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Original Article

In Vitro Evaluation of Color Stability, Translucency and Flexure Strength of Different CAD CAM Materials

Mohamed Mahmoud Abdelfattah[1] , Reem Saleh Elmabrok[2].

[1] Fixed Prosthodontics Department Faculty of Dentistry, Cairo University, Egypt.
[2] Fixed Prosthodontics Department, Faculty of Dentistry, Sert University, Libya.

Email: Mohamed.abdelgawad@dentistry.cu.edu.eg

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Abstract:

Aim: The aim was to evaluate the color stability, translucency and flexure strength of different CAD CAM materials after immersion in different staining solutions.

Subjects and Material: In this study we used 45 specimens. These specimens were prepared from different CAD CAM materials including glass ceramics, resin nano ceramics and hybrid ceramics (IPS E- max, Vita Enamic and Vita Suprinity respectively) (n=15 for each group). The color and translucency parameters were investigated using spectrophotometer initially and after exposing the specimens to various stained solutions (Cola, Coffee and distilled water). The flexure strength was evaluated using a universal testing machine (three point bending test) with a load cell of 5 kN. Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests).

Results: Regarding color stability, the results showed that there was significant change in color related to the Vita Enamic and Vita Suprinity groups when compared to the E.max group, when immersed in coffee rather than water and cola. Regarding translucency, there was no statistically significant difference between all types of ceramics. Regarding the flexure strength, there was a statistically significant difference between groups where the E.max show the highest strength and Vita Suprinity show least strength.

Conclusions: Immersion of the tested CAD CAM materials in different solutions did not change the color, translucency or the flexure strength of these materials .Except for Vita Enamic and Vita Suprinity when immersed in coffee the color stability was affected.

Keywords:CAD/CAM; Translucency Parameter; Color Stability; Flexure Strength.

Introduction:

Recently, using CAD CAM, dentists can produce different types of restorations with very high precision, quality and adaptation. Despite these advantages, the high cost and difficulties in its usage represent an obstacle in the way of spreading CAD CAM systems. Glass ceramics, zirconia, resin nano ceramics and hybrid ceramics are among these restorations, which can be milled from blocks that are free from defects or air bubbles, producing homogenous, strong and highly aesthetic restorations. [1]

The aim of this study was to evaluate the flexure strength, color and translucency of different CAD CAM materials (Lithium disilicate, zirconia reinforced glass ceramics and glass ceramic in a resin interpenetrating matrix).

The hypothesis of this trial was that there will be no change in color, translucency or flexure strength of the different CAD/CAM materials used in this trial.

Subjects and methods:

1- Specimen preparation:

Three groups were prepared, within each group there were 15 specimens, with total number of 45 specimens. These groups were created from different CAD CAM materials including glass ceramics (IPS E.max (Ivoclar Vivadent, Schaan, Liechtenstein) and hybrid ceramics (Vita Enamic (VITA Zahnfabrik H. Rauter GmbH) and Vita Suprinity (VITA ZahnfabrikH. Rauter GmbH)). The color and translucency of these specimens were evaluated before and after immersion in staining liquids. 45 specimens (10 mm × 2 mm) were prepared from the different CAD/CAM blocks with the aid of low speed saw (IsoMet®; Buehler, Lake Bluff,USA) under copious amount of coolant (figure 1). For glass ceramics group, and after sawing the specimens, crystallization cycle at 850°C for 10 min in the furnace (Programat® EP 5000; Ivoclar Vivadent) was done according to the manufacturer instructions. All surfaces of the specimens were polished under copious water irrigation using different silicon carbide paper points at low speed (300 rpm). Confirmation of specimen thickness was done using digital caliper. Ultrasonic cleaning in distilled water was done for all specimens for 10 minutes.

Figure 1: Specimens for all ceramic restorations.

2-Assessment of the color and translucency:

Specimen color measurement initially was done using a reflective spectrophotometer (model RM200QC; X-Rite GmbH,Neu-Isenburg, Germany) at 4 mm aperture size (figure 2). Specimens were centered in the measuring port. A white background (Commission internationale de l'éclairage (CIE) L* = 88.81, a* = −4.98,b* = 6.09) was selected and the measurements were made according to the CIE L*a*b* color space relative to the CIE standard illuminant D65, where L* refers to the degree of lightness (0–100), a* to the color coordinate on the red/ green axis and b* to the color coordinate on the yellow/blue axis. [2] The spectrophotometer was calibrated before each measurement. Three measurements were taken for each specimen and the average was recorded.

Figure 2: Spectrophotometer.

Specimen translucency measurement was done using the same reflective spectrophotometer against white (CIE L* = 88.81, a* = −4.98, b* = 6.09) and black (CIE L* = 7.61, a* = 0.45, b* = 2.42) backgrounds according to the CIE standard illuminant D65.

The translucency of the specimens were evaluated by determining the specimens color against black and white backgrounds and measuring the differences between each of them. This was done using the following equation [3]:

TP*= [(L*b − L*w)2 + (a*b − a*w)2 + (b*b − b*w)2]1/2

Where:

TP – translucency parameter

L* – degree of lightness

a* – color coordinate on the red/green axis;

b* – color coordinate on the yellow/blue axis. The subscripts (b) and (w) refer to the color of the specimens against the black and the white backgrounds respectively.

For each group, specimens were allocated randomly into three subgroups (n = 5 based on the staining solution used (coffee, cola and distilled water). Coffee staining solution was prepared by pouring 20 grams of coffee (Nescafé® Classic; Nestlé S.A., Switzerland) in one liter boiled distilled water, this mixture was stirred for ten seconds every five minutes until cooling to room temperature. This mixture was then filtered using filter paper. The second staining solution was Cola from (Coca-Cola®; Coca-Cola Company, Atlanta, USA). The last solution is the distilled water from (Nestle, Cairo, Egypt). The pH of each solution was measured using a pH meter (AD11; Adwa Instruments, Szeged, Hungary) and was 2.5, 5.5 and 6.9 for cola, coffee and water, respectively.

A 5 ml of each solution was poured into a vial. Then each specimen was placed in the vial and properly closed. These vials were placed in an incubator at 37˚C for 28 days. Solutions were freshened daily to avoid growth of bacteria or fungi. Solutions were stirred twice daily to avoid particle participation. After 28 days, specimens were removed, rinsed using distilled water and rubbed using gauze. Assessment of the color and translucency for each specimen was done as mentioned. The color difference (ΔE) was calculated according to the following equation:

ΔE = [(ΔL*) 2 + (Δa*) 2 + (Δb*) 2]½

ΔL* = L*after immersing in staining solution − L* at baseline

Δa* = a* after immersing in staining solution − a*at baseline

Δb* = b* after immersing in staining solution − b* at baseline

According to the 50:50% threshold, ΔE more than 1.2 was considered perceptible, whereas values more than 2.7 were considered clinically unacceptable. [4]

Differences in the translucency parameter values (ΔTP) were calculated using the following equation:

ΔTP = TP after immersing in staining solution – TP baseline

The ΔTP values more than 2 were considered perceivable. [5]

3-Assessment of flexure strength:

All samples were individually and horizontally mounted in a custom made loading fixture [three point bend test assembly; The specimens were supported with 13 mm distant stain less steel supports, with the damage site centrally located on the tensile side] on a computer controlled materials testing machine (Model 3345; Instron Industrial Products, Norwood,MA, USA) with a loadcell of 5 kN and data were recorded using computer software (Instron® Bluehill Lite Software) (figure 3).Then the samples were statically compression loaded until fracture at a crosshead speed of 1 mm/min.The Stress-strain curves were recorded with computer software (Instron® Bluehill Lite Software). Flexure strength were recorded following the formula:

FS (ó) =3F (L)/ 2wh2

Where; FS represent the flexure strength, F is the maximum load at the point of fracture, L is the length of the span, w is the width of the sample and h its height.

Figure 3: Universal testing machine.

Statistical analysis:

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). TP and flexural strength data showed parametric distribution while ΔE data showed non-parametric distribution. Data were presented as mean and standard deviation (SD) values. For parametric data; repeated measures ANOVA test was used to study the effect of ceramic type, immersion medium, time and their interactions on TP. One-way ANOVA test was used to compare between flexural strength values of the three ceramics. Bonferroni's post-hoc test was used for pair-wise comparisons when ANOVA test is significant. For non-parametric data; Kruskal-Wallis test was used to compare between the three ceramics as well as the three immersion media. Dunn's test was used for pair-wise comparisons when Kruskal-Wallis test is significant. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY:IBM Corp.

Results:

A. Color change (ΔE)

Comparison between ceramic types: (table 1)

After immersion in distilled water as well as cola; there was no statistically significant difference between ceramic types (*P*-value = 0.230, Effect size = 0.078) and (*P*-value = 0.827, Effect size = 0.135), respectively.

After immersion in coffee; there was a statistically significant difference between ceramic types (*P*-value = 0.042, Effect size = 0.36). Pair-wise comparisons between ceramic types revealed that there was no statistically significant difference between Vita Enamic and Vita Suprinity; both showed statistically significantly higher mean ΔE than E.max.

Table (1). The mean, standard deviation (SD) values and results of Kruskal-Wallis test for comparison between ΔE values of different ceramic types

Immersion medium	E.max		Vita Enamic		Vita Suprinity		*P*-value (Between ceramics)	Effect size *(Eta squared)*
	Mean	SD	Mean	SD	Mean	SD		
Distilled water	2.1	0.43	4.17	2.55	2.37^{E}	0.9	0.230	0.078
Cola	2.29	1.89	4.91	3.95	2.65^{E}	0.94	0.827	0.135
Coffee	2.11_{B}	0.73	3.57_{A}	3.38	4.66_{AD}	0.64	0.042*	0.36
P-value (Between media)	0.827		0.932		0.009*			
Effect size *(Eta squared)*	0.135		0.089		0.625			

**: Significant at P ≤ 0.05,*

A,B,C superscripts in the same row indicate statistically significant difference between ceramic types

D,E superscripts in the same column indicate statistically significant difference between immersion media

B. Translucency Parameter (TP)

Comparison between TP before and after immersion: (table 2)

As regards all ceramic types immersed in all media; there was no statistically significant change in mean TP after immersion.

Table (2). The mean, standard deviation (SD) values and results of repeated measures ANOVA test for comparison between TP values before and after immersion with different interactions of variables

Material	Immersion medium	Before immersion		After immersion		*P*-value	Effect size *(Partial eta squared)*
		Mean	SD	Mean	SD		
e.max	Distilled water	16.68	0.64	16.39	0.35	0.292	0.031
	Cola	16.82	1.39	16.01	0.83	0.231	0.04
	Coffee	16.38	0.51	16.12	1	0.336	0.026
Vita Enamic	Distilled water	12.23	1.61	11.61	0.87	0.363	0.023
	Cola	12.1	0.82	10.73	1.35	0.051	0.105
	Coffee	11.82	0.76	10.53	1.76	0.062	0.094
Vita Suprinity	Distilled water	16.97	1.19	16.34	0.4	0.583	0.008
	Cola	18.13	0.34	17.7	0.39	0.404	0.019
	Coffee	18.87	1.48	18.09	0.54	0.252	0.036

**: Significant at P ≤ 0.05*

C. Flexural strength (MPa) (table 3)

There was a statistically significant difference between mean flexural strengths for different ceramic types (*P*-value <0.001, Effect size = 0.938). Pair-wise comparisons between ceramic types revealed that e.max showed the statistically significantly highest mean flexural strength. Vita Enamic showed statistically significantly lower mean value. Vita Suprinity showed the statistically significantly lowest mean flexural strength.

Table (3). The mean, standard deviation (SD) values and results of one-way ANOVA test for comparison between flexural strength values (MPa) of different ceramic types

E.max		Vita Enamic		Vita Suprinity		*P*-value	Effect size *(Eta squared)*
Mean	SD	Mean	SD	Mean	SD		
334.3 ^{A}	22.7	211.5 ^{B}	21.4	170 ^{C}	15.5	<0.001*	0.938

*: Significant at P ≤ 0.05, Different superscripts in the same row indicate statistically significant difference between ceramic types

Discussion:

The aim of this study was to evaluate the effect of different solutions on the esthetic qualities of different CAD CAM ceramic restorations. These solutions are commonly consumed by individuals during their life and exposes the restorations to varieties of staining and changes of the PH, among such solutions like water, coffee and cola. These esthetic qualities include the translucency and the color changes of these restorations. Proper knowledge of the esthetic behavior of these restoration is of prime importance regarding the esthetic success rate of these restorations.[6]

There are several factors that may affect the color of dental ceramics. These factors include the nature of dental ceramic, technique of glazing, firing cycles and the crystalline content. The color of an object is determined by the wavelengths of light that is reflected by the object. Translucency can be described by the translucency parameter and is defined as the color difference of the material over white and black background. It also describes how the light pass through the material.[7]

Cola and coffee solutions were considered as a common materials for the evaluation of the staining tendency for different restorative materials. Many investigators accepted such materials for evaluation of color stability.[8]

E.max restoration is an all ceramic material, has the advantage of its long lasting durability, superior esthetic properties. It is composed mainly from lithium disilicate. This material has superior toughness, longevity and esthetic properties which makes it a highly rated restoration. It can be considered the best material shade match with dental tissue.[9]

Vita Enamic is a hybrid resin ceramic that can be manufactured with computer-aided design/computer-aided manufacturing (CAD/CAM) facilities. The porous feldspathic block that is infiltrated with resin does not need a furnace after being milled. It only needs to be finished and polished. It makes the single visit treatment possible.[1]

Zirconia reinforced lithium silicate ceramic is high-strength ceramic supplied as CAD CAM blocks. It is composed of 10% zirconia was added to lithium silicate .It has been suggested to be an esthetic and durable option for single restorations with high edge strength. [10]

Spectrophotometer was used in this study for assessment of color changes, it is considered a reliable device for both clinical and research uses. It has a great ability to evaluate interactions of color for both dental tissues and the restorative materials.[11]

The results of this study showed that the significant change in color was related to the Vita Enamic and Vita Suprinity groups when compared to the E.max group, when immersed in coffee rather than water and cola. The color change for both materials was more than 2.7 which is considered clinically unacceptable.[12]

Results of this study were in agreement with Kaan et al [13] and with Saba et al [14] who concluded that coffee adversely affect the esthetics and color of Vita Enamic. The author relate this finding to the water sorption of the resinous part of Vita Enamic which was the urethane dimethacrylate and triethylene glycol dimethacrylate.

Vita enamic is a type of hybrid resin matrix ceramics containing ceramic part (86 weight % / 75 volume %) and polymer part (14 weight % / 25 volume %). The polymer part composed of UDMA (Urethane Dimethacrylate) and TEGDMA (Triethylene Glycol Dimethacrylate). This change in color for the Vita Enamic group may be correlated to its resinous content. Presence of resin make the material more liable for water sorption with subsequent color change. [8]

With regards to Vita Suprinity, the significant color change may be related to its zirconia content. Zirconia may undergo phase transition from tetragonal to monoclinic phases when it is contained in water (low thermal degradation). This will be accompanied by displacement of particles from the surface of the material, leading to surface roughness and the infiltration of the solution into the material. This transformation can occur after a week of exposure. [15]

The staining mechanism of coffee can be done by adsorption of colorants particles on the surface of the material and by absorption of these particles onto the organic part of the material. This mechanism occur due to high affinity and high compatibility between the organic component and the yellow colorants of coffee. [16]

Also the acidity of the staining solutions has a great effect on its ability to infiltrate the resin component. The coffee solution is acidic with PH around 5.5.[17]

When immersed in distilled water and cola, E.max and Vita Suprinity show clinically acceptable color changes, where Vita Suprinity show more changes than E.max (this difference was insignificant). The highest color stability of E.max was due to lack of irregularities, microcracks on the surface of the material after polishing, producing highly stable surface structure, which prevent diffusion of solution into the material and avoiding dissolution of the

These results were in agreement with Alsayed et al [19] who conducted a study to evaluate the color stability of Vita Suprinity and Emax, and found that Vita Suprinity showed more significant color change than the Emax group. The author stated that this finding occur due to breakdown of the metal oxides followed by formation of peroxides which is responsible for color change.

Translucency is a superior characteristic of ceramics, which is important to mimic the highly translucent dental enamel. The chemical nature of ceramics, crystal size, crystal structure, porosities, internal flaws, and surface quality are among the variables that affect the translucency of the restorative material.[20]

Translucency is the property of the material allowing the light passage with scattering it in a way that the image will not be clearly seen. It lies between complete transparency and complete opacity. Translucency can be controlled by the transmission, reflection and absorption of light through the material.[21]

Regarding translucency parameter (TP), there was no statistically significant difference between all types of ceramics before and after immersion in all immersion solutions. As the change not exceeding 2, this change will not be clinically perceptible. [5]

Results of this study show that the translucency parameters values which recorded after staining was lower than that was recorded at the baseline for all CAD/CAM materials. The greatest difference for the translucency parameter was recorded for the Vita Enamic group and this could be related to the resinous content of the material as discussed before regarding the color change. The least difference for the translucency parameter was recorded for the E max group and this could be related to the characteristic crystalline composition of the silicate crystals.

These results were in agreement with Buyukkaplan et al [22] who conducted a study to evaluate the effect of coloring liquids on translucency of hybrid ceramics and found that there was no statistically significant difference in translucency before and after staining.

Regarding the flexure strength, there was a statistically significant difference between these materials, with the highest strength was related to E.max group followed by Vita Enamic followed by the least flexure strength for the Vita Suprinity group. Due to its zirconia content, Vita Suprinity showed the least flexure strength, this may be related to low thermal degradation and phase transformation. This transformation takes place in the surface, transforming the tetragonal phases to the monoclinic phases in presence of humidity. This transformation will be accompanied with stress corrosion followed by microcracks formation. This allow humidity to transfer to the bulk of the material by capillary attraction allowing the process to occur in its bulk. [23]

Due to the presence of lithium disilicate crystals which are dispersed in a homogenous pattern with interlocking platelet like shape, this will prevent any crack formation and propagation with subsequent improved mechanical properties for the E.max. This finding was in agreement with Vafaee et al who conducted a study to compare the flexure strength of E max and hybrid ceramics and found that the Emax show the highest values. [24]

According the results, the null hypothesis was rejected with regards the translucency parameters and was accepted for both color changes and the flexure strength, as the color of the ceramic material was affected by the immersion medium. One of the factors that may affect color and translucency is the surface topography of the material. Further studies will be needed to evaluate the effect of different staining solutions on the surface topography of the material and how this effect change the color and the translucency.

Conclusions:

Within the limitations of this study, Vita Enamic followed by Vita Suprinity were the two ceramics most affected by coffee, which resulted in the highest colour shift. The translucency was affected after immersion, this affection was not clinically perceptible. The differences between materials' flexure strength were not affected by immersion in staining solutions.

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