EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org
VOL. 70, 2441:2449, JULY, 2024
PRINT ISSN 0070-9484 • ONLINE ISSN 2090-2360
FIXED PROSTHODONTICS AND DENTAL MATERIALS
Submit Date : 23-02-2024 • Accept Date : 29-04-2024 • Available online: 10-07-2024 • DOI : 10.21608/EDJ.2024.272943.2957

EVALUATION OF THE COLOR CHANGE AND SURFACE ROUGHNESS OF REINFORCED COMPOSITE (BRILIANT CRIOS) AFTER IMMERSION IN ACIDIC BEVERAGE (AN IN-VITRO STUDY)

Shaimaa Rabee Ali*, Rana Mahmoud Sherif** *and* Rasha Nabil Sami**

ABSTRACT

Objective: Evaluate the color change and surface roughness of reinforced composite (BRILIANT CRIOS) after immersion in artificial saliva then acidic beverage (Pepsi).

Materials & Methods: Samples from reinforced composite (BRILIANT CRIOS) were immersed in artificial saliva and acidic beverage (Pepsi). A total of 23 samples were prepared 1mm in thickness and (14 × 12 × 18 (mm) in dimensions. The average color change (Delta E*) was computed following immersion in artificial saliva and an acidic beverage. Using spectrophotometer analysis, color parameters were assessed both before and after the immersion. The surface roughness was measured with a non-contact profilometer. The Shapiro-Wilk test was used for statistical analysis. Data had a parametric distribution, thus we used repeated measures ANOVA and the Bonferroni post hoc test to examine them. The significance level was set at $P \leq 0.05$.

Results: showed that the color change of Brilliant Crios samples immersed in Pepsi ΔE_2 was significantly higher than artificial saliva ΔE_1 while Pepsi samples had the highest surface roughness rating, followed by baseline samples, while artificial saliva samples had the lowest value.

Conclusion: reinforced composite (BRILIANT CRIOS) samples showed color changes above the clinical acceptable limit when immersed in artificial saliva and Pepsi in comparison to surface roughness beyond the clinically acceptable level after immersion in acidic beverage (Pepsi).

KEY WORDS: Reinforced composite, artificial saliva, acidic beverage.

* Assistant Professor of Fixed Prosthodontics, Faculty of Dentistry, Cairo University
* Professor of Fixed Prosthodontics, Faculty of Dentistry, Cairo University

INTRODUCTION

CAD/CAM has provided many advantages for the practitioner and patient over the conventional technique. New materials are being used to fabricate indirect dental restorations as a result of recent developments in digital dentistry and computer-aided design and computer-aided manufacturing (CAD/CAM) technologies.[1]

Recently, CAD/CAM composite materials have been introduced as an alternative to ceramics, enabling ease of milling, reduced chipping susceptibility, intraoral repair ability, and less wear of opposing teeth. These materials vary in matrix composition, filler type, filler size, and filler amount.[2]

Since CAD/CAM composites are polymerized at high pressure and temperature, they have better mechanical qualities than conventional composite resins for direct restorations because of their higher density and greater degree of monomer conversion. This resulted in the creation of resilient ceramics in the form of hybrid ceramics (Polymer Infiltrated Ceramics Network) or nanoceramics (resin nanoceramics) that are both highly durable.[3]

Among indirect composite blocks, Brilliant Crios has (71 wt%) inorganic filler (9,10) and Its elastic modulus is 10 GPa, which is comparable to dentin's (11-19 GPa).Moreover, feldspathic ceramic network with a fine structure (86 wt%) is infiltrated by polymer (14 wt%) to form hybrid ceramics, or Vita Enamic.(11) Introducing both materials attempts to produce a material that closely resembles the modulus of elasticity of dentin, making milling and intraoral repairing easier.[4]

Dental materials in the oral cavity are exposed to a range of conditions, such as eating patterns, food and beverage coloring ants, oral hygiene, and mechanical, chemical, and thermal activities that might eventually alter the material's qualities. The impact of aging on the mechanical properties of CAD/CAM composite resins was examined in several in vitro investigations, which came to the conclusion that these materials are prone to aging-related material degradation. [5] However, the impact of aging on these materials' color, gloss, and surface roughness has only been the subject of a small number of researches to far. Prior research has already documented color changes following immersion in Pepsi that are clinically undesirable.[6]

Due to increase in the number of products available in the dental market and the introduction of new ones, today's clinicians meet a challenging decision when selecting a reinforced composite material.[7]

Yet, evaluation of the color change and surface roughness under acidic beverage (Pepsi) are important parameters for long lasting survival and esthetics of dental restorations. Therefore, this study was proposed to evaluate both color change and surface roughness of reinforced composite (Brilliant Crios) With different aging solutions after immersion in different media.

The first null hypothesis was that there will be no color change of reinforced composite (BRILIANT Crios) after immersion in artificial saliva then acidic beverage (Pepsi).

The second null hypothesis was that there will be no change in surface roughness of reinforced composite (BRILIANT Crios) after immersion in artificial saliva then acidic beverage (Pepsi).

MATERIALS AND METHODS

Sample preparation:

Block-sized samples of reinforced composite (BRILIANT Crios) measuring (14 × 12 × 18) (mm) were cut using an electric isoMet 4000 microsaw and shade A2 LT were cut into rectangular shapes with a 1 mm thickness. Using a Buehler diamond disc and water coolant, the cutting was done at a speed of 2500 rpm.

TABLE (1) Commercial names, description, chemical compositions (In wt%), and manufacturer of different materials used in this study:

Materials (Commercial names)	Description	Chemical composition (In wt%)	Manufacturer
BRILIANT Crios CAD/CAM blocks **(Figure 1)**	Reinforced composite Shade LT A2 Size: C 14 Dimensions: 14 × 12 × 18 (mm)	**Dental glass** Barium glass Size < 1.0 µm **Amorphous silica** SiO2 Size < 20 nm **Resin matrix** Cross-linked methacrylates **Pigments** Inorganic pigments such as ferrous oxide or titanium dioxide	Coltène/Whaledent AG Altstätten / Switzerland
Artificial saliva	Artificial saliva	1 gram sodium carboxymthyle cellulose, 4.3 gram Xilotol, 0.1 g potassium chloride, 40 mg potassium phosphate, 1 mg potassium thiocyanate and 100 ml de-ionized water. PH=7.0.	Chemical laboratory (Faculty of Pharmacy, Mansoura University, Egypt)
Pepsi	Acidic beverage	Carbonated Water, High Fructose Corn Syrup, Caramel Color, Sugar, Phosphoric Acid, Caffeine, Otric Acid, Natural Flavor, Potassium and Phosphorus PH= 2.53	pepsi (Pepsi, Pepsi-Cola Co.) Cairo, Egypt

A total of twenty three rectangular-shaped samples (n=23) with dimensions (14 × 12 × 1) were designed and constructed in a standardized manner.

Every sample is polished and finished.:

Finishing and polishing of all samples is performed with the same operator and same manner in accordance with the manufacturer's instructions in order to standardize the process and create a flat surface, which was required for the measurement of color changes.

A custom made cylindrical Teflon mold was created from Teflon blank. The mold has a rectangular central housing with the same dimensions of samples and 1 mm thickness for holding the sample during the finishing procedure.

All reinforced composite samples (BRILIANT CRIOS) were manually finished and polished without coolant by Coltene Diatech Finishing & Polishing Kit for BRILLIANT Crios, following the manufacture recommendation.

To be ready for baseline measurement the finished and polished samples were stored in dry, tight sealed plastic containers.

Samples immersed in artificial saliva:

Using a Portable reflective spectrophotometer, the color of each sample was determined prior to its immersion in artificial saliva. The samples were placed in the middle of the measurement port with the aperture size set at 4 mm. Measurements were taken against the Commission Internationale de l'Eclairage (CIE) standard illuminant D65, using a white background as the reference point. The CIE L*a*b* color space describes the degree of lightness, a* the color on the red/green axis, and b* the color on the yellow/blue axis. Prior to every measurement, the spectrophotometer was calibrated.

Using a 3D non-contact optical profilometer, surface Topography was quantitatively characterized. Every sample was placed into a digital microscope (U500X, Digital Microscope, Guangdong, China) perpendicularly. The twenty-three samples were photographed at a fixed magnification of 90X using a USB digital microscope with an integrated camera (U500X Digital Microscope, Guangdong, China) linked to an IBM compatible personal computer. A resolution of 1280 × 1024 pixels was used to record each image. The highest resolution of 2272 x 1704 pixels was used when taking the pictures. Eight LED lamps, each with a control wheel for adjustment, were used to create illumination with a color index (Ra) that was almost 95%.

To standardize the region of roughness measurement, digital microscope images were cropped using Microsoft Office Picture Manager to 350 x 400 pixels.

Software called WSxM was used to evaluate the cropped photos. All boundaries, dimensions, frames, and measured parameters in the WSxM program were expressed in pixels.

Following the baseline color and surface roughness measurements. all samples (n=23) were immersed immediately into 20 ml of artificial saliva in tightly sealed plastic containers which were coded from 1 to 23 and incubated[10] at 37°c **±** 1° C for three weeks.

Artificial saliva was changed once daily. The samples were then removed using a tweezer, blotted dry using a tissue paper and the color of each sample was assessed using a spectrophotometer ,then the surface roughness was assessed using a profilometer .

Samples immersed in an acidic beverage (Pepsi):

A plastic syringe was used to extract 20 mL of Pepsi to fill up twenty three plastic containers. Samples were stored at 37° **±** 1° C in an incubator for 3 weeks **Dalia A. et al (2017).** Tested solution was changed regularly every day to avoid their fermentation and deposition. After 3 weeks, all samples were removed by a tweezer , washed under runny distilled water for 5 minutes and dried using tissue paper. At this point, color and surface roughness measurements were recorded and performed under the same conditions and in the same manner described for the baseline measurements..

The color changes were calculated according to the equation by the difference between the baseline color (L*, a*,b*) and after immersion in artificial saliva (L*, a*,b*). It was considered (ΔE^*_1).

The effect of Pepsi on color change was measured by the difference between the artificial saliva color (L*, a*,b*) and after immersion in Pepsi (L*, a*,b*). It was considered (ΔE^*_2).

The color changes (ΔE*) of the samples were evaluated using the following formulas:

- Color changes after saliva immersion were calculated according to this equation:

$$\Delta E^*_1 \text{ CIELAB} = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})\ ½$$

- Color changes after Pepsi immersion were calculated according to this equation:

$$\Delta E^*_2 \text{ CIELAB} = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})\ ½$$

Where: L =* lightness (0-100), a=*change the color of the axis (red/green) and b=* color variation axis (yellow/blue).

RESULTS

R statistical analysis software, version 4.3.1 for Windows, was used to conduct the statistical analysis. The mean and standard deviation figures were used to present numerical data. By utilizing the Shapiro-Wilk test to examine the data distribution, they were examined for normalcy. Surface roughness data had a parametric distribution and were subjected to a post hoc Bonferroni test after a repeated measures ANOVA. Color changes data were non-parametric and were analyzed using

signed rank test. Correlations were analyzed using Spearman's rank order correlation coefficient. The significance level was set at $p<0.05$ within all tests.

The color change of artificial saliva for the samples showed a minimum of 0.55 and a maximum of 4.74 with mean and standard deviation (±SD) (2.20 ±0.97). While, the color change of Pepsi for the samples showed a minimum of 0.51 and a maximum of 9.86 with mean and standard deviation (±SD) (2.97 ±1.95).

TABLE (2) Descriptive statistics for color change (ΔE^*_1) and (ΔE^*_2)

	Mean ± SD	Minimum	Maximum
ΔE^*_1 of Artificial saliva	2.20±0.97	0.55	4.74
ΔE^*_2 of Pepsi	2.97±1.95	0.51	9.86

Comparison between ($\Delta E^*_{1\&2}$) of different interactions:

Mean and standard deviation (±SD) values of color change ($\Delta E^*_{1\&2}$) after samples immersion in artificial saliva then Pepsi were presented numerically in Table (3) and graphically in Fig. (1)

The color change of Brilliant Crios samples immersed in Pepsi ΔE^*_2 (2.97±1.95) was significantly higher than artificial saliva ΔE^*_1 (2.20±0.97) ($p=0.029$).

TABLE (3) Mean and standard deviation (±SD) for color change (ΔE*) of Brilliant Crios after immersion in artificial saliva then Pepsi.

Color change (ΔE*) (mean±SD)			
ΔE^*_1 (Artificial saliva)	**ΔE^*_2 (Pepsi)**	**u-value**	**p-value**
Mean±SD	**Mean±SD**		
2.20±0.97	2.97±1.95	841.00	0.029*

; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)

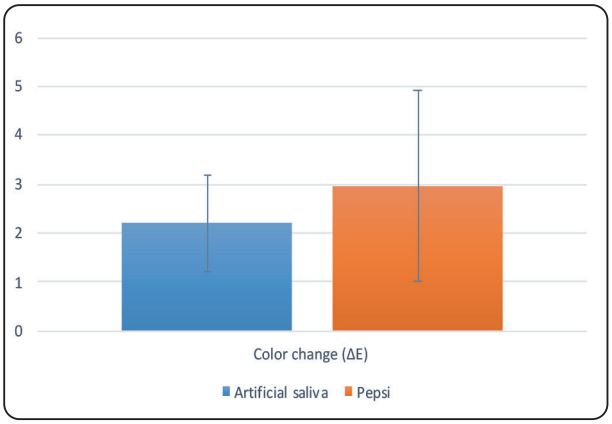

Fig. (1) Bar chart showing color change (ΔE*) of Brilliant Crios after immersion in artificial saliva then Pepsi

Quantitative surface roughness measures (Ra) (µm)

Descriptive statistics:

Descriptive statistics of surface roughness (µm) for all samples (n=23) are presented in Table (4)

The baseline surface roughness for the samples showed a minimum of 0.2849 and a maximum of 0.2958 with mean and standard deviation (±SD) (0.2902±0.0032).The surface roughness of artificial saliva for the samples showed a minimum of 0.278 and a maximum of 0.2981 with mean and standard deviation (±SD) (0.2897±0.0039). While, the surface roughness of Pepsi for the samples showed a minimum of 0.2885 and a maximum of 0.2975 with mean and standard deviation (±SD) (0.2927±0.0021).

TABLE (4) Descriptive statistics of surface roughness (µm)

	Mean±SD	Minimum	Maximum
Baseline	0.2902±0.0032	0.2849	0.2958
Artificial saliva	0.2897±0.0039	0.278	0.2981
Pepsi	0.2927±0.0021	0.2885	0.2975

Comparison of surface roughness (Ra, µm) between baseline, artificial saliva and Pepsi:

Surface roughness (μm) mean and standard deviation (±SD) measurements for artificial saliva and Pepsi were presented numerically in Table (5) and graphically in Fig. (2)

There was a significant difference between roughness values measured at baseline, artificial saliva and Pepsi (f=19.29, p<0.001). The highest value was measured in Pepsi samples (0.2927±0.0021), followed by baseline samples (0.2902±0.0032), while the lowest value was found in artificial saliva samples (0.2897±0.0039). Post hoc pairwise comparisons showed Pepsi samples to have significantly higher values than baseline and artificial saliva (p<0.001).

TABLE (5): Mean ± standard deviation (±SD) of surface roughness (μm) for baseline, artificial saliva and Pepsi

Baseline	Artificial saliva	Pepsi	f-value	p-value
Mean ±SD	Mean±SD	Mean±SD		
0.2902 ±0.0032^{B}	0.2897 ±0.0039^{B}	0.2927 ±0.0021^{A}	19.29	**<0.001***

Means with different superscript letters within the same horizontal rows are significantly different *; significant (p ≤ 0.05) ns; non-significant (p>0.05)

Correlation between color change and surface roughness:

Numerical correlations were shown between Brilliant Crios' color change and surface roughness in Table (6) and graphically in Fig. (3)

The results showed that there was no significant difference correlation between color changes (ΔE*) and surface roughness (Ra) which were (rs=0.073, p=0.395).

TABLE (6) Correlation between color change and surface roughness

r_s	p-value
0.073	0.395ns

rs=Spearman rank order correlation coefficient *; significant (p ≤ 0.05) ns; non-significant (p>0.05)

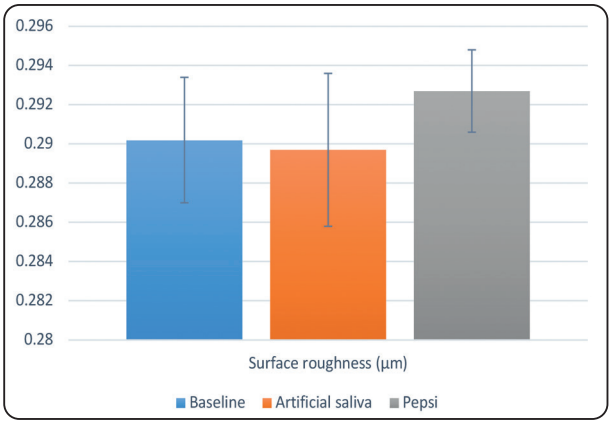

Fig. (2) Bar chart showing average surface roughness (μm) for baseline, artificial saliva and Pepsi

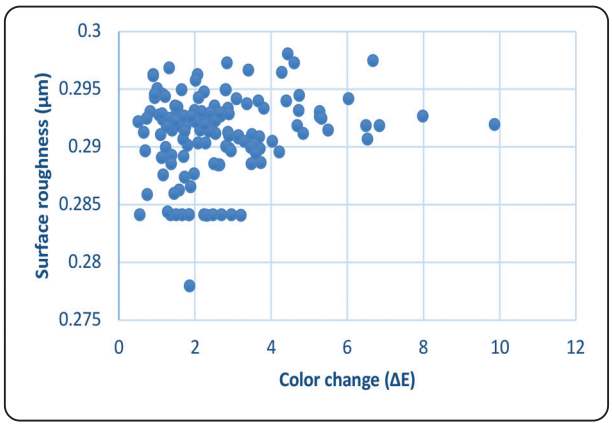

Fig. (3) Scatter plot showing the correlation between color change and surface roughness

DISCUSSION

Patients' awareness of aesthetics has grown over the last 20 years, and the effectiveness of newly developed CAD/CAM materials has been demonstrated. Therefore, in order to satisfy patients' high aesthetic standards, their optical behavior needs to be thoroughly studied. [8]

In the present study, recently introduced BRILIANT Crios which is a reinforced composite contain 70% glass and amorphous silica was selected. The elastic modulus of BRILLIANT Crios is 10 GPa, which is comparable to dentin's (11-19 GPa), reduced wear of opposing teeth, ease of milling, reduced susceptibility to chipping, and capacity for intraoral repair . Hence, these materials were chosen for testing in the current study because of their alleged benefits, as stated by the manufacturer.[9]

BRILLIANT Crios shade A2 LT was selected as this shade was the most commonly used in posterior provisional crowns fabrication due to suitability to color change and has low rigidity in comparison to dental ceramics.

The most popular acidic beverage among people at the time of the study's selection was Pepsi beverage solution. With a PH of 2.53, it is a strong acid made out of sugar, carbonated water, phosphoric acid, and caramel color. [10]

Dental restorative materials may undergo color and surface roughness changes when exposed to the oral cavity. These changes can be brought on by a number of factors, such as the material's kind, surface finishing, the patient's eating habits, and oral hygiene practices. The discoloration of dental materials caused by colored beverages, like coffee and Pepsi, can have an adverse influence on the aesthetic result and cause patients to become dissatisfied with their restorations. Acidic drinks with low pH levels may also weaken the surface integrity of the material, increasing wear and roughness on the surface and eventually causing discoloration. [11]

Therefore, this study aimed to evaluate the color change and surface roughness of reinforced composite (BRILIANT CRIOS) after immersion in artificial saliva then acidic beverage solution (Pepsi).

Because it was an in vitro study, it provided a uniform and controlled fabrication procedure and prevented the variation of natural tooth factors, which is crucial to provide data that is more similar to what would occur in a clinical situation.[12]

The low-speed sectioning machine, called the isoMet system, cut Brilliant Crios blocks with the least amount of waste and deformation. The minimum recommended thickness for these materials to be employed in fixed restorations was found to be 1mm for Brilliant Crios in this investigation. The measurements were 14 × 12 × 1 mm, which made it simple for the testing apparatus to record the results. Each sample's thickness was confirmed using a digital caliper to ensure that no factors might potentially influence the final color change and surface roughness results.[13]

Color change and surface roughness are closely related. Bacterial biofilms and stains seem to be more prevalent on rough surfaces. The impact of surface finishing techniques and polishing products on the material's color shift and surface roughness has been highlighted in numerous research. In order to achieve a smooth surface, the samples in this study were finished and polished using DIATECH polishers in accordance with the manufacturer's instructions. This was done by the same technician for standardization purposes to achieve flat surfaces, which would allow the spectrophotometer's contact tip to contact the surface without angulation.[13]

Following three weeks of immersion in a Pepsi beverage solution, surface roughness and color change were measured in this study. One week spent immersed in a laboratory is comparable to seven months of consuming one cup of coffee and one can of Coca-Cola every day, according to published research. In the current investigation, three weeks of immersion was the equivalent of twenty-one months of beverage consumption. [14]

To maintain a freshly mixed solution, artificial saliva and Pepsi beverage solution were also replaced on a daily basis. To replicate and sustain the ideal temperature of the oral cavity, all samples were housed in an incubator set at 37°. [15]

The color difference was measured in the current investigation using a Portable reflective spectrophotometer because it has been demonstrated to be more accurate and faster than other shade-taking techniques due to its reproducibility, ability to remove subjectivity and its portability. A color difference of 1 ΔE* may be detected with a spectrophotometer, although a color difference of 3.3 ΔE* can be detected visually. Since it is the most traditional and widely used method in research, the color difference was obtained in the study using the classical CIELab formula ΔEab. [16]

A 3D non-contact optical profilometer interference microscope, which has been demonstrated to be more dependable and superior in quantitative surface topographic investigation, was used to evaluate the surface roughness. In order to produce an accurate qualitative representation of the samples, it is additionally attached to a camera that takes a 3D surface texture image of the entire sample. [17]

Results showed that immersion media has significant effect on color change values.

Therefore, the first null hypothesis was that there will be no color change of reinforced composite (BRILIANT Crios) after immersion in artificial saliva then acidic beverage (Pepsi) was rejected.

Pepsi beverage solution showed a high stain impact on reinforced composite material (Brilliant Crios) in this study, which could be attributed to the presence of yellow pigments with low polarity which facilitating its penetration into the resin matrix. These findings were in agreement with **Eldwakhly et al. (2019); Stamenkovic et al. (2020)** who proved that the greatest color change of hybrid ceramics and nanocomposites were seen with Pepsi beverage solution. [18]

Furthermore, polymers frequently take up colors and water from the highly discolored chromogenic meal. According to studies, the hydrophilic nature of the TEGDEMA component of the polymer in Brilliant Crios is what causes color absorption. [19]

Therefore, the color change may be easily related to the nature of this resin matrix. The presence of TEGDMA content may lead to water uptake and, consequently, color variations induced by the absorption of the staining solution (Pepsi). [20]

The second null hypothesis was that there will be no surface roughness of reinforced composite (BRILIANT Crios) after immersion in artificial saliva acidic then beverage (Pepsi) was rejected.

The readings were close to the threshold (0.2μm), which was thought to be a clinically acceptable limit for surface roughness, therefore even with statistical significance, the difference was clinically insignificant. This means that there will be a higher chance of plaque buildup and stain formation if the value has surpassed this level.

According to manufacture the decrease in surface roughness after immersion in artificial saliva could be due to the absorbed water which either filled porosities or was absorbed in the polymer matrix itself leading to expansion of the material and thus initiate a smooth surface.[21]

The increase in surface roughness after immersion in Pepsi could be due to the effect of acid in degrading the matrix and exposing rough surfaces.[22]

Being an in-vitro study, one of the study's shortcomings was that it didn't accurately represent the conditions that exist in the oral cavity and other influencing elements like occlusion, temperature fluctuations, PH levels, and water. Additionally, the curves and convexities of the tooth structure's three-dimensional shape were not replicated by the flat samples. Thus, further in-vivo research should be done to improve correlation with clinical contexts.

CONCLUSION

Within the limitations of this study, it was concluded that:

1. BRILIANT Crios showed color changes above the clinical acceptable limit when immersed in artificial saliva and Pepsi.

2. Increase the Surface roughness will affect color changes.
3. Surface roughness will increase when immersing in acidic media

REFERENCES

1. Shenoy A, Shenoy N. 2010''Dental ceramics: An update. J Conserv Dent.;13(4):195-203.
2. Jassim ZM, Majeed MA. Comparative evaluation of the fracture strength of monolithic crowns fabricated from different all-ceramic CAD/CAM materials (an in vitro study). Biomed & Pharmacol J. 2018; 11(3):1689-1697.
3. Gracis S, Thompson V, Ferencz J, Silva NR, Bonfante E.A new classification system for all-ceramic and ceramic-like restorative materials. Int J prosthodont.2015; 28(3): 227-235.
4. Seyidaliyeva, A., Dipl.-ing, S.R., Evagorou, Z., Hassel, A.J., Rammelsberg, P., and Zenthöfer, A. (2020). Color Stability of Polymer-Infiltrated-Ceramics Compared with Lithium Disilicate Ceramics and Composite, J Esthet Restor Dent. 32:43–50
5. Özarslan, M.M, Büyükkaplan, U.Ş., Arslan, M., and Türker, N. (2016). Effects of Different Surface Finishing Procedures on the Change in Surface Roughness and Color of a Polymer Infiltrated Ceramic Network Material. The Journal Of Advanced Prosthodontics 8 (1): 16– 20.
6. M. Reymus et al.Food solutions and cigarette smoke-dependent changes in color and surface texture of CAD/CAM resin composites - an in vitro study Int. J. Prosthodont.(2021)
7. Elwardani G, Sharaf AA, Mahmoud A. (2019) Evaluation of colour change and surface roughness of two resin-based composites when exposed to beverages commonly used by children: an in-vitro study. Eur Arch Paediatr Dent. Jun; 20(3):267-276.
8. Colombo, M., Poggio, C., Lasagna, A., Chiesa, M., & Scribante, A. (2019). Vickers micro-hardness of new restorative CAD/CAM dental materials: evaluation and comparison after exposure to acidic drink. Materials, 12(8), 1246.
9. Arocha M.A., Basilio, J., Llopis, J., Bella, E.D., Roig, M., Ardu, S., Mayoral, J.R. (2014). Colour Stainability of Indirect CAD – CAM Processed Composites vs. Conventionally Laboratory Processed Composites after Immersion in Staining Solutions. Journal of Dentistry. 42(7): 831-8.
10. Alencar-Silva, Flávia J., et al. (2019): "Effect of beverage solutions and toothbrushing on the surface roughness, microhardness, and color stainability of a vitreous CAD-CAM lithium disilicate ceramic." The Journal of prosthetic dentistry 121.4 711-e1.
11. Yu, O.Y., Zhao, I.S., Mei, M.L., Lo, E.C., and Chu, C.H. (2017). A Review of the Common Models Used in Mechanistic Studies on Cariology Research. Dentistry Journal 5(2): 20
12. Acar O, Yilmaz B, Altintas SH, Chandrasekaran I, Johnston-WM. (2016)''Color stainability of CAD/CAM and nanocomposite resin materials. J Prosthet Dent; 115: 71-75.
13. Ossama B. Abouelatta. (2010); 3D Surface Roughness Measurement Using a Light Sectioning Vision System. Proceedings of the World Congress on Engineering Vol I.
14. Lauvahutanon, S., Iwasaki, N., Oki, M., and Finger,W.J. (2017). Discoloration of Various CAD / CAM Blocks after Immersion in Coffee Restorative Dental Endodontic Journal 42(1): 9-18.
15. El Sayed, S.M., Basheer, R.R., and Bahgat, S.F. (2016). "Color stability and fracture resistance of laminate veneers using different restorative materials and techniques." Egyptian Dental Journal 62(1): 1-15.
16. Incesu, E., and Yanikoglu, N. (2016). Evaluation of the Effect of Different Polishing Systems on the Surface Roughness of Dental Ceramics. The Journal of Prosthetic Dentistry, 124(1) 100–109.
17. Stamenkovic, D.D., Tango, R.N., Todorovic, A., Karasan, D., Sailer, I., Paravena, R.D. Staining and Aging-Dependent Changes in Color of CAD-CAM Materials, The Journal of Prosthetic Dentistry 126(5):672-678.
18. Quek SHQ, Yap AUJ, Rosa V, Tan KBC, Teoh KH. (2018)'' Effect of staining beverages on color and translucency of CAD/CAM composites. J Esthet Restor Dent; 30: E9-E17.
19. Soderholm KJ. Leaking of filler in direct composites. J Dent Res 1983;62 :126-30.
20. Vichi A, Ferrari M, Davidson CL. Color and opacity variations in three different resin-based composite products after water aging. Dent Mater. 2004;20(6):530–534.
21. Kurt A., Çelik G. (2018) Evaluation of physical and optical propertıes of hybrid CAD/CAM materıals. J Dent Fac Atatürk Uni.; 28: 498-503.
22. Koizumi, Hiroyasu & SAIKI, Osamu & NOGAWA, Hiroshi & Hiraba, Haruto & OKAZAKI, Tomoyo & MATSUMURA, Hideo. (2015). Surface roughness and gloss of current CAD/CAM resin composites before and after toothbrush abrasion. Dental Materials Journal. 34. 881-887. 10.4012/dmj.2015-177.