International Journal of Chemical and Biochemical Sciences
(ISSN 2226-9614)

Journal Home page: www.iscientific.org/Journal.html

Evaluation of the colour stability of different ceramic materials with two thicknesses

[1]Ahmad Khaled Aboelfadl, [1]Kamal Khaled Ebeid,
[2]Shahad Faris Mahdi ALrubaie

[1]Faculty of Dentistry, Ain Shams University, Egypt

[2]Dental operator at altabib clinics, Faculty of Dentistry Future University, Egypt

Abstract

Society places a great emphasis on aesthetics, & there is a constant rise in the demands placed on dental restorations' aesthetics. The aim of this in-vitro research was to study the impact of the finishing protocol on the color stability parameter of different glass-ceramic materials with two different thicknesses, before & after thermocyling. One hundred twelve specimens had been prepared with standard dimensions of one mm & two mm thickness & ten mm diameter for the four different glass-ceramic materials. The ceramic specimens had been separated into 4groups according to ceramic material (n=28): IPS e.max Press, CeraMotion, Rosetta SP & CeltraPress, each group had been subdivided into two sub-groups according to the specimen thickness (n=14): 1 mm and 2 mm. Each sub-group was further split into 2 divisions according to the finishing protocol (n=7): glazed only & polished then glazed. The results of our study all samples have shown color change within visually perceptible but clinically acceptable level (more than 1 and less than 3.7), emax glazed samples (1mm&2mm) together with emax glazed and polished samples (1mm) have shown significantly higher ΔE beyond the clinically acceptable level. Increasing ceramic thickness from 1 mm to 2 mm has shown better color stability in Emax group. Polishing before glazing increased color stability in Emax while decreased it in Celtra.

Keywords: Color change, Ceramic materials, Color stability.

Full length article **Corresponding Author*, e-mail: shahad_faris@yahoo.com Doi # https://doi.org/10.62877/24-IJCBS-24-25-19-24

1. Introduction

The expectations & demands for the aesthetics of dental restorations are always rising, as is the great value placed on an attractive smile in society. For this reason, accurate color matching based on neighbouring teeth is an extremely difficult yet crucial duty for the dentist or dental technician [**1**]. All-ceramic restorations are usually chosen in dental treatments because of its aesthetic qualities, biocompatibility, & wear resistance. This is especially true for procedures where maintaining the appearance of real teeth is crucial. In addition to the ceramic's technical & aesthetic qualities, colour stability is crucial for the success & durability of the restorations [**2**]. For ceramic restorations, especially monolithic restorations, to be successful over the long term, optical qualities such as colour & translucency are just as important as mechanical ones [**3, 4**]. Oral cavity restorations are susceptible to color changes due to a variety of circumstances, including temperature, humidity, food consumption, & smoking behaviors [**5**]. Restorative materials are exposed to a variety of different liquids, temperature changes, load stress, & tooth brushing in the oral environment. The aesthetic aspect of a restoration is just as important to its success as its mechanical & physical characteristics [**6**]. The goal of this in-vitro research was to study the impact of the finishing protocol on the color stability parameter of different glass-ceramic materials with 2 different thicknesses, before & after thermocyling.

2. Materials and Methods

One hundred twelve specimens had been prepared with standard dimensions of one mm & two mm thickness & ten mm diameter for the four different glass-ceramic materials. The ceramic specimens had been separated into 4groups according to ceramic material (n=28): IPS e.max Press, CeraMotion, Rosetta SP & CeltraPress, each group had been subdivided into 2sub-groups according to the specimen thickness (n=14): 1 mm and 2 mm. Each sub-group was further split into 2 divisions according to the finishing protocol (n=7): glazed only & polished then glazed. Using digital software according to these dimensions, 3D virtual design was constructed then 3D-printed castable resin specimens had been fabricated followed by spruing, investing & pressing. Each material was pressed and finished according to its protocol and then color stability was measured for all the specimens before & after aging by thermocycling in a coffee solution.

2.1. Materials

The materials, brand name, manufacturer and composition

2.2. Methods

112 specimens of pressable glass-ceramics were fabricated and split into four main groups according to the type of ceramic material (n= 28): **Group A:** Lithium disilicate glass-ceramic (IPS e.max press by Ivoclar Vivadent). **Group B:** Lithium disilicate glass-ceramic (CeraMotion LiSi press by Dentaurum). **Group C:** Lithium disilicate glass-ceramic (Rosetta SP by HASS Corporation). **Group D:** Zirconia reinforced lithium silicate (ZLS) (Celtra press by Dentsply). Each group had been split into 2sub-groups according to the thickness of the specimen (n = 14).

Subgroup I: 1 mm thickness.
Subgroup II: 2 mm thickness.

Each subgroup had been split into 2 divisions according to finishing procedures (n = 7).

Division 1: glazed only.
Division 2: polished and glazed.

2.3. Sample preparation

2.3.1. Designing of specimen

A digital 3D builder software[1] technology had been employed to precisely create specimens with a diameter of ten mm & thicknesses of one & two mm, with necessary shape chosen using (insert object tool). After making changes, the design had been saved as STL file.

2.3.2. Fabrication of castable resin discs

3D building programme produced an STL file, which had been exported to a 3D printer.[2] to fabricate the specimens using castable resin[3]. Utilising a wash & cure equipment, the 3D printed specimens had been cleaned & preserved[3], for six minutes. All specimens' dimensions had been checked using digital caliber.

2.3.3. Fabrication of ceramic discs

For every ceramic material, each castable resin disc had been sprued, invested, & pressed in accordance with manufacturer's specifications. A 2.5–3.5 mm diameter sprue had been fastened to the resin disc's edge before being fastened to the 100 g ring. Investment material was poured into each ring[4] Utilising a vacuum mixer for nine minutes & letting it settle for twelve minutes, as directed by the maker. Following the removal of the ring former, the investment had been turned upside down & heated to 850°C for 45 minutes in a burnout furnace. This allowed gases to exit the investment without leaving any residue behind (fig 3).

2.3.4. Heat pressing & Devesting

Pressing & firing had been then carried out in Programat ep3010 furnace[5] according to each manufacturer. With a starting temperature of 700°C, a heating rate of 45°C/min, holding time of thirty minutes, & a pressing period of three minutes at pressure of 2.7bar, plunger size, & an appropriate programme were chosen. The plunger had been used to find out where to cut the investment once it cooled. After carefully dissecting the investment, the discs had been extracted by airborne particle abrasion (50µm Al2O3 at 1 bar, 30 PSI) (11).

2.4. Finishing protocols

2.4.1. Glazing

Following the devestment of every specimen, sprues had been eliminated & the specimens had been glazed in accordance with each material figure's manufacturer's directions (3). Only 1 surface of half the examples had a transparent glaze applied to it; the other surface remained unglazed. utilizing a digital calibre to verify that there have been no dimensional alterations by measuring each specimen after glazing (fig 4).

2.4.2. Polishing

On the other half of the specimens, a straight handpiece with a low speed that had been attached to an adaptor had been used for polishing (fig 5). Diapro rubber polishing cups were used for the polishing procedure [6] Using 2 types of grits—medium & fine—for forty seconds per grit.

2.5. Tests and Measurements

2.5.1. Color stability

All samples (n = 112) were measured for color stability on a grey background using a VITA easyshade spectrophotometer device. In accordance with the manufacturer's instructions, each specimen had been measured three times independently on glazed surface, with device's tip touching specimen each time. This procedure was repeated after thermocycling. Following the tabulation of L, a, & b coordinates, the mean for each distinct coordinate had been determined. Every ten measurement cycles, the VITA simple shade gadget had been calibrated again. In dental research, colour formulas are used to quantitatively represent the variations in colour among 2 things. CIE L*a*b* system, which approximates consistent distances among colour coordinates, is the source of the most often used ΔE formula; ΔE*= [(ΔL*)2+ (Δa*)2 + (Δb*)2]1/2 **[15].**

2.5.2. Thermocycling

Aging of all the specimens was done through 5000 cycles of thermocycling in a coffee solution. According to manufacturer's instructions, coffee solution had been prepared by mixing 1round tablespoon of coffee[7] with 177 mL of boiled tap water. The coffee was left for 5 minutes

[1] ExoCAD, Darmstadt, Hessen, Germany
[2] 3D printer, ANYCUBIC, Shenzhen Anycubic Technology Co., Ltd, China
[3] Savoy Castable LCD Green, MAKTech 3d
[4] Bellavest SH, BEGO Bremer Goldschlägerei Wilh, Germany
[5] Ivoclar Vivadent, Schaan, Liechtenstein
[6] EVE Ernst Vetter GmbH, Pforzheim, Germany
[7] Nescafe Classic, Nestle, Cairo, Egypt

before filling up the plastic containers. **159**(65) Then, the samples were thermocycled for 5000 cycles[8] in the coffee solution at 5 °C/55 °C with dwell time of thirty second & bath transfer time of ten second (fig 6). **160** The coffee solution was replaced for all samples with a freshly prepared coffee solution every 24 hours in the hot & cold baths. Coffee remnants had been eliminated from the specimen surfaces after 5000total hot & cold cycles by washing under running water followed by washing using distilled water then dried with sterile gauze prior to measurements color stability was then measured again by VITA Easy shade (fig 7).

2.6. Statistical analysis

By examining the distribution of the data & applying normalcy tests (Kolmogorov-Smirnov & Shapiro-Wilk tests), numerical data had been examined for normality. The distribution of colour change (ΔE) data was non-normal, or non-parametric. The 4 ceramic kinds were compared using the Kruskal-Walli's test. When the Kruskal-Walli's test is significant, pairwise comparisons had been performed using Dunn's post-hoc test. The 2 thicknesses and the 2 finishing methods had been compared using the Mann-Whitney U test. A significant threshold of $P < 0.05$ had been established. With IBM SPSS Statistics for Windows, Version 23.0, statistical analysis was carried out. NY / Armonk: IBM Corp.

3. Results

With glazing & ceramic thicknesses 1 mm as well as 2 mm, between ceramic kinds, there had been a statistically significant difference (P-value = 0.006, Effect size = 0.777) & (P-value = 0.001, Effect size = 0.994). Comparing ceramic kinds pairwise, it was found that e.max exhibited the biggest colour change that was statistically significant. All three Celtra, ceraMotion, & Rosetta demonstrated statistically significantly decreased ΔE values; there had been no statistically significant difference among them. With glazing and polishing, ceramic thicknesses 1 mm, among ceramic kinds, there had been a statistically significant difference (P-value = 0.008, Effect size = 0.668). Comparing ceramic kinds pairwise, it was found that e.max exhibited the biggest colour change that had been statistically significant. All three Celtra, ceraMotion, & Rosetta demonstrated statistically significantly decreased ΔE values; there had been no statistically significant difference among them. There was a statistically significant difference among the ceramic kinds with a thickness of 2 mm (P-value = 0.005, Effect size = 0.742). With e.max and ceramic thickness 1 mm, there had been no statistically significant difference among the 2 finishing techniques (P-value = 0.142, Effect size = 0.199). While with 2mm thickness, glazing explained statistically significantly higher ΔE than glazing and polishing (P-value = 0.009, Effect size = 2.928). With Celtra and ceramic thickness 1 mm, there had been no statistically significant difference among the 2 finishing techniques (P-value = 0.347, Effect size = 0.623) (table 1). While with 2mm thickness, glazing explained statistically significantly lower ΔE than glazing and polishing (P-value = 0.009, Effect size = 2.928). With ceraMotion and ceramic thickness 1 mm, glazing indicated statistically significantly higher ΔE than glazing and polishing (P-value = 0.016, Effect size = 2.336). While with 2 mm thickness, there had been no statistically significant difference among the 2 finishing techniques (P-value = 0.117, Effect size = 1.141) (table 2).

With Rosetta and ceramic thicknesses 1 mm as well as 2 mm, there had been no statistically significant difference among the 2 finishing techniques (P-value = 0.347, Effect size = 0.623) & (P-value = 0.142, Effect size = 1.043), respectively (table 3). With e.max and glazing, there had been no statistically significant difference among the 2 thicknesses. While with glazing and polishing, 1 mm thickness explained statistically significantly higher ΔE than 2mm thickness. With Celtra and glazing, there had been no statistically significant difference among the 2 thicknesses. While with glazing and polishing, 1mm thickness showed statistically significantly lower ΔE than 2mm thickness. With ceraMotion, glazing as well as glazing & polishing, there had been no statistically significant difference among 2 thicknesses for each finishing technique, respectively. With Rosetta, glazing as well as glazing & polishing, there had been no statistically significant difference among 2 thicknesses.

4. Discussion

In contrast to metal ceramic restorations, all ceramic restorations are recognised as a significant therapeutic choice in fixed prosthodontics. Their observed strength & enhanced aesthetic qualities may be the reason for this. Consequently, the restorations utilised in the anterior & posterior regions are made using a wide variety of ceramic materials. The pressable ceramic materials had been suggested to have higher mechanical properties when compared to the CAD-CAM fabricated ones [**7**]. Thus, the main goal of our research had been to evaluate the color stability of different pressable ceramic material. Thus, in this research four glass ceramic materials were selected for comparative evaluation regarding the impact of thickness & finishing protocol on the color stability of these ceramic materials. Specifically, zirconia-reinforced lithium silicate (ZLS) (Celtra LiSi press by Dentsply) & lithium disilicate glass-ceramic (IPS e.max press, ceraMotion, Rosetta SP) both prior to & following thermocycling in a staining solution. In our study, ceramic discs were designed using 3D builder software for standardization of dimension of ten mm diameter with 1mm & 2mm thickness [**8**]. Castable resin discs were fabricated using a 3D printer in order to get all samples of exact dimensions through a standard digital workflow. After fabrication of all samples, digital caliber has been used to ensure that all samples had the same dimensions before getting pressed. After words, restorations go through series of adjustment steps including finishing and polishing with or without glazing according to material composition and manufacturer's instructions. Glazing ceramic restorations is a standard laboratory process that gives the completed restorations aesthetically pleasing & hygienic glass coated surfaces. It is the best way to provide smoother surface. However, many studies have stated that manual polishing is mandatory to get smooth surface when compared with glazing procedures [**9**].

[8] Julabo FT 200, Germany

Figure 1: (A): IPS e.max press. (B): CeraMotion LiSi press.
(C): Rosetta SP. (D): Celtra Press

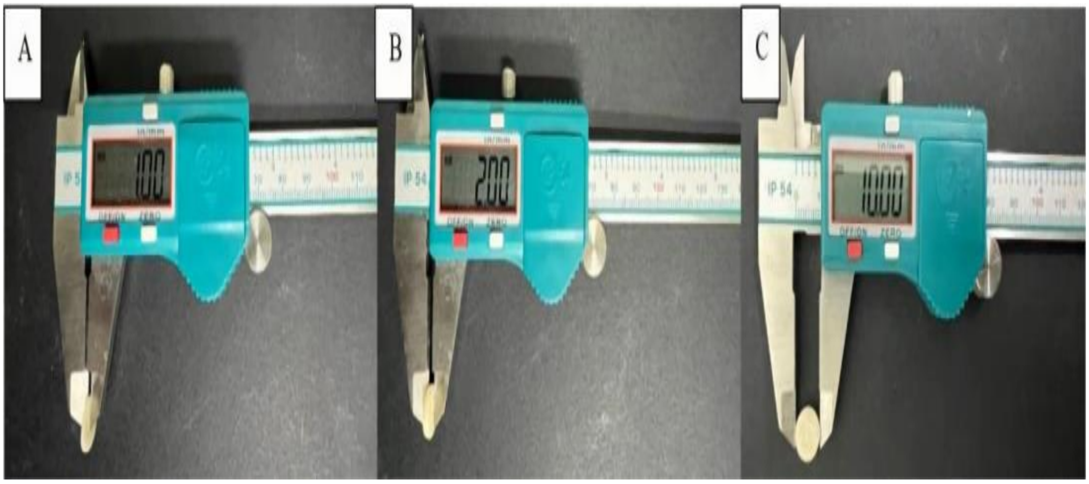

Figure 2: (A) 1 mm thickness disc. (B) 2 mm thickness disc. (C) 10 mm diameter disc

Figure 3: Glazing tools.

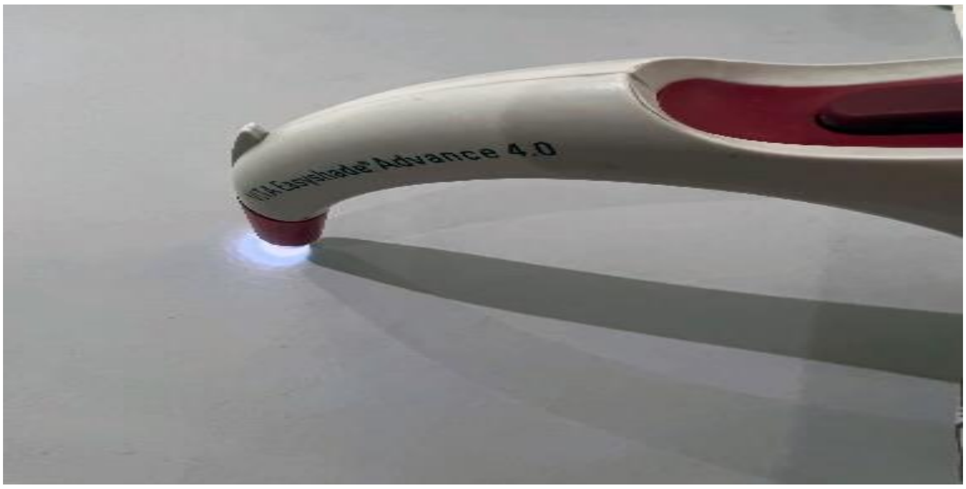

Figure 4: VITA Easyshade Advance on a grey background

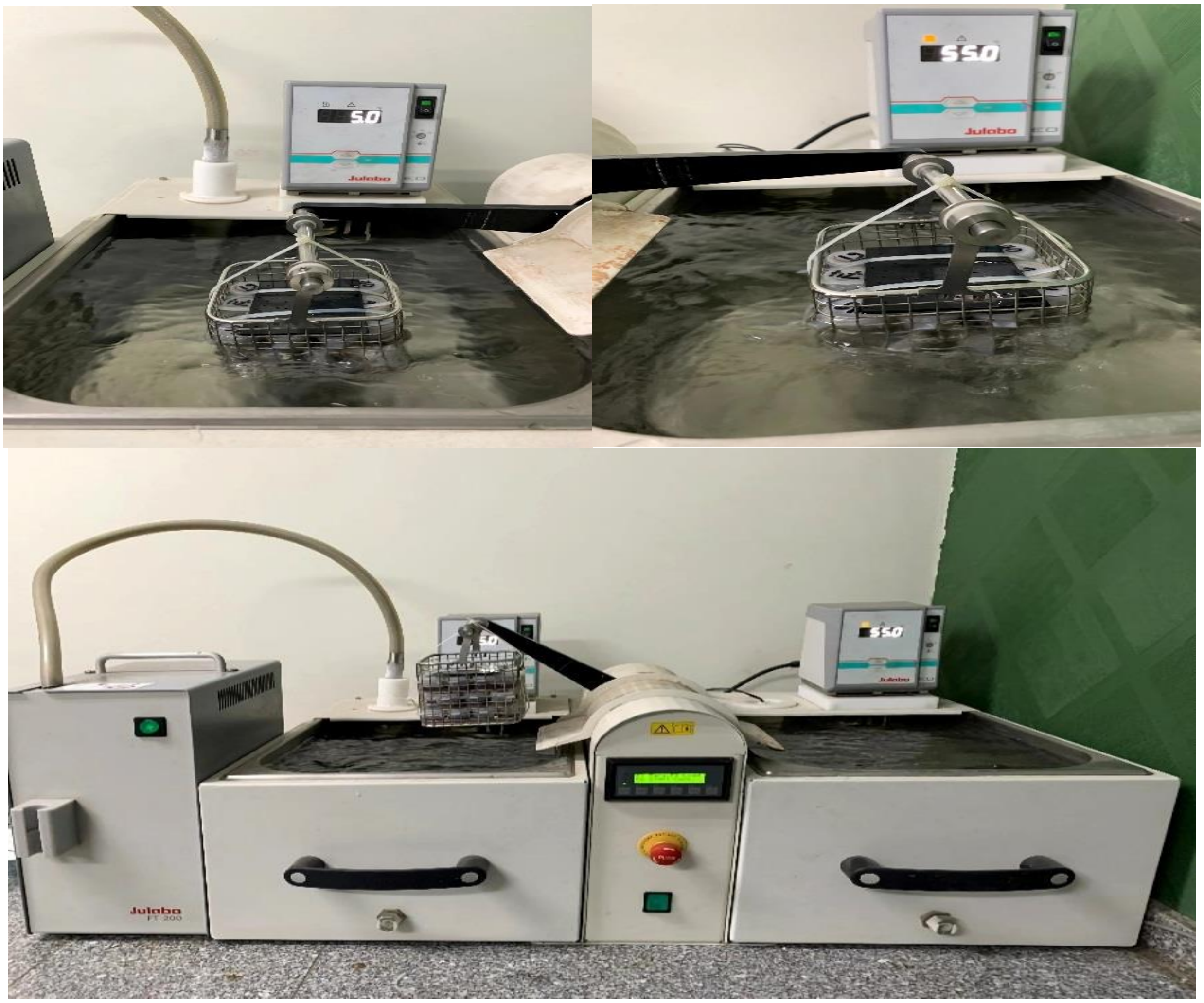

Figure 1: Thermocycling of samples 5 °C/55 °C in (Julabo FT 200)

Figure 6: Samples after thermocycling.

Table 1: Descriptive statistics & results of Kruskal-Wallis test to compare among (ΔE) of the four ceramic types

Finishing technique	Thickness	e.max		Celtra		ceraMotion		Rosetta		P-value	Effect size (Eta squared)
		Median (Range)	Mean (SD)	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
Glazing	1 mm	10.3 (6.2-14.2) ^{A}	10 (3.6)	1.2 (0.9-1.7) ^{B}	1.4 (0.4)	1.5 (1.1-3.3) ^{B}	1.7 (0.9)	2 (1.4-6.3) ^{B}	2.7 (2.1)	0.006*	0.777
	2 mm	6.5 (6.4-6.9) ^{A}	6.6 (0.2)	1.1 (0.8-1.4) ^{B}	1.1 (0.3)	1.4 (1.2-1.6) ^{B}	1.4 (0.2)	1.6 (1.5-1.8) ^{B}	1.6 (0.1)	0.001*	0.994
Glazing and polishing	1 mm	5.4 (2.2-7.6) ^{A}	5.2 (2.8)	1 (0.9-1.4) ^{B}	1.1 (0.2)	1 (0.9-1.1) ^{B}	1 (0.1)	1.5 (1-2.2) ^{B}	1.6 (0.5)	0.008*	0.668
	2 mm	0.8 (0.7-1.2) ^{B}	0.9 (0.2)	1.9 (1.5-2.1) ^{A}	1.8 (0.3)	1 (0.7-1.7) ^{B}	1.1 (0.4)	1.8 (1.6-2) ^{A}	1.8 (0.2)	0.005*	0.742

*: Significant at P ≤ 0.05, Different superscripts in the same row show statistically significant differences among ceramic types

Table 2: Descriptive statistics & results of Mann-Whitney U test to compare among (ΔE) of the 2 finishing techniques

Ceramic type	Thickness	Glazing		Glazing and polishing		P-value	Effect size (d)
		Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
e.max	1 mm	10.3 (6.2-14.2)	10 (3.6)	5.4 (2.2-7.6)	5.2 (2.8)	0.142	0.199
	2 mm	6.5 (6.4-6.9)	6.6 (0.2)	0.8 (0.7-1.2)	0.9 (0.2)	0.009*	2.928
Celtra	1 mm	1.2 (0.9-1.7)	1.4 (0.4)	1 (0.9-1.4)	1.1 (0.2)	0.347	0.623
	2 mm	1.1 (0.8-1.4)	1.1 (0.3)	1.9 (1.5-2.1)	1.8 (0.3)	0.009*	2.928
ceraMotion	1 mm	1.5 (1.1-3.3)	1.7 (0.9)	1 (0.9-1.1)	1 (0.1)	0.016*	2.336
	2 mm	1.4 (1.2-1.6)	1.4 (0.2)	1 (0.7-1.7)	1.1 (0.4)	0.117	1.141
Rosetta	1 mm	2 (1.4-6.3)	2.7 (2.1)	1.5 (1-2.2)	1.6 (0.5)	0.347	0.623
	2 mm	1.6 (1.5-1.8)	1.6 (0.1)	1.8 (1.6-2)	1.8 (0.2)	0.142	1.043

*: Significant at P ≤ 0.05

Table 3: Descriptive statistics & results of Mann-Whitney U test to compare among (ΔE) of the 2 ceramic thicknesses

Ceramic type	Finishing technique	1 mm		2 mm		P-value	Effect size (d)
		Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
e.max	Glazing	10.3 (6.2-14.2)	10 (3.6)	6.5 (6.4-6.9)	6.6 (0.2)	0.209	0.863
	Glazing and	5.4 (2.2-7.6)	5.2 (2.8)	0.8 (0.7-1.2)	0.9 (0.2)	0.014*	2.928
Celtra	Glazing	1.2 (0.9-1.7)	1.4 (0.4)	1.1 (0.8-1.4)	1.1 (0.3)	0.175	0.951
	Glazing and	1 (0.9-1.4)	1.1 (0.2)	1.9 (1.5-2.1)	1.8 (0.3)	0.009*	2.928
ceraMotion	Glazing	1.5 (1.1-3.3)	1.7 (0.9)	1.4 (1.2-1.6)	1.4 (0.2)	0.917	0.066
	Glazing and	1 (0.9-1.1)	1 (0.1)	1 (0.7-1.7)	1.1 (0.4)	0.917	0.066
Rosetta	Glazing	2 (1.4-6.3)	2.7 (2.1)	1.6 (1.5-1.8)	1.6 (0.1)	0.251	0.78
	Glazing and	1.5 (1-2.2)	1.6 (0.5)	1.8 (1.6-2)	1.8 (0.2)	0.347	0.623

*: Significant at P ≤ 0.05

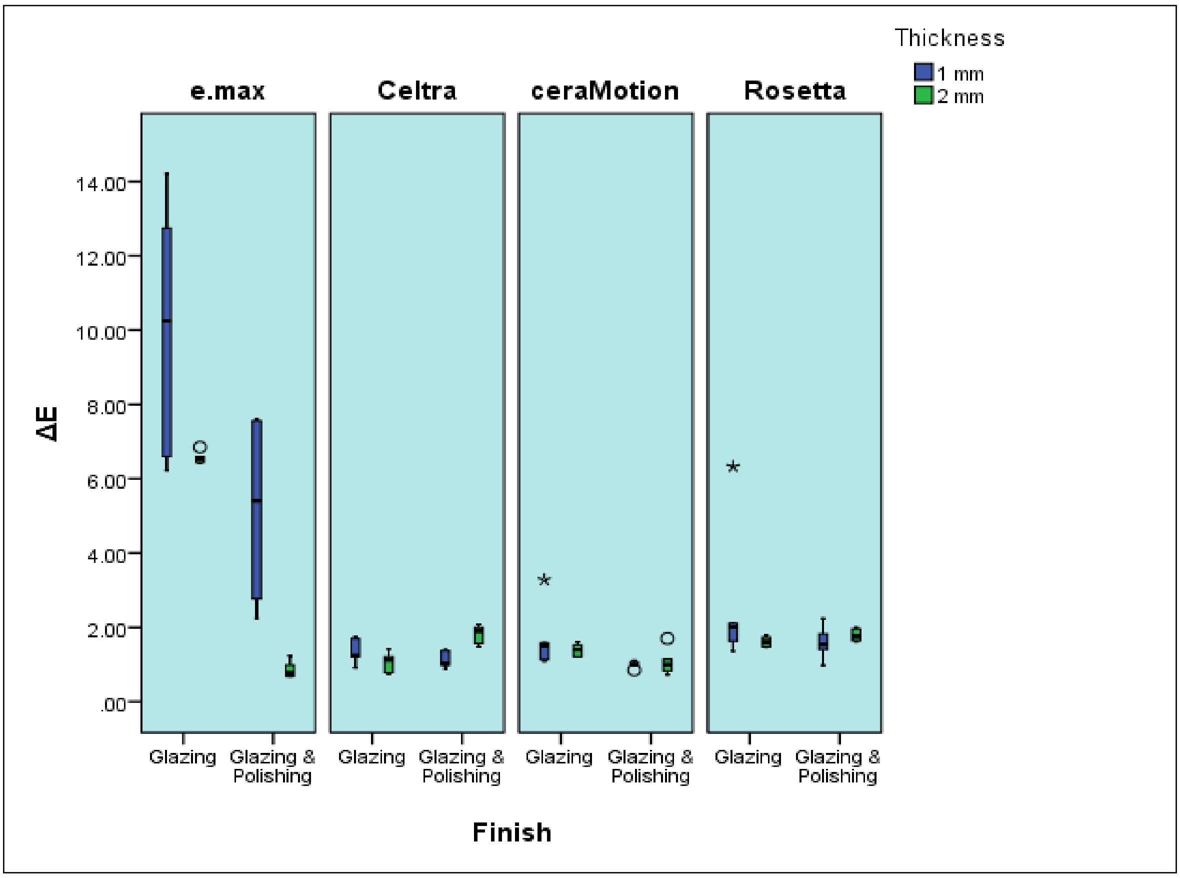

Figure 7: Box plot representing median & range values for (ΔE) of the 2 thicknesses (Stars and circle represents outliers)

According to other studies, the surface roughness of ceramic materials is affected differentially by surface finishing, polishing, or glazing. The vita easy shade spectrophotometer had been used in the present research to measure the specimens' colour coordinates. In dentistry, spectrophotometers are thought to be among the most precise tools for measuring colour. It calculates how much light an object reflects. The shade tab equivalent of this reflectance value is transformed. Thermocycling had been used in this research to simulate the aging of ceramic materials to examine the degree of sustainability of translucency after a specific period. The selected beverage was coffee as it is the commonly used hot drink among patients [10]. Our in vitro study and other studies did the aging of all samples through 5000 cycles of thermocycling in a coffee solution [11]. As 5000 cycles of coffee thermocycling simulate 6 months of intra-oral use. Regarding the results of our study all samples has shown color change within visually perceptible but clinically acceptable level (more than 1 and less than 3.7). Thus, the null hypothesis was rejected. An exception was the emax group, where emax glazed samples (1mm&2mm) together with emax glazed and polished samples (1mm) have shown significantly higher ΔE (color change) beyond the clinically acceptable level (more than 3.5), while emax glazed and polished samples with 2 mm thickness have shown not only clinically acceptable level but even visually imperceptible level ΔE less than 1 (0.9). Those findings have shown the significant effect of glazing and polishing together with increasing the thickness from 1 to 2 mm among the emax group. These results could be interpreted by the specific microstructure of different types of glass ceramics, it is well known that the optical properties depend on the crystal size differences in refractive indexes of the gassy matrix & the crystalline phase, moreover transluscency and color stability are decreased with increasing the size and the number of the crystalline phase. Regarding emax, the crystalline phase might have increased the number and size of the crystals together with being needle shaped could explain low color stability in comparison to other recently introduced ceramics where manufacturer includes nanosized crystals in the microstructure. This explanation could also interpret the improvement of color stability of emax after polishing and increase thickness to 2mm where the polishing improves the refractive index of the crystals to match the glassy phase minimizing the color change after aging while increasing the thickness. On the contrary to the emax group and regarding the celtra group glazing only showed significant lower ΔE values than glazing and polishing in 2mm thickness which implies that polishing before glazing has a negative impact on the color stability of the celtra samples. This could be interpreted by its microstructure being zirconia reinforced lithium silicate with highly homogeneous fine crystalline structure with rounded & rod like crystals which are claimed to be finer and less in percentage than emax [12]. This could interept its good results of color stability with glazing only however polishing might have affected the crystalline content, shape and distribution among glassy matrix. On the other hand, celtra have shown significantly higher ΔE (color change) in polished and glazed samples with 2 mm. Similarly this finding was previously explained and attributed to its microstructure. Our study is similar to Alp et al. [13]. After being thermocycled in coffee, the LDS material showed a higher colour difference value than the ZLS groups in both the glazed & polished groups. All materials had colour difference values that were less than the perceptibility threshold, except for the polished LDS material. Though noticeable, the colour variations seen with polished LDS material were clinically acceptable. Pires et al. [11] revealed that the material's capacity to retain colour was impacted by the thickness of the LDS-press ceramic. Significantly less colour change was observed when the material's thickness reached 2mm as opposed to 1.5mm. Acar et al. [14] examined the colour stainability of CAD-CAM & nanocomposite resin materials following coffee thermocycling at various thicknesses (0.5, 0.7, 1.0, & 1.2 mm) & found that the LDS material, independent of thickness, showed the highest colour stability. At all tested thicknesses, the LDS ceramic's colour change was not clinically discernible. Another study Linah M. Ashy et al. [15] Regardless of the type of cement employed, there had been no significant difference in the colour stability of high-translucency monolithic lithium disilicate & zirconia ceramics at 1mm restoration thickness. Regarding Ceramotion and Rosetta, there had been no significant difference among the 2 finishing techniques in both 1mm and 2mm thickness which implies color stability even in thin sections. This could be explained by their microstructure. Moreover, it has been claimed that they have low reaction layer after pressing providing homogenous and smooth surfaces. This might explain the insignificant differences in such groups between glazing and polishing and glazing only in 1mm and 2mm thicknesses.

5. Conclusions

Increasing ceramic thickness from 1 mm to 2 mm has shown better color stability in Emax group. Polishing before glazing increased color stability in Emax while decreased it in Celtra. Finishing protocols and ceramic thickness did not significantly affect color stability in Rosetta & Ceramotion.

References

[1] K. Hynková, S.K. Sarao, I. Voborna, L. Levin. (2022). Effect of assessor's sex on visual color matching in dentistry: A systematic review of the literature. Journal of Esthetic and Restorative Dentistry. 34(2): 383-396.

[2] B. Kanat-Ertürk. (2020). Color stability of CAD/CAM ceramics prepared with different surface finishing procedures. Journal of Prosthodontics. 29(2): 166-172.

[3] W.M. Johnston. (2014). Review of translucency determinations and applications to dental materials. Journal of Esthetic and Restorative Dentistry. 26(4): 217-223.

[4] L. Jiang, Y. Liao, Q. Wan, W. Li. (2011). Effects of sintering temperature and particle size on the translucency of zirconium dioxide dental ceramic. Journal of Materials Science: Materials in Medicine. 22: 2429-2435.

[5] M.A. Arocha, J.R. Mayoral, D. Lefever, M. Mercade, J. Basilio, M. Roig. (2013). Color stability of siloranes versus methacrylate-based

composites after immersion in staining solutions. Clinical oral investigations. 17: 1481-1487.
[6] A. Della Bona, J.R. Kelly. (2008). The clinical success of all-ceramic restorations. The Journal of the American Dental Association. 139: S8-S13.
[7] B.O. Salem, D.M. Elshehawi, G.A. Elnaggar. (2022). Fracture resistance of pressed ZLS crowns versus pressed LD crowns under thermo-mechanical cycling. Brazilian dental journal. 33: 103-109.
[8] Y. Yang, J. Yu, J. Gao, J. Guo, L. Li, Y. Zhao, S. Zhang. (2016). Clinical outcomes of different types of tooth-supported bilayer lithium disilicate all-ceramic restorations after functioning up to 5 years: a retrospective study. Journal of Dentistry. 51: 56-61.
[9] M. Kurt, M.B. Güngör, S.K. Nemli, B.T. Bal. (2020). Effects of glazing methods on the optical and surface properties of silicate ceramics. Journal of Prosthodontic Research. 64(2): 202-209.
[10] U. Erdemir, E. Yildiz, M.M. Eren, S. Ozel. (2013). Surface hardness evaluation of different composite resin materials: influence of sports and energy drinks immersion after a short-term period. Journal of Applied Oral Science. 21: 124-131.
[11] L.A. Pires, P.M. Novais, V.D. Araújo, L.F. Pegoraro. (2017). Effects of the type and thickness of ceramic, substrate, and cement on the optical color of a lithium disilicate ceramic. The journal of prosthetic dentistry. 117(1): 144-149.
[12] F. Zarone, G. Ruggiero, R. Leone, L. Breschi, S. Leuci, R. Sorrentino. (2021). Zirconia-reinforced lithium silicate (ZLS) mechanical and biological properties: A literature review. Journal of Dentistry. 109: 103661.
[13] G. Alp, M.G. Subasi, W.M. Johnston, B. Yilmaz. (2018). Effect of surface treatments and coffee thermocycling on the color and translucency of CAD-CAM monolithic glass-ceramic. The journal of prosthetic dentistry. 120(2): 263-268.
[14] O. Acar, B. Yilmaz, S.H. Altintas, I. Chandrasekaran, W.M. Johnston. (2016). Color stainability of CAD/CAM and nanocomposite resin materials. The journal of prosthetic dentistry. 115(1): 71-75.
[15] L.M. Ashy, A. Al-Mutairi, T. Al-Otaibi, L. Al-Turki. (2021). The effect of thermocyclic aging on color stability of high translucency monolithic lithium disilicate and zirconia ceramics luted with different resin cements: an in vitro study. BMC Oral Health. 21: 1-7.