Asian Journal of Chemistry Vol. 22, No. 8 (2010), 6224-6230

Colour Changes of Tooth-Coloured Materials in the Different Solutions

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The purpose of this study is to evaluate the effect of material (light polymerized composite *versus* heat-polymerized acrylic), surface smoothness (rough *versus* smooth), staining solution (coffee, tea, Turkish coffee, distilled water or mouthwash) and time (baseline, 7 and 30 days) on colour change in a sample of tooth-coloured resins. Twenty-four specimens of each material were evaluated before and after 1, 7 and 30 days of exposure to the different solutions (coffee, tea, Turkish coffee and distilled water) at a constant temperature of 37 ± 1 °C. In addition, 6 specimens were evaluated before and after 6, 12 and 24 h immersion in mouthwash (Andorex; Kim Pa, Istanbul, Turkey). Colour changes (ΔA) of materials were analyzed by use of a spectrophotometer. Data were analyzed with three-way analysis of variance (ANOVA). The highest mean value (ΔA) for the Turkish coffee was 0.98. The light-polymerized composite material tested was the least colour stable.

Key Words: Tooth-coloured resins, Composite resin material, Acrylic resin material, Discolouration.

INTRODUCTION

The appearance of natural teeth and restorative materials varies according to colour and translucency. The esthetic properties of an existing restoration are important factors that affect clinical success. Although the initial colour match of a light-polymerized restoration may be established, long-term colour changes can occur because of surface staining[1-3].

Resin composites are known to be susceptible to various degrees of decolouration on prolonged exposure to the oral environment[4-6]. Clinically, it has been reported that saliva, food components and beverages may affect the colour stabilities of resin composites[7]. In addition, mouthwash is also implicated as a decolourizing agent[8,9], because the use of mouthwash has become popular recently[10]. Aside from being an effective caries and gingivitis control method and topical relief measure for oral lesions, people tend to use mouthwash for social such as bad breath[9-12].

Colour change due to extrinsic staining can be alleviated to some degree by polishing the resin composite surface. Since the particulate filler resin composites have a higher content of inorganic filler, it is expected that they may be superior in strength and colour stability[13]. Change in translucency and colour of resin composites

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was observed in studies using artificial aging[13-15]. It was demonstrated that the chemical and light polymerized composites showed significantly lower colour change than the chemical-polymerized composites[15].

External and internal factors may change the colour of esthetic restorative materials[1,16-21]. Internal factors involve chemical changes of the materials[22,23]. Extrinsic factors for decolouration include staining by adhesion or penetration of colourants from tea, coffee, nicotine and coloured solutions[24]. Colour changes of the acrylic resin materials may also be caused by the oxidation of the amine accelerator[25,26]. The heat-polymerized acrylic resin materials were significantly less susceptible to staining than the light-polymerized resin composite[27-29].

The purpose of this study is to compare the effect of material (light polymerized resin composite *versus* heat-polymerized acrylic resin), surface smoothness (rough *versus* smooth), staining solution (coffee, tea, Turkish coffee, distilled water or mouthwash) and time (baseline, 7 and 30 days) on colour stability of tooth-coloured resins.

EXPERIMENTAL

In this study, the effect of staining solutions on heat-polymerized acrylic resin material (Biodent, K-B plus, Dentsply, D-63264, Dreieich, Germany) and light-polymerized composite material (Dentacolour, paste, Kulzer GmBH, Wehrheim, Germany) were compared.

Preparation of test specimens: Thirty specimens for each material were prepared 20 mm in diameter and 0.5 mm in thickness. A stainless steel disc to prepare the light-polymerized composite specimens, 20 mm in diameter and 1 mm in thickness, was machined. A single-mix impression of this disc was made with a silicone rubber impression material (Speedex, Coltene Whaledent, Mahwah, NJ) to fabricate a mold. Light-polymerized composite materials were made by incrementally placing the material in this mold in 3 increments[30].

The specimens were light-polymerized for 40 seconds after each increment by use of a light-polymerizing unit (Hilux 250, Benlioglu, Dental Inc, Ankara, Turkey). During the final light-polymerization process, a clear slab was placed over the mold to obtain a flat surface for the specimens. The heat-polymerized acrylic discs were prepared in the same molds and underwent a short-time polymerization in a water bath under air pressure of 80 psi and a temperature of 75 °C for 20 min (polymerization equipment: Ivoclar, Ivomat, Schaan, Austria).

The specimens in each group were then divided in 2 groups (n = 15). Half of the specimens were abraded on both sides with silicone carbide paper (No. 600, 3 M dental, Minn.) and the other half were polished. Light-polymerized composite discs were polished with polishing disks (Sof-Lex discs, 3M ESPE, Dental Products, Seefeld, Germany) or rubber points (Reddish Stone, Torino, Italy). Heat-polymerized acrylic resin discs were polished to a high gloss using fine flour of pumice with a cloth wheel.

A total of 60 specimens (30 for each resin material) were included in the study. Half the specimens in each group were then selected for each surface treatment (rough *versus* smooth). Three samples from each material/smoothness group were then treated with each of the staining solutions (coffee, tea, Turkish coffee and distilled water, mouthwash). Twenty-four specimens for each resin material was stored in coffee, tea, Turkish coffee and distilled water at a constant temperature of 37 ± 1°C for 1, 7 and 30 days. Six samples for each test material were stored in 20 mL of one of the mouthwash (Andorex; Kim Pa, Istanbul, Turkey) for 6, 12 and 24 h. The period of 12 h was reported as the equivalent time to 1 year of 2 min daily mouthwash use[19].

To prepare coffee solution, 15 g of coffee powder (Nescafe classic; Nestle, Societe des Produits, S.P.N., Switzerland) was poured into 500 mL of boiling distilled water. The tea solutions was prepared by immersing 5 prefabricated doses of tea (Lipton, yellow label, Corlu, Turkey) into 500 mL of boiling water for 10 min.

Turkish coffee was prepared by adding 5-7 g of a commercial brand (Kurukahveci Mehmet Efendi,TS 3117,Y. Dudullu, Istanbul) in 65 mL cold water, it is taken off the heat once it comes to a boil.

Distilled water was used as a control. During this period the staining solutions were changed once a week. Before any measurements were made, all specimens were removed from the solutions and rinsed in distilled water. Excess water on the surfaces was removed with tissue paper and the specimens were allowed to dry.

Absorption measurements: Colour changes of the specimens were determined through absorption measurements of the specimens by choosing 3 selected areas of solid specimens by using a UV/vis/NIR spectrophotometer (Shimadzu UV-3101 PC UV/vis/NIR scanning spectrophotometer, Serial Number: A10283800107KL, Producer Firm: Shimadzu Corporation, Tokyo).

The instrument used for the measurement is a double beam spectrophotometer. It contains reference or standard and specimen holders. To determine a specific wavelength which is sensitive colour changes of the specimens, we took the absorption spectrum of the specimen untreated by the different solutions in the 400-800 nm region. Then, the absorption measurements were carried out at 450 nm by choosing air as reference. The absorption measurements at the wavelength indicated were directly correlated with the colour of each specimen before and after treatments with staining solutions, mouthwash and distilled water. Therefore absorbance of the specimens was determined by using Lambert-Beer Law given as[31,1]:

$$A = \varepsilon \cdot b \cdot C$$

where A = absorbance of specimen which is unitless, C = concentration of the acrylic resin material in g, ε = absorption coefficient that is 40.87 g^{-1} cm^{-1} determined at 450 nm for the specimen and b = thickness of specimen disc that is 0.5 mm. This formula was used for the determination of colour changes of the specimens. For this purpose, the absorption measurements of each disc were made before the treatment with colour degrading materials. Then, the values of these absorption measurements were recorded. After this point, the specimens were treated with staining materials and mouthwash then, absorption measurements were repeated

under the same conditions. By taking absorbance differences of the specimens with treated colour degrading solutions and without treatments, It was determined ΔA values that represent colour differences of each specimen. Therefore, ΔA values were used for the interpretation of experimental findings.

Statistical analysis: The effects of material, staining solutions, surface smoothness, immersion time and interaction effects among them were analyzed with the three-way analysis of variance at $\alpha = 0.05$. Data representing colour differences (ΔA) for the various groups were compared by use of the paired t test.

RESULTS AND DISCUSSION

The three-way analysis of variance showed significant differences between the means of the test specimens. The effects of material, staining solutions, surface smoothness, immersion time and interaction effects among them was statistically significant ($p < 0.001$). Turkish coffee and coffee produced slightly larger colour changes than tea. The light-polymerized composite material showed the poorest colour stability after immersion in coffee and tea. The highest mean value (ΔA) for the Turkish coffee was 0.98. The heat polymerized specimens showed good colour stability values (ΔA = 0.30 in tea solution, 0.69 in Turkish coffee, 0.63 in coffee). At 30 days the colour changes of materials were significantly different at $p < 0.001$. Light-polymerized composite material was the material with the highest ΔA. The smooth heat-polymerized acrylic materials were slightly darker than the rough specimens (Fig. 1). After immersion in distilled water, the specimens had a lower colour change than after exposure to staining solutions. These specimens showed a little colour changes after stored in the mouthwash for 24 h (Fig. 2).

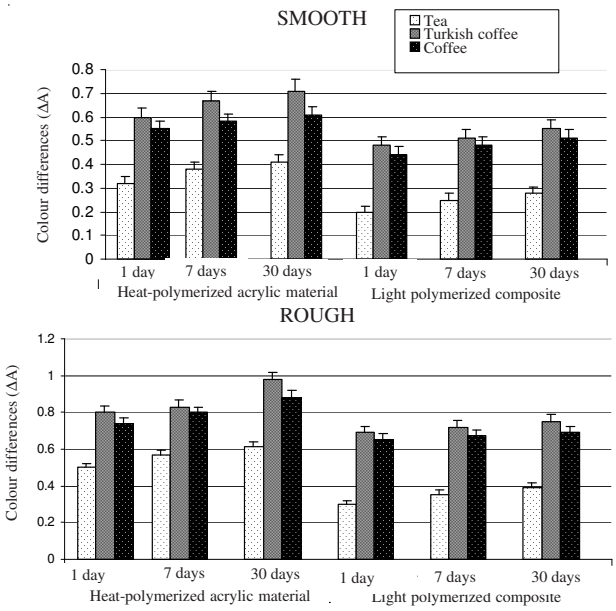

Fig. 1. Bar graph of colour differences (ΔA) of tooth-coloured materials in different solutions. Vertical lines represent SD

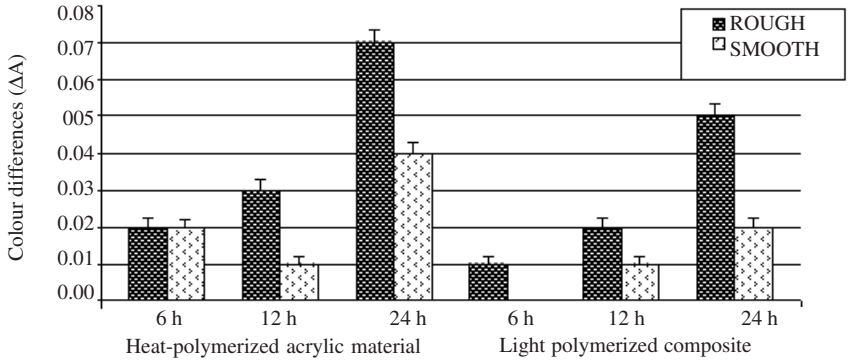

Fig. 2. Bar graphs of colour differences (ΔA) of materials in mouthwash. Vertical lines represent SD

Colour differences can cause absorption differences at a particular wavelength. Therefore, one can use absorption technique to understand what happens to the specimen after a chemical or physical treatment of the sample. One advantage of absorption technique is that most of the laboratories may have absorption spectrophotometers and this technique is much easier to carry out experiments. This system was preferred for the present study.

The composite materials can absorb water or solutions as tea, coffee at a higher rate because of a high diffusion coefficient in comparison to methyl methacrylate based resins[5,6]. These properties may explain the cause of the excessive colour change observed for the light-polymerized composite.

Koumjian *et al*.[29] evaluated the *in vivo* decolouration of resin materials. They found that the heat-polymerized acrylic resin material showed significantly less staining than the light polymerized composite material, which is in agreement with the results of Yannikakis *et al*.[27] and present study.

The immersion of composites in water for a prolonged period may irreversibly affect their colour[16]. The methyl methacrylate materials (Q-C), after 30 days of immersion, were more colour stable than the light polymerizing composite material, which is in agreement with the findings of Crispin and Caputo[28] and Yannikakis *et al*.[27] The light polymerizing composite specimens were the least colour stable. In general, an interpretation based on chemical composition showed the methyl methacrylate evidenced the least amount of darkening[28].

It was suggested that the chemically and light polymerized composite and heat-polymerized acrylic materials exhibited the less colour change than chemically polymerized composite-based resin material[27]. The particular filler composites have stable translucency and colour[13]. There was no particular difference in colour stability between the particulate composites and the conventional veneering composites. Both filler content and particle size are critical to dispersion of the light beam. For this reason, microfilled composites with smaller and more numerous particles scatter more light then microhybrid composites with larger and fewer glass particles[4].

In the present study, it was showed less colour stability in light polymerized composite content microfilled. Typical properties of microfilled composites are highly filled, higher values of polymerization shrinkage, water sorption and thermal expansion as compared with microhybrid composites[31]. In the composites containing urethane monomers and *bis*-GMA were observed discolouration[32]. The magnitude of the colour change could not be associated with the amount of filler content[33].

Um and Ruyter[16] reported approximately twice as much discolouration in tea as in coffee for resin-based veneering materials. In the present study, decolouration of heat-polymerizing acrylic materials exposed coffee and Turkish-coffee were of the same magnitude. Penetration of colourants in to the materials probably did not occur as with resin-based veneering materials with coffee. After 30 days in staining solutions, Turkish-coffee produced higher decolouration value ΔA than tea. As Turkish-coffee is very dark and dense liquid, it causes colourness especially on rough surfaces. Crispin and Angelo[28] stated that the tea-coffee solution caused the greatest amount of darkening over 30 days period.

Heat-polymerized acrylic materials have been shown to exhibit satisfactory colour stability[28,34,35]. In this study, the heat-polymerized acrylic resin material exposed to the coffee and tea solutions showed better colour stability than the light-polymerized composite material. The resin specimens absorbing these colourant solutions may also undergo staining. The absorption is undoubtedly due primarily to the polar properties of resin molecules. However, it has been proven that the mechanism is diffusion of water molecules that penetrate according to the laws of diffusion[36].

Nakamura *et al*.[13] suggested that the composites had decreased in translucency by the first 2 weeks after the start of water immersion. Decolouration can also occur by oxidation and result from water exchange within the polymer matrix and its interaction with unreacted polymer sites and unused initiator or accelerator[4].

Gurdal *et al*.[37] discussed that the effects of mouthwash on restorative materials may differ depending on many *in vivo* factors. The colour changes of the materials in the mouthwash after 12 h were not different from that of control solution. In the present study, after 24 h of immersion in mouthwash, the specimens showed a little colour change. Difference between the studies may be the result of different materials used storage time.

Conclusion

Within the limitations of the study, the following conclusions were drawn: Staining solutions, materials, immersion time and surface smoothness were significant factors affecting colour stability. Light-polymerized composite recorded the greatest ΔA values when immersed in Turkish coffee. It was statistically significant ($p < 0.001$). The coffee solutions exhibited more staining capacity than the tea solution ($p < 0.001$). In rough materials more colour change observed than polished materials.

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(*Received*: 20 November 2009; *Accepted*: 7 May 2010) AJC-8683