

Effect of Simulated Gastric Juice on Color Stability of Different Artificial Teeth

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ABSTRACT

Objective: The current study aimed to evaluate the gastric juice effect on the artificial teeth discoloration in patients with gastroesophageal reflux disease (GERD) under in vitro conditions.

Methods: Three different artificial teeth (Ivostar, Vivodent PE, Phonares II) were used in the study (n=12). A spectrophotometer (VITA Easyshade Compact; VITA Zahnfabrik, Bad Säckingen, Germany) was used for initial color measurements after keeping the specimens in distilled water for 24 h. Then, they were immersed in 5% hydrochloric acid (HCl) at 37°C (pH=2) for 91 h and the color measurements were repeated. The CIEDE2000 formulation was used to calculate the color changes. The statistical analysis was performed with one-way ANOVA and Tukey HSD tests.

Results: Although the color differences of Vivodent PE and Phonares II materials did not exhibit a statistically significant difference ($p=0.95$; $p > .05$), there was a significant difference between Ivostar and other materials ($p=0.02$, $p=0.01$). The 50:50% detection threshold (PT) was exceeded with Vivodent PE and Phonares II materials, while the 50:50% acceptability threshold (AT) was exceeded with Ivostar material.

Conclusion: After exposure to gastric acid, all groups exhibited perceptible color differences. In the group of acrylic resin artificial teeth, the color difference was above acceptability threshold and would be better to improve. While the acrylic resin artificial teeth exhibited the highest discoloration, artificial teeth containing nanohybrid composite resin showed the least discoloration. These should be considered in the selection of artificial teeth in patients with GERD.

Keywords: artificial teeth, color stability, discoloration, gastric acid, gastroesophageal reflux disease

1. INTRODUCTION

Artificial teeth are important in the functional, phonetic, and esthetic success of removable dentures by replacing missing natural teeth (1,2). There are different kinds of artificial teeth such as composite resin, acrylic resin, highly cross-linked acrylic resin, and porcelain (3). The esthetic properties of all artificial teeth should be maintained for a long time without any color change. The discoloration is usually observed due to coloring agents and the acidity of consumed food and beverages (4-6).

Another important condition that creates an acidic environment in the mouth is gastroesophageal reflux disease (GERD), which is an important health problem due to its complications and negative impact on quality of life. It is usually caused by improper relaxation of the lower esophageal sphincter and backflow of stomach contents into the esophagus (7). The proteolytic pepsin in the gastric juice returning to the oral environment removes the protective dental membrane on the tooth surface and has an abrasive

effect on the teeth (8,9). It is indicated that reflux affects not only natural teeth, but also the surfaces of restorative materials (10-13). Myklebost et al (14) investigated the gastric juice effect on the surface roughness of various filling materials and reported that the surface roughness of these materials increased. Another study indicated that acidic beverages changed the color stability and surface roughness of artificial teeth (4).

Spectrophotometers have been used for the measurement of these color changes (6) with CIELAB or CIEDE2000 formulas (15). Two main thresholds are used for these formulas, namely the acceptability threshold (AT) and the perceptibility threshold (PT). They offer quality control to evaluate dental materials' clinical performance and facilitate their selection, as well as interpret various findings in clinical dentistry and dental research (16). The 50:50% PT means that half of the observers notice a color difference between two items, while the others observe no difference. In the 50:50% AT, half of the

observers consider that the color difference is acceptable, while the others consider it unacceptable (15,17).

In the literature, there have been studies on the effect of gastric acid juice on different restorative materials (11,12,18-21), but there has been no study on artificial teeth. Therefore, the aim of the current study was to evaluate the gastric juice effect on the discoloration of artificial teeth in patients with GERD under in vitro conditions. The null hypothesis was that simulated gastric juice would not affect the discoloration of artificial teeth.

2. METHODS

The tested artificial teeth and their chemical compositions are shown in Table 1. Since the sample size was determined as 11 in each group according to the power analysis (95% confidence interval and 5% margin of error), a total of 36 artificial teeth (A2 color, n=12) were used. A spectrophotometer (VITA Easyshade Compact; VITA Zahnfabrik, Bad Säckingen, Germany) was used for initial color measurements after keeping the specimens in distilled water for 24 h. Following the initial measurements, the specimens were immersed in 5% hydrochloric acid (HCl) at 37°C (pH=2) for 91 hours, which is equivalent to 1 year of HCl exposure in a patient with GERD (13). The samples were washed with distilled water, and dried, and the color measurements were repeated. Color changes (ΔE_{00}) were calculated with the CIEDE2000 formulation.

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T \left(\frac{\Delta C'}{k_C S_C}\right) \left(\frac{\Delta H'}{k_H S_H}\right)}$$

The $\Delta L'$, $\Delta C'$, and $\Delta H'$ in the formulation describe the variation in hue, chroma, and lightness between two different measurements. RT is the rotation factor and S is the weighting function. KH, KC, and KL, representing parametric factors, were standardized to 1. The 50:50% AT was accepted as $\Delta E_{00}:1.8$ and the 50:50% PT as $\Delta E_{00}:0.8$ (16).

Statistical analysis was performed with IBM SPSS V23 software (IBM Corp., NY, USA). One-way analysis of variance (One-way ANOVA) and Tukey HSD tests were used to compare ΔE_{00} values. The significance level was set at $p < .05$.

Table 1. The artificial teeth with their chemical composition.

Artificial tooth	Manufacturer	Composition
Ivostar	Ivoclar Vivadent	conventional polymethylmethacrylate acrylic resin
Vivadent PE	Ivoclar Vivadent	highly cross-linked DCL acrylic
Phonares II	Ivoclar Vivadent	nano-hybrid composite

DCL: Double cross-linked.

3. RESULTS

Table 2 demonstrated the results of the color change of each material. The One-way ANOVA test indicated a statistically significant difference in color stability of the tested materials exposed to the acidic solution ($p=0.007$; $p < .05$). Although the color differences of Vivadent PE and Phonares II materials did not exhibit a statistically significant difference ($p=0.95$; $p > .05$), there was a significant difference between Ivostar and other materials ($p=0.02$, $p=0.01$) according to Tukey HSD test.

The highest color difference was observed in the Ivostar material ($\Delta E_{00}=2.14 \pm 0.40$), while the lowest was observed in the Phonares II material ($\Delta E_{00}=1.72 \pm 0.23$). Color differences in Vivadent PE and Phonares II materials exceeded the 50:50% PT ($\Delta E_{00}=0.8$) and Ivostar material exceeded the 50:50% AT ($\Delta E_{00}=1.8$).

Table 2. The color change results of the materials.

Material	n	Mean \pm SD	F	p
Ivostar	12	2.14 \pm 0.40 ^a	5.879	0.007
Vivadent PE	12	1.77 \pm 0.31 ^b		
Phonares II	12	1.72 \pm 0.23 ^b		
Total	36	1.88 \pm 0.36		

*Different letters indicate a statistical significant difference; SD:Standard deviation.

4. DISCUSSION

The null hypothesis that simulated gastric juice would not affect the discoloration of artificial teeth was rejected. Because, the simulated gastric juice affected the color stability of all tested artificial teeth and the color differences of all groups exceeded the 50:50% PT value.

Color stability is an important feature for all dentures, as discoloration may indicate damage or aging of the material (6). Therefore, artificial teeth should be resistant to staining and remain for a long time without discoloration, as well as have an esthetic appearance (22). It has been reported in the literature that commonly consumed acidic and colored beverages caused color changes in both the denture and acrylic resin teeth (4,6,22,23). Because, these beverages can disrupt artificial teeth, induce abrasion, irregularities, and discoloration, and eventually reducing the lifespan of the denture (6).

The CIELAB (ΔE^*_{ab}) and CIEDE2000 (ΔE_{00}) formulations are used to calculate color differences. The CIEDE2000 formula is more useful in the measurement of color differences in a clinical context, because it reflects the human perception of color differences better than the other formula (15). Tieh et al (14) also recommended using the ΔE_{00} formula instead of the traditional ΔE^*_{ab} for a more reliable interpretation of changes in clinical instrumental color analysis. The acceptability threshold (AT) and the perceptibility threshold (PT) are used in this formula (16). PT defines the lowest perceptible color difference that can be detected by an

observer, AT defines the acceptable color differences (15,17). Although, a comprehensive review stated that different AT and PT values exist in the literature (17), a study on tooth-colored restorative material was selected as a reference for the present study (16). The color differences in the Vivodent PE and Phonares II groups were above 50:50% PT, meaning they were just noticeable changes and still below acceptable color differences. Therefore, these color differences were not required to correct. On the other hand, the color difference in the Ivostar group was above 50:50% AT and would be better to improve.

GERD is a gastrointestinal system disease that is seen in many individuals in society, but its serious damage cannot be noticed. Studies indicated a correlation between GERD and dental erosion (9,25). It has been reported that the average rate of dental erosion in patients with GERD is 24%, and the rate of GERD in patients with dental erosion is 32.5% (26). In these patients, the low pH gastric fluid entering the oral environment affects not only natural teeth but also restorative materials (10,11,18,20,21). Cengiz et al (11) investigated the effects of gastric juice on indirect laboratory composite materials and concluded that gastric acid affected these materials causing clinically unacceptable discoloration. In another study, resin composite CAD/CAM (computer-aided design/computer-aided manufacturing) materials (Paradigm MZ100, Lava Ultimate) exhibited surface modifications after exposure to acid (20). Gastric acid exposure had varying degrees of influence on different properties of some CAD/CAM ceramic materials (19,21) and caused some surface changes even in zirconia (12).

In the present study, a significant difference was observed between the color stability of tested artificial teeth after gastric acid exposure. The differences in content of these materials may cause this result. The highest color change was observed in the Ivostar group ($\Delta E_{00}=2.14$), which may be related to the conventional polymethylmethacrylate (PMMA) acrylic resin content. Because, PMMA-containing teeth have a significant conversion rate and low levels of dibenzoyl peroxide remaining after the conversion reaction, which can induce color instability (22). The material also has no cross-linked chains and is less resistant to plasticizer loss (3). Therefore, gastric acid may induce the PMMA plasticization period, which increases the discoloration effect. The Vivodent PE material contains highly cross-linked DCL (Double Cross-Linked) acrylic according to the manufacturer. This material is a modified version of PMMA, and both its matrix and polymer are cross-linked (27). Its statistically significant lower color change ($\Delta E_{00}=1.77$) compared to the Ivostar group may be associated with this structural difference, as its highly cross-linked structure can be more resistant to acidic environments. The Phonares II group ($\Delta E_{00}=1.72$) demonstrated the lowest color change. The material contains nano-hybrid composite and PMMA. It also includes a urethane dimethacrylate (UDMA) matrix and many different fillers (3). In a study of Yuzugullu et al (3), it was indicated that different cleansing solutions did not significantly affect the surface roughness or

microhardness of the material, which proves the structural stability of the material.

The absence of clinical conditions such as saliva, dietary habits and cleansing procedures, and the use of a single brand material for each type of artificial teeth are some of the limitations of the present study. Further studies are necessary to compare more artificial tooth brands and analyze the other features such as surface gloss, roughness and microhardness.

5. CONCLUSION

Within the limitations of the current study;

1. After exposure to gastric acid, all groups exhibited perceptible color differences.
2. In the group of acrylic resin artificial teeth, the color difference was above acceptability threshold and would be better to improve.
3. While the acrylic resin artificial teeth exhibited the highest discoloration, artificial teeth containing nanohybrid composite resin showed the least discoloration.

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