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Research Article

Assessment of Color Stability and Surface Roughness of Esthetic Restorative Materials

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Abstract

Background: Recently composite inlays, onlays, veneers and crowns can be constructed by CAD/CAM techniques using prefabricated composite resin blocks manufactured under controlled conditions.

Objectives: This study was carried out aiming to shed the light on the effects of different oral media on the surface roughness and color changes of two esthetic restorations.

Materials and Methods: In this study a total of thirty disc samples were machine milled by the aid of CAD/CAM system. The samples were divided according to the material of construction into two main groups. Each group was composed of 15 samples as follows: **Group I:** constructed from milled composite resin blocks. Group II: constructed from milled feldspathic porcelain blocks. All sample groups were then immersed in 20ml of artificial saliva for 24 hours to be baseline assessment. Each group was further subdivided into three subgroups each of five samples according to the type of immersion media. The samples of subgroup (1) were immersed in the acid media for 12 days. For subgroup (2) the samples were immersed in topical fluoride agent for 6 hours. While for subgroup (3) the samples were immersed in the mouth wash for 12 hours. All immersion times were equivalent to consumption of the materials of immersion media for one year by the patient.

Results: Composite samples that immersed in mouth wash showed statistically significant higher Ra value compared to the ceramic samples that immersed in the mouth wash which showed statistically significant lower Ra value. Spectrophotometer measurements of all the groups and subgroups revealed statically significant higher mean ΔE values for ceramic groups than the composite resin groups. All changes in the color were clinically acceptable except for ceramic samples that immersed in acid media.

Conclusion: Clinically unacceptable color change (ΔE) was encountered with ceramic samples immersed in acid media while the color change (ΔE) of the remaining groups was acceptable for both materials.

Keywords: *CAD/CAM System; Surface Roughness; Color Stability; Esthetic Restorative Materials*

Introduction

Esthetic dentistry is intricately linked with all-ceramic dental restorations. When it comes to prosthetic dentistry, all-ceramic materials are the ideal materials to meet the requirements associated with patients' and dentists' esthetic and cosmetic needs. All-ceramic restorations, with no metal substructure, allow superior translucency and can be used where esthetics are paramount. In spite of the advantages of all-ceramic restorations, including esthetic appearance, biocompatibility, and durability, such materials have some disadvantages. The potential of brittle catastrophic fracture and abrasive wear of the opposing natural teeth are considered among these disadvantages. Also, from the practical point of view, fragility during trial insertion and cementation, and toxicity of hydrofluoric acid are also considered as disadvantages. So, there was a need to look for other materials with properties better than the ceramic. Recently composite inlays, onlays, veneers and crowns can be constructed by CAD/CAM techniques using prefabricated composite resin blocks manufactured under controlled conditions [1]. There is increasing interest in the use of composite resin blocks, due to their optimal stiffness and wear characteristics and because they offer some advantages over feldspathic ceramics. Composite resin restorations are near to the fracture resistant of feldspathic ceramics. In addition, they can be modified for esthetic or functional reasons with the simple in-office procedure, in contrast to ceramics, which usually require laboratory firing to add ceramic and to accomplish the definitive surface glazing. Furthermore, the adhesive treatment of a composite resin restoration is safer because it does not require the use of hydrofluoric acid, which is indicated for surface treatment of "etchable" feldspathic and glass ceramics. This is important when the clinician must manage repairs of a restoration intraorally [2]. Many researches in the last years are concerned with the ability of esthetic restorative materials to withstand the variable changes in the oral environment, especially changes in pH values. It was believed that, surface roughness may affect esthetic by changing the surface textures of esthetic restoration, increasing the scattering of incident light and consequently affecting the color stability [3]. Thereby, this study was carried out aiming to shed the light on the effects of different oral media on the surface roughness and color changes of two esthetic restorations.

Classification of ceramics based on processing techniques:

For ease of understanding, classification according to processing techniques [4] is advocated. Generally, there are

1. Powder slurry technique
2. Pressing ceramic
3. Machinable ceramic

The construction technique determines the properties relevant to clinical performance. Specifically, a machined block is assumed to perform better than powder/liquid versions of the same material [5].

Composite resin blocks for fixed restorations

A new resin-based composite material has been introduced for use in fabricating CAD/CAM restorations. The manufacturer claims several advantages over restorations milled from CAD/CAM ceramic blocks this include easier finishing and polishing, kindness to the natural dentition with regard to wear and easier to make add-on adjustment. Paradigm MZ100 Block is a strong, wear-resistant, and esthetic mill block that provides a fast and easy-to-use alternative to porcelain blocks restorations. Paradigm MZ100 blocks are made from 3M Z100 Restorative material under optimized process conditions that assure thorough cure and a high degree of crosslinking. This process contributes to excellent physical properties and clinical performance. Paradigm MZ100 blocks are designed for use in the CEREC system and are mounted on a mandrel for use in CEREC machines. Paradigm MZ100 material is radiopaque. Paradigm MZ100 restorations are bonded to tooth structure with an adhesive resin cement such as 3M RelyX ARC Adhesive Resin Cement [6]. Paradigm MZ100 block material contains 85 wt% ultrafine zirconia-silica ceramic particles that reinforce a highly crosslinked polymeric matrix. The polymer matrix consists of bisGMA (Bisphenol A diglycidyl ether dimethacrylate) and TEGDMA (tri[ethylene glycol] dimethacrylate), and employs a patented ternary initiator system. The ultrafine zirconia-silica filler particles are synthesized by a patented sol-gel process that results in a unique structure of nanocrystalline zirconia dispersed in amorphous silica. The particles have a spherical shape, and an average particle size of 0.6 micrometer. The filler imparts radiopacity, wear resistance, and strength. These fillers and polymer components yield a resilient composite with excellent strength and wear, high polish ability, lifelike esthetics, and superb milling characteristics [7].

Surface roughness

Surface roughness (Ra) refers to the finer irregularities of the surface texture that usually result from the action of the manufacturing process or material condition and is measured in micrometers or microinches [8]. It is an important characteristic of dental materials. Materials with roughened surfaces enhance bacterial adhesion, have smaller free surface energy. In addition to promoting plaque adherence, roughened materials also suffer from increased staining. Surface roughness affect esthetic by changing the texture of esthetic restoration, so it affects the color stability by increasing scattering of incident light [9]. Surface roughness decreases luster resulting in dull, non-esthetic restorations. It is therefore an important variable to consider when examining the effects of orally ingested materials to be highly conscious of the aesthetics of their dentition. Brief survey of some of the surface roughness measurement techniques currently available showed that, Stylus profilometer are the most common instruments used today for roughness measurement; however, more recent techniques such as Scanning Tunneling Microscopy (STM) and Atomic Force Microscopy (AFM) have presented improved spatial resolution and are, therefore, suitable for capturing finer details. Light-section microscope and Scanning Electron Microscopes (SEM) are also used to measure the surface roughness.

Color system in dentistry

The modern understanding of color originated in the discovery of the spectral nature of light by Isaac Newton in the 1600s. Newton considered light to be a stream of particles. His experiments with prisms showed that white light can split into individual colors [10]. Furthermore, he noted that light of different colors had different refrangibility, for example blue light is refracted more than red light, when it passes from air into a medium of higher refractive index such as a prism. We now know that Newton`s famous experiments demonstrated that light consists of energy of different wavelengths. The eye is sensitive to broad band of wavelengths with approximated range 380-780 nm. The visible spectrum represents only a small fraction of the full electromagnetic spectrum. Within the visible spectrum certain wavelengths give rise to certain visual sensations. For example, the shorter wavelengths are perceived to be violet and blue [11]. The perceived color response results from a reflection or absorption of transmitted white light beam. The eye can distinguish differences in only three parameters of color. These parameters are wavelength, luminous reflectance and excitation purity [11]. The color of an object is influenced by its physical properties, the nature of the incident light on the object, the relationship to the surrounding colored objects and the subjective assessment of the observer. These factors can cause a tooth to look very different among different observers i.e. two surfaces match under one type of light but not match under one or more other types of light. This phenomenon is called metamerism [12]. For a variety of reasons such as worldwide recognition, consistency, flexibility and simplicity the Munsell color system is the system of choice for visual measurements and color matching in dentistry. Hue, value and chroma are the dimensions which describe color in Munsell system [13].

Hue, the first dimension of color, is the easiest to understand and in Munsell`s words "it is that quality by which we distinguish one color family from another, as red from yellow, green from blue or purple". Value, the second dimension of color, is the degree of lightness or darkness of a color in relation to a natural gray scale extending from absolute black to absolute white [9]. Because the human observer is so very sensitive to slight differences in value, it is the most important color dimension in dentistry.

Chroma, it is that quality by which we distinguish a strong color from a weak one. Chroma describes the amount of hue in the color i.e. chroma is only present when there is hue [11]. Instrumentally color is measured and expressed in term of 3 coordinate value (L*. a*, b*) which locate the object`s color within the CIELAB color space. The L* coordinate value represent the brightness of an object, the a* value represents the red or green chroma, and the b* value represents the yellow or blue chroma [10]. The color difference (ΔE) of 2 objects can then be determined by comparing the differences between respective coordinate values for each object. The formula used for calculating color differences in this system is shown below:

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

When ΔL*.Δa* and Δb* are different in color parameters for the 2 specimens measured for comparison [13].

Materials

In the present study the following materials were used:

1. CAD/CAM composite resin blocks (Paradigm MZ 100 Blocks; 3M ESPE, St. Paul, Minn)
2. CAD/CAM feldspathic porcelain blocks (Sirona CEREC blocs, Sirona dental company. GmbH. Fabrikstrasse 31 D- 64625, Bensheim Germany).
3. Artificial saliva.
4. Acid media (mirinda, orange, Pepsi Cola, Cairo, Egypt).
5. Topical Fluoride (Alpha-dent Home care fluoride gel, Dental technologies, 6901 N HAMLIN AVENUE, LINCOLNWOOD, ILLINOIS 60712 USA)
6. Mouth wash (Antiseptol, KAHIRA PHARMA and CHEM.IND.CO)

The composition and manufacturer of used materials are presented in table 1.

Material	Product	Composition	Manufacturer
CAD/CAM composite blocks	Paradigm MZ100 block for Cerec	Contains 85 wt% ultrafine zirconia-silica ceramic particles that reinforce a highly crosslinked polymeric matrix.	3M ESPE
CAD/CAM feldspathic porcelain blocks	Cerec blocs	Fine-structure feldspar ceramic, SiO_2 56 - 64%, Al_2O_3 20 - 23%. Na_2O 6 - 9%, K_2O 6 - 8%, CaO 0,3 - 0,6%, TiO_2 0,0 - 0,1% of total weight	Sirona dental company
Acid media	Mirinda orange beverage (acidic medium), pH = 2.85.	Carbonated water, sugar, citric acid, emulsifiers, natural flavor.	Pepsi Cola, Cairo, Egypt
Topical Fluoride	Alpha-dent Home care fluoride gel	0.4% stannous fluoride, ascorbic acid, carbomer, citric acid, flavor, glycerin, triethanolamine.	Dental technologies
Mouth wash	Antiseptol	Chlorohexidine gluconate 0.1%, ponceaur 4R (E124), a synthetic "coal tar" dye and azodye.	KAHIRA PHARMA and CHEM. IND.CO
Artificial saliva	Composition: 2.2 g/L gastric mucin, 0.381 g/L sodium chloride, 0.231 g/L calcium chloride, 0.738 g/L potassium phosphate, 1.114 g/L potassium chloride, 0.02% sodium azide, trace of sodium hydroxide to PH 7.0 [18].		In chemistry lab

***Table 1:** The composition and manufacturer of the used materials.*

Methods

This study was carried out aiming to shed the light on the effects of different oral media on the surface roughness and color changes of two esthetic restorations. In this study a total of thirty disc samples were machine milled by the aid of CAD/CAM system. The samples were divided according to the material of construction into two main groups. Each group was composed of 15 samples as follows:

- **Group I:** Constructed from milled composite resin blocks.
- **Group II:** Constructed from milled feldspathic porcelain blocks.

All sample groups were then immersed in 20ml of artificial saliva for 24 hours to be baseline assessment. Each group was further subdivided into three subgroups each of five samples according to the type of immersion media. The samples of subgroup (1) were immersed in the acid media for 12 days. For subgroup (2) the samples were immersed in topical fluoride agent for 6 hours. While for subgroup (3) the samples were immersed in the mouth wash for 12 hours. All immersion times were equivalent to consumption of the materials of immersion media for one year by the patient. For quantitative evaluation of surface roughness, all samples were subjected to profile metric measurements. While fore qualitative assessment of the surface topography SEM evaluation was carried out for selected samples from the different groups and subgroups. Color measurement tests were also conducted for all the samples by spectrophotometer. These measurements were made twice, once after artificial saliva immersion and again after storage in different immersion media for the specific time. Student's t-test was used to compare between mean Ra and (ΔE) of the two groups. One- way Analysis of Variance (ANOVA) was used to compare between Ra and (ΔE) of different media and different interactions. Tukey's post-hoc test was used for pair-wise comparison between the mean values when ANOVA test is significant. Pearson's correlation coefficient was used to determine significant correlation between surface roughness and color changes. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

Results

Results of the surface roughness measurements

Results of the effect of material type on the surface roughness

In artificial saliva, there was no statistically significant difference between samples in the ceramic group (0.95 μm ± 0.21) and composite group (0.69 μm ± 0.20) at $P \leq 0.05$.

For acid media, there was no statistically significant difference between the ceramic group (1.18 μm ± 0.41)) and composite group (1.23 μm ± 0.19) at $P \leq 0.05$.

Also, for topical fluoride, there was no statistically significant difference between the ceramic group (1.15 μm ± 0.26) and composite group (1.21 μm ± 0.29) at $P \leq 0.05$.

In case of mouth wash, the composite group showed statistically significant higher means Ra value (1.05 μm ± 0.20) than ceramic group (0.51μm ± 0.06) at $P \leq 0.05$.

All values for the tested materials and media are presented numerically in table 2 and graphically in figure 1.

Materials	Composite		Ceramic		P-value
Media	**Mean**	**SD**	**Mean**	**SD**	
Saliva	0.69	0.20	0.95	0.21	0.087
Acid	1.23	0.19	1.18	0.41	0.829
Fluoride	1.21	0.29	1.15	0.26	0.767
Mouth wash	1.05	0.20	0.51	0.06	<0.001*

Table 2: *The mean, standard deviation (SD) of Ra values of tested materials as affected by the different immersion media.*
**: Significant at P ≤ 0.05.*

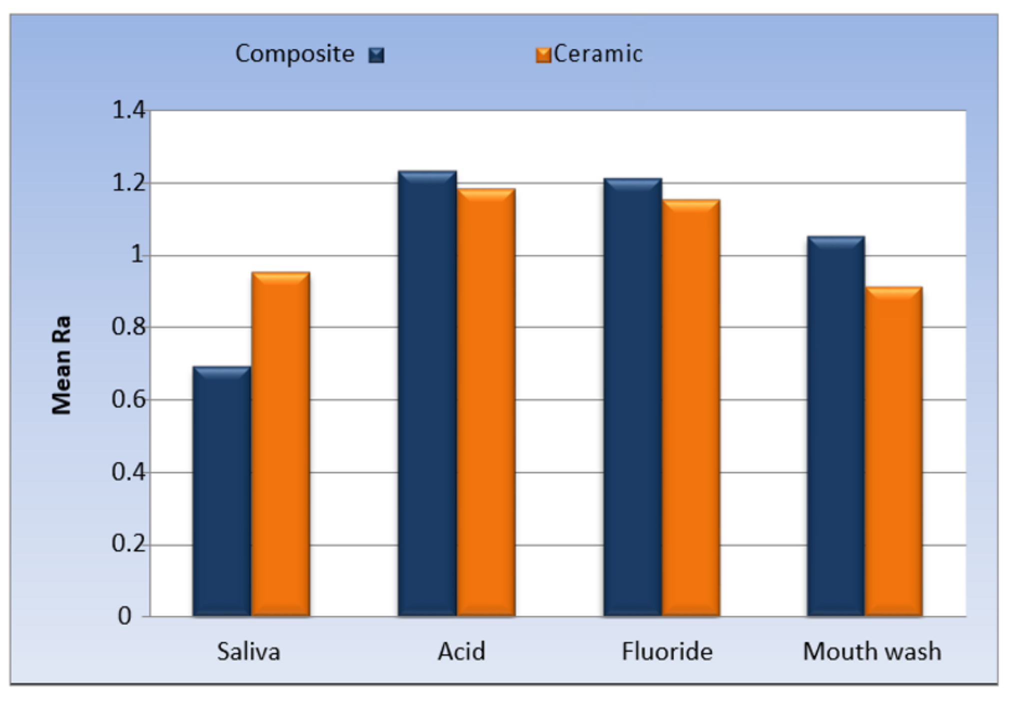

Figure 1: *Histogram of mean Ra values of tested materials as affected by the different immersion media.*

Results of the effect of different media on the surface roughness of tested materials

For group I (composite resin)

There was no statistically significant difference between Ra values after immersion in acid (1.23 µm ± 0.19), fluoride (1.21 µm ± 0.29) both showed the statistically significantly highest mean Ra values. Mouth wash showed significantly lower mean value. (1.05 µm ± 0.20) and saliva showed the statistically significantly lowest mean Ra value (0.69 µm ± 0.20) at P ≤ 0.05.

For group II (ceramic)

There was no statistically significant difference between acid media (1.18 μm ± 0.21) and Fluoride (1.15 μm ± 0.26); both showed the statistically significant highest mean Ra values. Saliva showed significantly lower mean Ra value (0.95 μm ± 0.26). Mouth wash showed the statistically significant lowest mean Ra value (0.51 μm ± 0.06) at P ≤ 0.05. All values for the tested materials and media are presented numerically in table 3.

Material	**Composite**		**Ceramic**	
Media	**Mean**	**SD**	**Mean**	**SD**
Saliva	0.69^{c}	0.20	0.95^{b}	0.21
Acid	1.23^{a}	0.19	1.18^{a}	0.41
Fluoride	1.21^{a}	0.29	1.15^{a}	0.26
Mouth wash	1.05^{b}	0.20	0.51^{c}	0.06
P-value	0.001*		0.004*	

***Table 3:** The mean, standard deviation (SD) of Ra values as affected by the material types.*

**: Significant at P ≤ 0.05, Different letters are statistically significantly different according to Tukey's test.*

Comparison between different interactions

There was no statistically significant difference in Ra values between the composite resin samples immersed in acid (1.23 μm ± 0.19), composite resin samples with fluoride application (1.21 μm ± 0.29), ceramic samples immersed in acid (1.18 μm ± 0.21) and ceramic with Fluoride application (1.15 μm ± 0.26); all showed the statistically significantly highest mean Ra values at P ≤ 0.05.

There was no statistically significant difference between composite resin samples immersed in mouth wash (1.05 μm ± 0.26) and ceramic samples immersed in saliva (0.95 μm ± 0.21); both showed lower mean Ra values at P ≤ 0.05. This was followed by composite samples immersed saliva (0.69 μm ± 0.20) which showed significantly lower mean value at P ≤ 0.05. Ceramic samples immersed in mouth wash showed the statistically significantly lowest mean Ra value (0.51 μm ± 0.06) at P ≤ 0.05. All values for the tested materials and media are presented numerically in table 4.

Material x Media	**Mean**	**SD**	**P-value**
Composite x Saliva	0.69^{c}	0.20	< 0.001*
Composite x Acid	1.23^{a}	0.19	
Composite x Fluoride	1.21^{a}	0.29	
Composite x Mouth wash	1.05^{b}	0.20	
Ceramic x Saliva	0.95^{b}	0.21	
Ceramic x Acid	1.18^{a}	0.41	
Ceramic x Fluoride	1.15^{a}	0.26	
Ceramic x Mouth wash	0.51^{d}	0.06	

***Table 4:** The mean and standard deviation (SD) of Ra values for the interactions between tested materials and different immersion media.*

**: Significant at P ≤ 0.05, Different letters are statistically significantly different according to Tukey's test.*

Results of the effect of different media on the color change (ΔE) of the tested materials

Results of the effect of material type on the color change (ΔE)

For acid media, the ceramic group showed statistically significant higher mean ΔE value (4.77 ± 0.34) than composite group (3.02 ± 0.35) at P ≤ 0.05.

While for topical fluoride media, the ceramic group showed statistically significant higher mean ΔE value (2.58 ± 0.35) than composite group (1.71 ± 0.25) at P ≤ 0.05.

In case of mouth wash media, the ceramic showed statistically significant.

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Higher mean ΔE value (0.97 ± 0.09) than composite group (0.62 ± 0.05) at $P \leq 0.05$.

All values for the tested materials and media are presented numerically in table 5.

Material	**Composite**		**Ceramic**		
Media	**Mean**	**SD**	**Mean**	**SD**	**P-value**
Acid	3.02	0.35	4.77	0.34	< 0.001*
Fluoride	1.71	0.25	2.58	0.35	0.002*
Mouth wash	0.62	0.05	0.97	0.09	< 0.001*

Table 5: *The mean, standard deviation (SD) of ΔE values of tested materials as affected by the different immersion media.*
**: Significant at P ≤ 0.05.*

Discussion

With regard to the effect of immersion media on the surface roughness of the tested materials, results of the present study demonstrated a statistically significant increase in surface roughness of composite resin samples after immersion in all tested media, compared to the roughness recorded after immersion in artificial saliva. The Ra value of composite resin samples immersed in acid media (Ia) was significantly higher (1.23 μm) than the control group (0.69μm), this may be due to hydrolytic degradation of the composite resin surface in aqueous environment and deterioration of its surface by the acidity of citric acid in the selected beverage. This finding was in agreement with Lussi., *et al.* [14] who reported that the erosive activity of citric acids as ingredients of beverages. This result was supported also by liberman., *et al.* [15] who found that, an aqueous environment can interfere with the characteristics of composite resin and even lead to hydrolytic degradation over time. Results of the current study are also consistent with the findings of Fay., *et al.* [16] and Hamouda [17]. They reported that increased consumption of low pH beverage, caused deterioration of the composite resin materials' surfaces. The Ra value of composite resin samples subjected to topical fluoride application (If) was also significantly higher (1.21 μm) than control group (0.69 μm). The data also indicated that 0.4% SnF_2 (pH = 4), caused increase in Ra values due to erosive action of its acidity. This finding was in agreement with the study of Yeh., *et al.* [18] who reported the dissolution effect of acidulated phosphate fluoride (APF) on composite filler particles.

Regarding the effect of the immersion media on the color change of the tested materials, results of the current study revealed statistically significant color changes in composite resin samples after immersion in the tested media but still clinically acceptable according to Um and Ruyter [19]. Composite resin samples immersed in acid media recorded the highest ΔE value (3.02) followed by composite resin samples with topical fluoride application (1.71) and mouth wash (0.62) respectively. Results of the present study also revealed a statically significant color changes (ΔE) in ceramic samples after immersion in the tested media. According to Um and Ruyter [19] this color change was clinically unacceptable for ceramic samples immersed in acid media (4.77) but the color change for ceramic samples subjected to topical fluoride and immersed in mouth wash was clinically acceptable (2.58 and 0.97 respectively).

By comparing the results of ΔE values of the ceramic groups with the composite resin groups, all ceramic groups showed statically significant higher ΔE values than composite resin groups after the immersion in different media. This finding was in agreement with the study of Fasbinder [20] who found the resin based composite inlays had a significantly better color match than did the ceramic inlays at three years. In this *in vitro* study, the most significant finding was that both types of restorative materials are susceptible to roughness and color change with acid media. However, it must be noted that there were some limitations to this study. This study did not account for the role of saliva. The effect of acidic food or drinks will be reduced because of its dilution effects and through the action of buffering systems. Furthermore, the oral cavity presents a more complex testing environment.

Conclusion

Within the limitations of this study the following conclusions were derived:

1. Increasing the acidity of immersion media by lowering the pH value resulted in increase in the surface roughness of the tested restorative materials (composite resin and ceramic).
2. Clinically unacceptable color change (ΔE) was encountered with ceramic samples immersed in acid media while the color change (ΔE) of the remaining groups was acceptable for both materials.

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