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# USAF Graduate Prosthodontics Master of Science Committee



## Report on Oral Examination

We the undersigned, as participants of the USAF Master of Science Committee, report that on 8 Mar 2018 we examined CPT Farzan Pouranfar regarding his (her) (protocol / thesis) defense for a research project entitled: Effect of Toothbrushing on Surface Characterization of Ceramic-Polymer Materials

By signing our names below we recommend (approval / disapproval) for the aforementioned resident to proceed with the process of obtaining a Master of Science degree from the Uniformed Services University of the Health Sciences (USUHS).

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Comments/Recommendations: PRE + POST Block THICKNESS REF: STAIN THICKNESS  
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**Effect of Tooth Brushing on Surface Color of Ceramic-Polymer Materials: An In Vitro Study**

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## Effect of Toothbrushing on Surface Characterization of Ceramic-Polymer Materials

### ABSTRACT

New millable ceramic-polymer materials have been introduced with claims of convenient placement of visible-light-cured extrinsic stains. **Purpose:** The purpose of this study was to examine the effects of toothbrushing on the change in color of extrinsic characterization of ceramic-polymer materials. **Materials and Methods:** Two ceramic-polymer materials (Cerasmart, GC; Enamic, Vita) and one lithium-disilicate material (IPS e-max CAD; Ivoclar Vivadent) were examined. Each block material was characterized and glazed per manufacturer's instructions. Specimens were then brushed in a toothpaste slurry with artificial saliva using a toothbrush machine with a soft toothbrush. CIE - L\*a\*b\* values were recorded with a spectrophotometer at baseline and at 3, 6, 9, and 12-year equivalent simulated years of brushing (7,300 strokes/yr). A mean change in color ( $\Delta E^*$ ) and standard deviation were determined for each group and brushing interval. **Results:** Cerasmart and Enamic had a significantly greater  $\Delta E^*$  compared to IPS e.max CAD at each time interval. The  $\Delta E^*$  was not significantly different between Cerasmart and Enamic except at 3 years. Cerasmart and Enamic had a significant increase in  $\Delta E^*$  between each time interval, whereas for IPS e.max CAD, the increase in  $\Delta E^*$  was only significant at 9 and 12 years of brushing. **Conclusions:** The extrinsic stains on the ceramic-polymer materials may be more susceptible to change from toothbrushing compared to the lithium-disilicate material. However, the change may only be clinically perceptible to the naked eye ( $\Delta E^* > 2.3$ ) after 9 years of brushing the ceramic-polymer materials.

KEYWORDS: Extrinsic stains, ceramic-polymers, brushing

## INTRODUCTION

The creation of dental restorations which mimic natural teeth is increasingly important in restorative dentistry.<sup>1</sup> Improved materials, technique, and shade selection systems have made this goal attainable. Custom coloration is commonly employed to mimic the broad range of colors and characteristics displayed by natural teeth.<sup>2</sup> Ceramic restorations are customized via superficial application of pigments (commonly known as “extrinsic staining”). These pigments are strategically applied using a fine brush to create desired effects.<sup>3-5</sup>

Unlike intrinsic characterization of ceramic restorations, the extrinsic characterization is in direct contact with the oral environment and abrasives, and therefore at higher risk of fading.<sup>5</sup> Consequently, as a result it has been recommended that extrinsic stains be placed as deeply as possible to enhance longevity.<sup>6</sup> It is well accepted that toothbrushing with fluoride toothpaste is the most effective approach for plaque removal and dental caries prevention.<sup>7-9</sup> It is therefore recommended to brush twice a day for two minutes.<sup>7</sup> Unfortunately, abrasives are commonly integral to toothpastes and may have an adverse effect on surface characterization of restorations. Garza *et al.* demonstrated that twelve years of toothbrushing did not produce a clinically relevant shade change or increase in the surface roughness of extrinsically stained and/or glazed IPS e.max Press (Ivoclar Vivadent, Amherst, NY) pressable ceramics.<sup>10</sup> Aker *et al.* indicated the use of a normal toothbrush with a common toothpaste could wear away surface characterization applied to feldspathic porcelain restorations in a period of 10-12 years. However, colors lasted longer when a layer of protective glaze was applied.<sup>5</sup>

There are three main groups of dental ceramic and ceramic-like materials available – glass-matrix, polycrystalline, and ceramic polymers.<sup>11</sup> Glass-matrix ceramics contain nonmetallic inorganic ceramic materials that present with a glass phase. These materials tend to be the most esthetic, but have lower flexural strengths, and they are relatively

brittle. Polycrystalline ceramics contain nonmetallic inorganic ceramic materials that do not present any glass phase. These materials usually exhibit high flexural strength, but lack esthetics without extrinsic staining or esthetic ceramic veneering. Ceramic polymers are made up of predominantly inorganic refractory compounds that usually include porcelains, glasses, ceramics, glass-ceramics, in addition to organic polymers. These materials have a modulus of elasticity close to that of dentin, and they are not as brittle as the glass-matrix and polycrystalline ceramics. Nevertheless, ceramic polymers may require extrinsic staining to achieve acceptable clinical esthetics.<sup>11</sup>

The new ceramic-polymer materials appear to fall on a spectrum between polymer and ceramic, with some materials, such as Lava Ultimate (3M ESPE, St. Paul, MN), Cerasmart (GC America, Alsip, IL), and Shofu HC (Shofu, San Marcos, CA) containing primarily polymer materials. On the other hand, Enamic (Vita, Yorba Linda, CA), reportedly contains more ceramic material.<sup>11-14</sup> In this study, the longevity of light-cured characterization was of interest. Two ceramic-polymer materials, Cerasmart and Enamic, were chosen because they represent both ends of the spectrum of ceramic-polymer materials and are marketed with a dedicated proprietary light-polymerized staining kit. Cerasmart is composed of a combination of bis-methacryloxyethoxy phenyl propane (BisMEPP), urethane dimethacrylate (UDMA), and dimethacrylate (DMA) with silica and barium glass fillers at 71% by weight. GC claims Cerasmart is a “force absorbing hybrid ceramic CAD/CAM block”, with the same flexible amorphous nano-ceramic technology as their G-aenial Universal Flo composite material (200-nm strontium glass particles).<sup>13</sup> Enamic is composed of predominately a feldspar-ceramic network enriched with aluminum oxide (86% wt or 75% vol) and a polymethyl-methacrylate (14% wt or 25% vol) that permeates the feldspar-ceramic matrix to yield a restorative material that is both strong and elastic as claimed by the manufacturer.<sup>14</sup> The glass-ceramic, lithium disilicate (IPS e.max CAD, Ivoclar Vivadent) was chosen as the control because it is a commonly used

material that has been well studied and clinically successful with over 96% success rate.<sup>15</sup> The material is milled in an intermediate blue state composed of 40% lithium metasilicate crystals. After crystallization, the material crystallizes to approximately 70% fine-grain lithium disilicates, creating increased strength and wear resistance.<sup>15</sup>

Extrinsic characterization of dental restoratives is usually carried out by applying a desired colorant to external surfaces of a restoration to achieve the desired effect. According to Ivoclar Vivadent technical instructions, for glass ceramics such as IPS e-max CAD, the characterized restoration must be placed in a ceramic oven capable of reaching temperatures of 840°C.<sup>16</sup> In contrast, both Vita and GC recommend extrinsic characterization via visible light polymerization of their methacrylate-based surface stains.<sup>17,18</sup>

No studies have reported the effect of toothbrushing on extrinsically characterized ceramic-polymer materials. The purpose of this *in vitro* study was to evaluate the effect of toothbrushing on the surface of ceramic-polymer materials, specifically surfaces treated with visible light-cured stains. Changes in color of the ceramic-polymer materials from the toothbrushing process were determined using the CIE (Commission Internationale de l'Eclairage) L\* a\* b\* color space. L\* indicates lightness (L+ = lightness and L- = darkness), the a\* coordinate represents the red/green range (a\*+ = redness and a\*- = greenness) and the b\* coordinate represents for the yellow/blue range (b\* + = yellowness and b\*- = blueness). The L\* a\* b\* system allows the numeric definition of a color as well as the overall difference between two colors ( $\Delta E^*$ ).<sup>19</sup> The null hypothesis suggested there would be no difference in the change in  $\Delta E^*$  based on type of ceramic material over 3, 6, 9, and 12 equivalent years of simulated toothbrushing.

## **MATERIALS AND METHODS**

Blocks from each of the three tested materials in shade A2 (Cerasmart, Enamic and IPS e.max CAD) were polished using an Ecomet 6 (Lake Bluff, IL) lapping table in conjunction with silicon-carbide paper which ranged from 320-grit through 420-grit. Each block's thickness was measured with a digital caliper and then covered with 120um-thick masking tape (3M) with a window cut in the area to be stained and glazed for standardization. The metal stubs of the IPS e.max CAD blocks were removed and the blocks were crystallized in a ceramic oven (Programat P500, Ivoclar Vivadent) followed by staining (IPS e.max shade 1) and glazing as per the manufacturer's recommendation utilizing the same masking tape method as stated above. The metal stubs were then reattached to the IPS e.max CAD blocks with a commercial adhesive (Gorilla Glue, Gorilla Glue Co., Cincinnati, OH). Using a digital caliper the thickness of the stain and glaze was measured to assure standardization. The stain and the glaze were each approximately 60um thick for each sample.

Enamic specimens were treated with the Vita Enamic Stain Kit according to manufacturer's instructions.<sup>17</sup> The surface was etched with a 9.5% hydrofluoric acid gel for 60 seconds and then steam cleaned. The cleaning solution included in the kit was applied and air-dried. Masking tape was used in the same manner described above for standardization of the extrinsic stain and glaze. Next, silane was applied and air-dried. Stain 3Brown was applied and light cured for 30 seconds with Bluephase G2 LED Curing Light (Ivoclar Vivadent). Glaze was applied with a clean disposable brush and light polymerized for an additional 60 seconds. A digital caliper was used to assure standardization of the stain thickness.

Cerasmart blocks were stained and glazed using Optiglaze (GC America) according to the manufacturer's instructions.<sup>18</sup> First, the Cerasmart blocks were sandblasted with 50 microns of aluminum oxide (AccuFlo, Comco Inc., Burbank, CA) at a

distance of 10mm at 80 PSI and then steam cleaned. Then, the Optiglaze Ceramic Primer II was applied and air-dried. Next, stain A-plus brown was applied and light cured for 40 seconds with the curing light as before. Finally, Optiglaze Clear was applied and light cured for 60 seconds. Baseline surface color measurements for individual blocks (CIE - L\*a\*b\*), were recorded with the spectrophotometer (Easysshade, Vita). A 3D printed index was utilized that held each block specimen and the spectrophotometer in the same orientation every time the color was measured. See Figure 1.

The specimens were mounted in a 10-station automated toothbrush machine (Sabri Dental Enterprises, Downers Grove, IL) using 3D-printed indexes. Soft filament toothbrush heads were sectioned from brush handles (GUM 311 Classic Toothbrush, Sunstar, Schaumburg, IL) and fixed to the machine brush arm. Each toothbrush head was applied to the stained surfaces with a force of 3N. All specimens were brushed for one-year intervals up to 12 equivalent-years of brushing with 87,600 strokes at a rate of 60 strokes per minute (1 Hz). Toothbrush heads were replaced every 7,300 strokes (one year equivalent).<sup>20</sup> An abrasive slurry consisting of toothpaste (Crest, Procter and Gamble, Cincinnati, OH) at a mixture of 21g per 80 mL of synthetic mouth fluid was utilized for experimental purposes. The synthetic saliva was prepared with the following solutions: Na<sub>3</sub>PO<sub>4</sub> - 3.90 mM NaCl<sub>2</sub> - 4.29 mM KCl - 17.98 mM CaCl<sub>2</sub> - 1.10 mM MgCl<sub>2</sub> - 0.08 mM H<sub>2</sub>SO<sub>4</sub> - 0.50 mM NaHCO<sub>3</sub> - 3.27 mM, distilled water, with a pH set to a level of 7.2.<sup>21</sup> A pH meter (Accumet XL50, Fisher Scientific, Waltham, MA) was used to measure pH. Specimens were removed from the automated toothbrush machine at prescribed intervals and color measurements were performed using the spectrophotometer and 3D printed index to orient each sample in the same way to the spectrophotometer tip. The mean of three readings per specimen was recorded for each L\*a\*b\* value and standard deviations ( $\Delta E$ ) were determined for each group at baseline, 3, 6, 9, and 12-year equivalent simulated years of brushing. Color change was measured using the formula:  $\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2$

+  $(\Delta b^*)^2 ]^{1/2}$ . Data were analyzed with a repeated measures ANOVA examining the effects of toothbrushing the ceramic materials on delta E\* over time (alpha = 0.05).

## RESULTS

The results of repeated-measures ANOVA indicated the existence of statistically significant differences based on material ( $p < 0.001$ ) and time ( $p < 0.001$ ), however, there were significant interactions ( $p < 0.001$ ). The delta E\* data also were analyzed with a one-way ANOVA per ceramic-polymer material and per time interval. A Bonferroni correction was applied because multiple comparison tests were completed (alpha=0.007). See table 1. Cerasmart and Enamic had a significantly greater  $\Delta E^*$  compared to IPS e.max CAD at each time interval. The  $\Delta E^*$  was not significantly different between Cerasmart and Enamic except at 3 years. Cerasmart and Enamic had a significant increase in  $\Delta E^*$  between each time interval, whereas for IPS e.max CAD, the increase in  $\Delta E^*$  was only significant at 9 and 12 years of brushing. See Figure 2.

## DISCUSSION

Ceramic-polymer materials may become increasingly prevalent as their performance appears to be similar or in some instances better than their ceramic counterparts. Fracture resistance, marginal and internal adaptation, wear characteristics of the material as well as the opposing natural dentition, are all comparable to lithium-disilicate restorations.<sup>22-26</sup> Furthermore ceramic-polymer restorations have greater machinability and less edge chipping than ceramic restorations.<sup>27</sup> A unique feature of a ceramic-polymer material is its resiliency or shock absorbing capacity.<sup>28,29</sup> This may be important in implant-born restorations, since they react to occlusal forces differently than natural teeth due to lack of periodontal ligaments.<sup>30</sup> Ceramic-polymer crowns were shown to be able to absorb more shock from occlusal forces than crowns made of zirconia,

ceramic material, or gold alloy, leading to less marginal bone loss around the implants. Materials with these characteristics have been accepted as suitable and a good alternative for single crown restorations.<sup>31-33</sup>

Indirect ceramic-polymer materials are cured under optimized temperature and pressure settings for a controlled and standardized polymerization. Polymerization in the laboratory allows for enhanced mechanical strength and improved stain resistance when compared to direct resin composite material.<sup>34,35</sup> Additionally, these polymers can be repaired using light-cured composite materials and readily characterized with light polymerized stains. However, these new ceramic-polymer materials may be less resistant to the abrasive effects of toothbrushing compared to ceramic materials. Extrinsic stains are often necessary to achieve comparable esthetics to ceramic materials. The longevity of these extrinsic stains must be questioned and studied for predictable outcomes.

In this study, significant increases in  $\Delta E$  were observed in the two stained and glazed ceramic-polymer materials after a 12-year equivalent of simulated toothbrushing when compared to extrinsic stains on IPS e.max CAD. Therefore, the null hypothesis was rejected. A  $\Delta E$  measure of 2.3 or higher falls in the “just noticeable difference” (JND) classification, meaning that the naked eye will begin to notice change in color around  $\Delta E$  of 2.3.<sup>36</sup> Garza *et al.* showed that it required 12 years of simulated toothbrushing for noticeable change on extrinsic stains on IPS e.max Press.<sup>10</sup> The current study had similar results with IPS e.max CAD. Compared to the IPS e.max CAD extrinsic stains, the Cerasmart and Enamic extrinsic stains displayed a significant difference in  $\Delta E$  starting at 6 years of simulated toothbrushing. However, both Cerasmart and Enamic extrinsic stains required 12 years of simulated toothbrushing to be clinically noticeable. The findings of the current study suggest that visible-light-polymerized extrinsic stains of ceramic-polymer materials may remain unchanged to the eye after at least nine years of toothbrushing.

However, only two ceramic-polymer materials were evaluated in this study. Further research is needed to understand the clinical significance of surface color changes demonstrated by ceramic-polymer materials in association with toothbrushing.

## **CONCLUSION**

The extrinsic stains on the ceramic-polymer materials may be more susceptible to change from toothbrushing compared to the lithium-disilicate material. However, the change may only be clinically perceptible to the naked eye ( $\Delta E^* > 2.3$ ) after 9 years of brushing the ceramic-polymer materials.

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Materials	Mean Delta E* (st dev)			
	3 yrs	6 yrs	9 yrs	12 yrs
Cerasmart (GC)	0.7 (0.1) Aa	1.2 (0.1) Ba	1.8 (0.1) Ca	3.3 (0.2) Da
Enamic (Vita)	0.4 (0.04) Ab	1.1 (0.2) Ba	1.9 (0.4) Ca	3.1 (0.3) Da
IPS e.max CAD (Ivoclar Vivadent)	0.2(0.1) Ac	0.2(0.1) Ab	0.3(0.1) Bb	0.8(0.2) Cb

Table 1. Mean delta E\* ( $\pm$  one standard deviation) for each of the ceramic materials at each simulated time interval. Groups with the same upper case letter per row or lower case letter by column are not significantly different ( $p > 0.007$ ).

