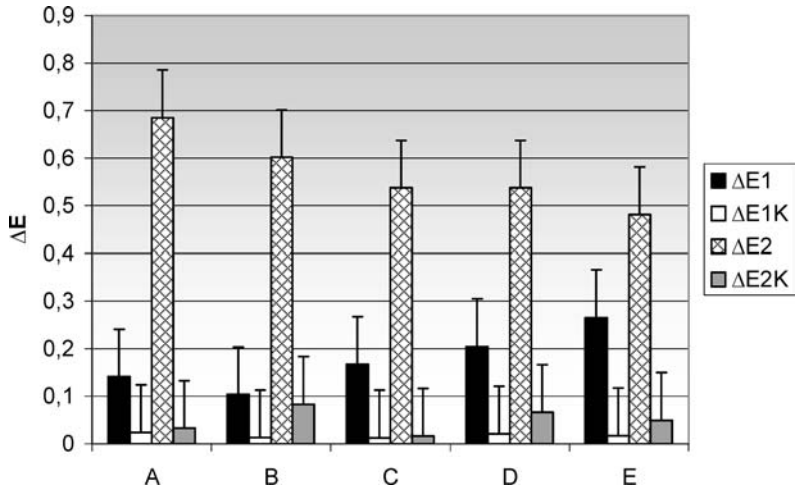

Figure 1 Mean color differences (ΔE^*_{ab}) for both glazed (ΔE1) and polished (ΔE2) samples in methylene blue and distilled water (ΔE1K, ΔE2K).

Table 3 NBS Critical remarks of color differences

Critical remarks of color differences	NBS unit
Trace	0–0.5
Slight	0.5–1.5
Noticeable	1.5–3.0
Appreciable	3.0–6.0
Much	6.0–12.0
Very much	12.0+

In general, the experienced clinician has learned to compensate for some of the disadvantages of porcelain. Unfortunately, low fracture resistance, potential for abrading occlusal structures, and difficulty in resurfacing and polishing the glazed surface continue to be the biggest problems associated with this material. Proper finishing and polishing of dental restorations are important in enhancing both the esthetics and longevity of restored teeth. Residual surface roughness, associated with improper finishing and polishing of dental restorations, can result in a number of clinical difficulties for both the dentist and the patient. These problems include excessive plaque accumulation, gingival irritation, increased surface staining, and poor or suboptimal esthetics of the restored teeth.

There have been many recommended techniques to decrease surface roughness, including auto glazing, super glazing, and polishing.[1]

Intraoral adjustments of the porcelain disrupt the glaze, resulting in a rougher surface and inferior surface properties. Various methods are available to disrupt the porcelain surface, but there has been no agreement on any superior method. A wide variety of finishing and polishing devices are available to the clinician. In general, the method used for polishing intraoral porcelain includes: (1) finishing diamonds, (2) rubber polishing instruments, and (3) diamond polishing paste. In the present study, the same method was used.

A number of studies have shown that the glazed porcelain provides a smooth and dense surface, and many have shown that a polishing sequence can produce an equally smooth surface, which may be esthetically better.[10] It has been stated that diamond polishing pastes alone are not sufficient to restore a glazed surface.[5,11] Other research reported that on the basis of visual examination, two polishing pastes were found to produce a surface equal to or better than oven glazing, while on the basis of the scanning electron microscopic (SEM) examination, oven glazing was found to produce the better surface.[12] Other studies have reported no significant differences between polished and glazed surfaces.[13–15] Fuzzi et al[16] stated that the oven glazing produces the best surface smoothness compared with other polishing methods under SEM examination.

Table 4 Color change of tested materials according to NBS units

	Glazed ΔE^*_{ab}	NBS	Polished ΔE^*_{ab}	NBS
A	0.1413	0.1299	0.6947	0.6391
B	0.1040	0.0956	0.6015	0.5533
C	0.1677	0.1542	0.5373	0.4943
D	0.2051	0.1886	0.5374	0.4944
E	0.2663	0.2449	0.4813	0.4427

NBS units = $1\,E_{ab} \times 0.92$.

Physical grain size and crystal size play an important part in surface topography. Not all materials can be made smooth. Even microscopic smoothness camouflages roughness at the atomic level.[1]

Conventional low-fusing porcelains are described as large grain porcelains and are also comparatively high in leucite content, whereas ultra low-fusing porcelains are composed of fine leucite crystals dispersed in a glass matrix. For that reason, manufacturers state that the polishing properties of these porcelains are much better than the conventional low-fusing porcelains.

Aggressive condensation of fine porcelain buildups is not recommended as it is with more conventional porcelains. It has been reported that these fine grain porcelains tend to exhibit more surface pitting from air entrapment or evacuated water than conventional porcelain, although all porcelains were fired under vacuum. It has also been stated that traditional condensation techniques need to be altered when dealing with these finer grain porcelains.[1] Smaller sizes tend to trap water during fabrication, so an increase in drying time is required. For the porcelains used in this study, manufacturers do not state a special condensation technique. The traditional condensation technique was used to prepare samples for the current research. This situation may have caused the indifferent results between the ultra low-fusing and conventional porcelains. Different condensation methods for ultra low-fusing porcelains may be an aim of future investigations.

Esquivel et al evaluated color stability of low-fusing porcelains for use with titanium, following the visual protocol described in ADA specification No. 69 and also using a colorimeter.[8] In the present study, the same two evaluation methods were performed.

Although colorimetry permits the quantitative assessment of color deviation, the value of color deviation (ΔE) that is within clinically acceptable limits has not yet been established. Goldstein and Schmitt[17] proposed that a ΔE value of greater than 0.4 is already detectable to the highly trained human eye. O'Brien et al[18] classified different values of ΔE, with 1 being excellent, 2 as clinically acceptable, and 3.7 as a poor match based upon clinical observations. The ADA established a ΔE value of 2 as the tolerance for shade guides.[8]

ΔE values obtained from both the glazed and the polished specimens in the present study were found to be lower than the ΔE values stated by the ADA and in O'Brien et al's study.[18]

Razzoog et al[2] stated that it would be clinically appropriate to compare ΔE values with standards of NBS Units.

NBS critical remarks of color difference are used for color comparison and quality control functions, because only the allowable ΔE^*_{ab} needs specification, rather than a range of allowed L^*, a^*, and b^* values. With the use of these values, it is possible to determine what an observer might report regarding the color change that occurs with porcelains. In the current study, given the NBS criteria, a "trace" staining was found in glazed samples while "slight" and "trace" staining were noticed in polished specimens. Using ΔE values and ADA criteria, the staining observed in all specimens was not clinically noticeable.

Conclusion

The results of our study showed a statistically significant difference in color stability among the polished and glazed specimens. It may be concluded that the glazed specimens showed a better color stability. On the other hand, the staining observed in the polished specimens was not clinically noticeable.

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