Effect of Thermo cycling on Color Stability of Acrylic Resin Materials Immersed in Denture Cleansers

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Abstract:
Objectives: To evaluate the effect of thermocycling on the color stability of heat and self-cure resins after immersion in denture cleansers.

Material and methods: Forty-eight disks of heat and self-cure resins were fabricated. The specimens of each material were divided into 4 subgroups (n = 12) and immersed in different denture cleansers (Distilled water {control}, Corega, StainAway Plus and Polident) daily for 1 week and first color measurements (T1) was recorded (before thermocycling). The specimens were then subjected to 5000 cycles of thermocycling and the second color measurements (T2) were recorded (after thermocycling).

Results: A significant increase of color change in self-cure compared to heat-cure resins after thermocycling (p=0.001). The color change in heat-cure resins immersed in different solutions was insignificant (p>0.05). Whereas, there was significant color changes in self-cure resins among denture cleansers (p<0.05). The mean difference of color change was greater in self-cure resins immersed in Corega (3.93 ± 2.71) and Polident (3.55 ± 2.06) compared to the control group (0.15 ± 1.66) and lower in specimens immersed in StainAway Plus (1.36 ± 1.60) compared to Corega. There was a significant decrease in the mean of color change after thermocycling in heat-cure resins immersed in distilled water and Stain Away Plus (p<0.05) and in self-cure resins immersed in Corega, Stain Away Plus and Polident compared to color change before thermocycling (p<0.05).

Conclusion: Aging process resulted in a significant color change in self-cure compared to heat-cure resins and the value of color difference was varied according to the denture cleanser used.

Keywords: Acrylic Resins, Color Stability, Thermocycling, Accelerated Aging

Introduction:
Dentures are commonly used to replace lost teeth in fully or partially edentulous patients to restore esthetic and function. Longevity of the dentures can be accomplished with regular follow up visits for evaluation and maintenance. Long term use of these prosthesis is usually accompanied with the need of relining of tissue-supporting area to adjust ill-fitting dentures resulting from bone resorption. This can be done directly or indirectly by the use of hard or soft liners. Acrylic resins are usually used for fabrication of different types of removable
prosthesis and for relining procedures due to the ease of manipulation and low cost.3 However, the properties of these materials change after insertion in the patient’s mouth due to exposure to fluids and complex oral conditions.4 The effect of aging on the physical properties of acrylic resins such as hardness,5,7 bond strength between denture base and reline material,8 water sorption and solubility of the resins7,9 has been widely reported.

Color stability is considered a critical factor to evaluate the success and the serviceability of the acrylic denture base materials.10 The change in the color of acrylic resins after immersion in food colorants, beverages and denture cleansers has been investigated3,6,7 However, color change could be induced intrinsically or extrinsically during the aging process. Intrinsic factors include the change within the structure of the material. While, extrinsic color change occurs as a result of absorption and adsorption of substance11,12 Several studies evaluated the effect of accelerated aging on soft acrylic and silicon based relining materials.5,10 Limited studies were conducted on hard resins. Therefore, the aim of this study is to evaluate the effect thermocycling on the color stability of heat-cure denture resins and self-cure hard relining acrylic resins after immersion in different denture cleansers. The null hypothesis tested was that aging process has no effect on the color stability of heat and self-cure resins.

Material and methods:

Specimen Fabrication

Forty-eight disks of heat-cure (Lucitone 199, Dentsply, Salzburg, Austria) and self-cure acrylic resin materials (Rapid Repair, Dentsplay, Salzburg, Austria) were prepared with unified shape, diameter and thickness (10 x 10 x 4 mm). The self-cure resin material was pressed in standardized silicon molds and polymerized according to the manufacturer’s instructions. The heat-cured acrylic resin material was packed into silicon molds invested with dental stone inside denture flasks. Then, cured according to the manufacturer’s instructions in Hanau curing unit (Teledyne Hanau Buffalo, NY, U.S.A). Specimens were stored in distilled water at 25°C for 50 ± 2 hours. Then, one surface of each specimen was finished using metal burs (DFS Daimon, Reidenburg, Germany) and stone wheel finishing burs (Shofu, San Marcos, U.S.A) mounted on slow speed hand piece. Later, it was polished using poly buffes brushes and polishing paste (Hatho, Freiburg, Germany) followed by a wet rag wheel with a slurry of pumice. The other surface was marked with a symbol and left unfinished to distinguish the experimental surface used to measure the color change of the material.

Table 1: Different denture cleansers and immersion procedures used in this study:

| Denture Cleansers and Control | Immersion Procedure |
|------------------------------|---------------------|
| Corega                       | Disks were immersed for 3 minutes followed by 5 strokes of brushing with soft toothbrush (Synsodine) and then rinsed with water and kept in container filled with water for 24 hours |
| Polident                     | Disks were immersed for 5 minutes followed by 5 strokes of brushing with soft toothbrush and then rinsed with water and kept in container filled with water for 24 hours |
| Stain Away                   | Disks were immersed for 15 minutes followed by 5 strokes of brushing with soft toothbrush and then rinsed with water and kept in container filled with water for 24 hours |
| Distilled Water (control)    | Disks were immersed for 10 minutes followed by 5 strokes of brushing with soft toothbrush and then rinsed with water and kept in container filled with water for 24 hours |
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Table 2. Ingredients of denture cleansers used in this study:

| Denture Cleansers | Manufacturer | Ingredients                                                                 |
|-------------------|--------------|------------------------------------------------------------------------------|
| Corega            | Dungarvan, Co. Waterford, Ireland. | Sodium Bicarbonate, Citric Acid, Sodium Carbonate, Potassium Monopersulfate, Sodium Carbonate Peroxide, Sodium Lauryl Sulfoacetate, Sodium Benzoate, PVP/VA Copolymer, Aroma. |
| Polident          | GlaxoSmithKline KK, Tokyo, Japan   | Sodium Bicarbonate, Citric Acid, Sodium Carbonate, Potassium Monopersulfate, Sodium Percarbonate, Sodium Lauryl Sulfoacetate, Sodium Benzoate, PVP/VA Copolymer, Aroma, Blue 1 Aluminum Lake, Blue 2, Yellow 5 Aluminum Lake, Yellow 5. |
| Stain Away Plus   | Regent Labs Inc, USA.              | Potassium Monopersulfate, Sodium Carbonate, Sodium Percarbonate, Sodium Bicarbonate, Citric Acid, Sulfamic Acid, Geropon, FD&C Blue. |

Immersion Procedures:
The specimens of each acrylic base were divided into 4 subgroups (n = 12) corresponding to the different denture cleansers used. Table 1 showed denture cleansers and immersion procedures. Specimens were immersed in distilled water (200 mL) as control and in three different denture cleansers (Corega, StainAway Plus and Polident) at 37°C according to the manufacturer's instructions. Table 2 showed ingredients of denture cleansers used in this study. For all groups, after each immersion, the specimens were rinsed in running water for 10 s, dried, immersed in a new solution and the procedure repeated 7 times over 7 days. After 1 week of immersion in the denture cleansers, the specimens were again rinsed with water for 10 seconds, air dried and the first color measurement (T1 - Before thermocycling) for each specimen was recorded.

Thermocycling Procedure:
After the first color measurement, the specimens were thermocycled between 5°C and 55°C with 30-second dwell times for 5000 cycles (Thermocycler THE-1100, SD Mechatronik GMBH, Feldkirchen-Westerham, Germany). The specimens were air dried and the second color measurements were recorded (T2 - After thermocycling).

Table 3. The National Bureau of Standards (NBS) units of color difference

| Marks of color difference | NBS units |
|---------------------------|-----------|
| Trace                     | 0.0 - 0.5 |
| Noticeable                | 0.5 - 1.5 |
| Slight                    | 1.5 - 3.0 |
| Appreciable               | 3.0 - 6.0 |
| Much                      | 6.0 - 12.0 |
| Very much                 | >12.0     |

Table 4. Mean and Std. Deviation of color change (ΔE) before and after thermocycling of acrylic resin materials

| Material | Solution | Mean ± Std. Deviation (Before thermocycling) | Mean ± Std. Deviation (After thermocycling) |
|----------|----------|---------------------------------------------|--------------------------------------------|
| Heat-cure| Distilled water | 2.45 (1.88)                               | 1.10 (0.31)                                |
|          | Corega   | 2.58 (1.92)                                | 2.01 (0.98)                                |
|          | Stain Away Plus | 2.90 (1.71)                               | 1.58 (0.67)                                |
|          | Polident | 2.25 (1.81)                                | 1.60 (0.75)                                |
| Self-cure| Distilled water | 2.46 (1.36)                               | 2.22 (0.99)                                |
|          | Corega   | 3.69 (2.93)                                | 1.77 (0.94)                                |
|          | Stain Away Plus | 2.83 (1.58)                               | 1.47 (0.79)                                |
|          | Polident | 3.42 (2.63)                                | 1.57 (1.55)                                |
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Color Measurements:
The color was measured in the center of the polished surface of each specimen using a spectrophotometer (Color-Eye 7000, NY, USA) against a white background under a standard illumination of D 65. The standard Commission International de l’ Eclairage (CIE L*a*b*) color system was used to assess color change (ΔE) of each specimen through the following equation:

$$\Delta E = \sqrt{((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)}$$

The color change was quantified by the National Bureau of Standards (NBS) units using the following formula NBS units=$\Delta E \times 0.92$ to correlate the differences in the color of the acrylic resin base materials with the clinical environment (Table 3).

Statistical Analysis:
The statistical tests were performed using the SPSS 16.0 program (SPSS Inc., Chicago, IL, USA). The data was normally distributed according to Kolmogorov-Smirnov test. Statistical analyses were performed using two-way repeated measure ANOVA, one-way ANOVA and paired sample t-test. All statistical analyses were set at a significance level of $p<0.05$.

Figure 2. Mean of color change (ΔE) of denture base materials before and after thermocycling

Results:
The null hypothesis tested in the present study was rejected since statistically significant color change was found in acrylic base materials after thermocycling ($p<0.05$). Table 4 showed the mean ± std. deviation of color change (ΔE) values for each denture base resin material before and after thermocycling procedure. Two-way repeated measure ANOVA test showed a significant increase of color change in self-cure compared to heat-cure acrylic resins after thermocycling ($p=0.001$). The color change in heat-cure resins immersed in different solutions was statistically insignificant ($p>0.05$). Whereas, there was significant color change in self-cure resins among different denture cleansers ($p<0.05$). One-way ANOVA and Tukey post hoc test for multiple comparisons showed that the mean difference of ΔE was greater in self-cure resins immersed in Corega (3.93 ± 2.71) and Polident (3.55 ± 2.06) compared to the control group (0.15 ± 1.66) and lower in specimens immersed in StainAway Plus (1.36 ± 1.60) compared to Corega (3.93 ± 2.71) (Fig 1). Paired sample t-test showed a significant decrease in the mean of color change after thermocycling in heat-cure resins immersed in distilled water and StainAway Plus ($p<0.05$) and in self-cure resins immersed in Corega, StainAway Plus and Polident compared to color change before thermocycling ($p<0.05$) (Fig 2).
Discussion:

This study evaluated the effect of aging on the color stability of a common heat-cure denture base resins and self-cure hard relining materials. The process of aging in the current study was simulated by thermocycling procedure.6,8,13 This was in contrast with other studies that produce aging in the form of ultraviolet light, temperature and water spray.5,10 The significant increase in color change in Rapid Repair compared to Lucitone 199 resins can be explained by the great amount of residual monomer in self-cure resins which act as a plasticizer in the polymer matrix resulting in rough surface with more pores that increase the susceptibility of color instability of the resins.14 Moreover, the presence of benzoyl peroxide and the oxidation of dimethyle-p-toluidine contributed to color degradation in self-cure resins.15,16 Another possible factor is the thermal and humidity changes during thermocycling that cause alteration in the matrix and resulted in intrinsic discoloration of the resins.5 This was in agreement with another study that reported a change in the refractive index of the matrix of composites after accelerated aging.17 Goiato et al 5 explained the mechanism of color change of denture base resins after thermocycling and disinfection with Efferdent cleansers and microwave energy by the absorption and adsorption of water molecules that lead to formation of micro cracks in addition to hydrolytic degradation of the polymer and deterioration in the infrastructure of the material. The same study reported color change of acrylic resin after microwave disinfection due to change in the temperature of the material and subsequent dimensional change with alteration on the superficial surface of the resins which also reported by other studies.18,19 In a similar way the change of the temperature during thermocycling in the current study could result in a similar effect on the materials tested and affect their color stability. The results showed that the mean in color difference was greater in self-cure resins immersed in Corega and Polident compared to the control group. While, StainAway Plus produced lower color change compared to Corega. This could be due to the mechanism of action of the denture cleansers. The solutions used in this study were alkaline peroxide type denture cleansers that contain sodium perborate and sodium bicarbonate. When these tablets dissolve in water, the alkaline peroxide solution release oxygen.20 This may cause hydrolysis of the resin by the mechanical action and cause color alteration. Another possible reason is the presence of colorants in the ingredients of the denture cleansers. Polident solution which produced greater color change compared to water, contains colorants such as: Blue 1 Aluminum Lake, Blue 2, Yellow 5 Aluminum Lake and Yellow 5. These could be absorbed by the resin materials and cause discoloration. On the other hand, StainAway Plus contains FD&C Blue colorant and it is recommended by the manufacturer for its bleaching effect on the dentures. This explains the color change of the resins after immersion in StainAway Plus.

Comparing the ΔE before and after thermocycling in each material for each solution, showed that there was a decrease in ΔE after immersion of heat-cure resins in distilled water and StainAway Plus and in self-cure resins immersed in Corega, Polident and StainAway Plus. This contributed mainly to the leaching out of coloring materials in the acrylic resins 5 and the effect of thermocycling process regardless of the denture cleansers used. This study showed a decrease in ΔE after thermocycling. The color change of self-cure resins was appreciable for specimens immersed in Polident and Corega and slight change for StainAway Plus. This was in agreement with another study which reported acceptable color change of acrylic resin within two years of simulated aging.13 Another study evaluated the influence of denture cleansers on acrylic resin over the period of 90, 180, 365 days of immersion in denture cleansers, found an appreciable change for most immersion periods in most of the solution for self-polymerized resins. Greater discoloration was noted for self-polymerized compared to heat-polymerized resins which was attributed to the type of the denture cleanser.7 On the other hand, Anil et al 22 reported a great chromatic alteration value in self-polymerized soft liners. The NBS units showed a very much color change for self-polymerized compared to noticeable change in heat-polymerized liners after accelerated aging using water spray and ultraviolet light in a weatherometer. The differences in the aging conditions and the materials explains the variation in the results between the studies. The present study have some limitations compared to other studies. These include the use of single aging protocol with one set for thermocycling, one evaluation period, and limited materials tested.

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The mechanism of color change after aging is still not clear and further long-term evaluation is recommended.

Conclusions:
Within the limitations of this study, it can be concluded that:

- Thermocycling resulted in a significant color change in self-cure resins compared to heat-cure resins.
- Corega and Polident produced greater color change in self-cure resins compared to the control group. While, lower change was noticed with StainAway Plus compared to Corega.
- No significant change was found among the solutions in heat-cure resins.

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