J Indian Prosthodont Soc (Apr-June 2014) 14(2):179–186
DOI 10.1007/s13191-013-0309-z

ORIGINAL ARTICLE

Effect of 5.25 % Sodium Hypochlorite on Color Stability of Acrylic and Silicone Based Soft Liners and a Denture Base Acrylic Resin

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Received: 9 April 2013 / Accepted: 31 July 2013 / Published online: 10 August 2013

Abstract The purpose of the current study was to investigate the effect of a chemical disinfectant (sodium hypochlorite 5.25 %) on color stability of a denture base acrylic resin and two processed soft denture lining materials of two different types (acrylic-based and silicone-based). Ten specimens from each type of materials tested were made (2 × 20 × 20 mm). All specimens were immersed in sodium hypochlorite (5.25 %). Colorimetric measurements for each specimen were taken before immersion, and after 24 h and 7 days of immersion. Color changes were evaluated using the CIE L*a*b* colorimetric system. Data were statistically analyzed with one-way analysis of variance (ANOVA) ($\alpha = 0.05$). ANOVA was followed by Bonferroni test to determine which groups differed from each other. ΔE and ΔL* of the silicone-based liner at the 1st and 7th days of immersion were significantly more than of denture base acrylic resin and acrylic-based liner. Change in ΔL* values of denture base acrylic resin and acrylic-based liner was small and statistically insignificant after 24 h of its immersion. However, the increase in ΔL* values of the acrylic-based liner after 7 days of immersion was considerably more than of denture base acrylic resin. Color changes in denture base acrylic resin and soft denture liners tended to increase with longer immersion times, and the color stability of the soft denture liners was influenced by its chemical type.

Keywords Color · Acrylic resin · Soft denture liner · Chemical disinfectant

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Introduction

Polymethylmethacrylate (PMMA) or acrylic resin has been successfully used for fabricating denture bases for many years [1]. It has favorable physical mechanical and cosmetic properties, and is easy to manipulate with inexpensive equipment [2]. Unfortunately, it still has some disadvantages, particularly its color instability and its sorption of oral fluids that is usually correlated with the ability of certain organisms to colonize the fitting surface of the denture [1].

For patients who cannot tolerate a conventional hard denture base, the use of soft denture liners can be advantageous [3, 4]. Soft denture liners are recommended for patients to improve load distribution on the denture bearing area and to avoid load stress concentrations [5]. These materials have been used for more than a century [6], and they are widely used as a cushion on the intaglio surfaces of the dentures in patients who suffer from traumatized oral mucosa, ridge atrophy, bony undercuts, bruxism, xerostomia, congenital oral defects requiring obturation, and for improving the retention of the dentures by engaging undercuts [5, 7–9].

The earliest soft liner was soft natural rubber and it was applied by Twichell in 1869 [5]. Since then, many compositions have been provided [10–12].

It has been revealed that the major reservoirs of *Candida albicans* and related *Candida* species are found on the fitting surface of the denture [13], and that soft liners are easily colonized and deeply infected by these organisms [14]. Therefore, cleansing dentures and soft liners is imperative procedure.

Although chemical denture cleansers have been believed to be an effective method to avoid *C. albicans* colonization and denture plaque formation [15, 16], a daily use of denture cleansers can influence the physical properties of denture acrylic resin bases and soft liners [17]. Thus, it is essential to use non-damaging chemical disinfectant [18].

Color stability is considered the most clinical significant property for all dental materials because color changes refer to aging or damaging of the materials [11, 12, 19, 20]. As ageing or changes in physical properties of soft denture lining materials appear to depend upon their type or composition [21], it is advantageous to study the effect of disinfectant agents on color stability of these materials in accordance with its composition.

To record changes in the color of dental materials a colorimetric instrument is used [22]. This instrument measures color and expresses it in terms of three coordinate values (L*, a*, b*) according to the Standard Commission Internationale de L'Eclairage (CIE Lab) Colour System.

Several studies have been carried out to determine the color changes of soft lining materials resulted from immersion in different food colorant solutions. It demonstrated that silicone type soft lining materials were more resistant to color change than the acrylic type soft liners [23, 24]. Identically, It was found that silicone soft liners were more stable in color change than the acrylic soft liners after immersing in denture cleansers [12].

The color change of a heat-polymerized acrylic resin was measured after its immersion in denture cleansers (Corega Tabs, Bony Plus), and it was clinically insignificant [25]. However, the color stability of denture base acrylic resins is influenced by the type of denture cleanser used [26]. Therefore, it is benefit to study the effect of sodium hypochlorite solution on color stability of denture base acrylic resins, since this solution is widely used in disinfecting prosthodontics.

The aim of the present investigation was to evaluate the effect of a chemical disinfectant (sodium hypochlorite 5.25 %) on color stability of a denture base acrylic resin and two processed soft denture lining materials of two different types. The null hypotheses was that (1) there would be no significant differences in the color change of the material groups and (2) there would be no significant differences in the color change between acrylic-based and silicone-based soft denture liners.

Materials and Methods

Materials involved in this study were processed soft lining materials of two different chemical types, Plasticized acrylic resin and Silicone-based material; besides a denture base acrylic resin. The materials and the manufacturers are summarized in Table 1. For soft lining materials and denture base acrylic resin specimens, a gypsum mold was fabricated (Fig. 1). A glass plate was applied in the bottom of the lower part of the flask after filling it partly with plaster of Paris, maintaining the upper surface of the plate completely clean of plaster. A wax rectangular piece (2 × 20 × 20 mm) was fixed on the upper surface of the glass plate. Dimensions of the specimen were selected in accordance with previous study [27]. Plaster mixture was poured to cover the glass plate and became fully at the level of the edges of the lower half of the flask without covering the upper surface of the wax piece. After plaster setting, it was painted with suitable separating medium. The upper half of the flask was filled with plaster, and then the flask was closed. It was pressed for 30 min until complete setting of plaster. The flask was opened, wax piece was removed and the formed mold was cleaned by hot water. Glass surface was completely dried, and gypsum surfaces were painted with separating medium. Heat-cured denture resin was mixed according to the manufacturers' recommendations, placed in the gypsum mold, and processed in water bath by using curing unit (Hanau Engineering Company, Buffalo, NY, USA) at 74 °C for 8 h. Soft materials were packed in the gypsum mold by means of a spatula. The materials were also processed in water bath in accordance with the manufacturers' instructions. After curing and cooling inside the water bath to room temperature, deflasking was carefully completed. Edges on all specimens were smoothed and trimmed to the proper design before data were collected. The surface used for collection data was the surface that was formed by processing against the glass plate in the gypsum mold. Ten specimens from each material were made. A power analysis (using G*Power Version 3.1.5) was done to determine the number of specimens required in each test group in order to determine if statistical differences existed between groups. Specimens were immersed in sodium hypochlorite (5.25 %) (National Cleaning Products Company, Dammam, Saudi Arabia). They were placed in separate glass bowls which filled with the disinfecting solution, taking into account using equal volumes of solution in each bowl, and change the solution daily. The same batch of disinfectant solution was used throughout the experimental period of study. Color measurements for each specimen were taken with a colorimeter (NR-3000, Nippon Denshoku, Tokyo, Japan) before immersion in the disinfectant solution, and after 24 h and 7 days of immersion (Fig. 2). Before the initial color measurements, the specimens were stored in distilled water for 24 h. The device was calibrated with its white calibration plate before colorometric measurements, and the white calibration standard plate was used as the background for each specimen during data collections to remove the effects of variations in background color during measurements [28]. The specimens were washed under water and air-spray dried prior to each color measurement. Color measurements were performed by applying the lens of the device at the center of glazed surface of specimen. Color changes (ΔE) were calculated with the use of Commission Internationale de L'Eclairage (CIE- LAB) uniform color scale [29], which recommended by American Dental Association (ADA). Colorimetric instruments measure color and express it in terms of three coordinate values (L*, a*, b*) [30, 31]. L* represents the lightness or darkness of the specimen. The a* represents the red-green chromaticity of the specimen. The b* represents the yellow-blue chromaticity of the specimen [28, 30–32].

ΔEs of specimens were calculated between the control (before immersion) and at 1st and 7th days of immersion in the disinfecting solution by using the following formula [28, 30–32]:

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

The critical mark of color change (ΔE) has been quantified by the National Bureau of Standards (NBS) with the NBS units for color difference (Table 2) [31, 32]. NBS units are expressed by the following formula:

$$\text{NBS unit} = \Delta E \times 0.92$$

Collected data were submitted to one-way analysis of variance (ANOVA) at significant level of 5 %. ANOVA was followed by Bonferroni test to determine which groups differed from each other.

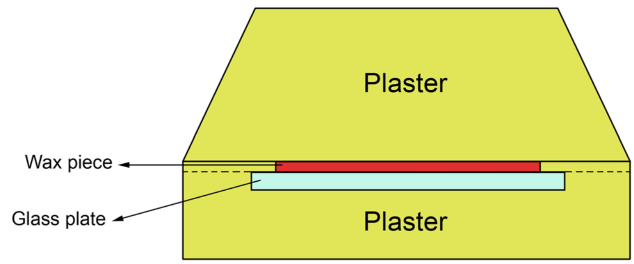

Fig. 1 Cross-section of gypsum mold used for fabrication of soft liners and denture base acrylic resin specimens

Fig. 2 Recording color measurements by the colorimeter

Results

Mean values for the CIE L*a*b* Color Scale (ΔE) tests of the three materials studied that immersed in sodium hypochlorite (5.25 %) for 24 h and 7 days are illustrated in Table 3. The effect of duration on color stability of the three materials tested was detected in the present study ($p < 0.05$), the color shift increased over time.

ΔEs of silicone-based liner at the 1st and 7th days of immersion were significantly more than ΔEs of denture base acrylic resin and acrylic-based liner ($p < 0.05$), however there was insignificant difference between ΔE of Vertex™ Soft and Vertex Regular after 1 day of immersion ($p > 0.05$) (Table 4).

Mean values ΔL* of the three materials studied that immersed in sodium hypochlorite (5.25 %) for 24 h and 7 days are illustrated in Table 5.

Immersion in sodium hypochlorite (5.25 %) for 7 days produced an increase in ΔL* (became lighter) for all materials tested ($p < 0.05$).

ΔL*s of silicone-based liner after 24 h of immersion were significantly more than ΔL*s of denture base acrylic resin and acrylic-based liner ($p < 0.05$). Change in ΔL* values of denture base acrylic resin and acrylic-based liner was small and statistically insignificant after 24 h of its

Table 1 Materials tested

Material	Symbol	Chemical type	Curing type	Manufacturer
Molloplast-B (soft denture liner)	M	Silicone-based material	Heat-curing	DETAX, Ettlingen-Germany.
Vertex™ Soft (soft denture liner)	V	Plasticized acrylic resin material	Heat-curing	Vertex-Dental, Zeist, The Netherlands
Vertex Regular	VR	Denture base acrylic resin	Heat-curing	Vertex dental, Zeist, The Netherlands

Table 2 Critical marks of color change according to the National Bureau of Standards

Critical marks of color difference	Textile terms (NBS units)
Trace	0.0–0.5
Slight	0.5–1.5
Noticeable	1.5–3.0
Appreciable	3.0–6.0
Much	6.0–12.0
Very much	>12.0

Table 3 Mean values and standard deviations of the ΔEs

Time of immersion	M ΔE Mean ± SD	V ΔE Mean ± SD	VR ΔE Mean ± SD
1 day	1.5420 ± 0.27948	0.5300 ± 0.22405	0.5430 ± 0.20543
7 days	9.5540 ± 1.01084	8.0210 ± 0.33574	7.3310 ± 0.44363

Table 4 Mean difference of materials tested at 1st and 7th day of immersion

Materials		ΔE		ΔL*	
		Mean Difference (1st day)	Mean Difference (7th day)	Mean Difference (1st day)	Mean Difference (7th day)
M	V	1.01200*	1.53300*	0.97700*	0.50700*
	VR	0.99900*	2.22300*	1.02300*	2.60900*
V	M	−1.01200*	−1.53300*	−0.97700*	−0.50700*
	VR	−0.01300	0.69000*	0.04600	2.10200*
VR	M	−0.99900*	−2.22300*	−1.02300*	−2.60900*
	V	0.01300	−0.69000*	−0.04600	−2.10200*

* The mean difference is significant at the 0.05 level

Table 5 Mean values and standard deviations of the ΔL*s

Time of immersion	M ΔL* Mean ± SD	V ΔL* Mean ± SD	VR ΔL* Mean ± SD
1 day	1.2190 ± 0.23115	0.2420 ± 0.10163	0.1960 ± 0.10448
7 days	8.1010 ± 0.19542	7.5940 ± 0.34545	5.4920 ± 0.19447

Table 6 Clinical color match according to color difference

Color difference, ΔE	Clinical color match
0	Perfect
1–2	Good
2–3.5	Clinically acceptable
>3.5	Mismatch

immersion ($p > 0.05$). However, the increase in ΔL* values of the acrylic-based liner after 7 days of immersion was considerably more than the increase in ΔL* values of denture base acrylic resin ($p < 0.05$) (Table 6).

Discussion

According to results of the current research, the stated null hypothesis was refused. It was appeared that all materials tested exhibited color differences that were statistically different after 7 days of immersion in sodium hypochlorite (5.25 %), and silicone-based denture lining material was less stable chromatically against this chemical disinfectant than acrylic-based one.

Lack of longevity of denture base materials and soft denture liners is an important problem in prosthodontics. The color stability of these materials may provide essential information about the serviceability of a prosthesis [24, 31, 33–35] and it may be the most significant factor for determining a patient's acceptance of it [24, 33]. Several researchers studied the influence of different food colorants on color stability of dental restorative materials and denture base acrylic resins [32, 36–38]. However, little information is available on the influence of denture cleansers on color stability of denture base acrylic resins and soft denture lining materials. The purpose of the present study was to estimate the effect of a chemical disinfectant on color stability of a denture base acrylic resin and two soft denture lining materials of two different chemical types.

There are two color systems used to assess chromatic differences: the Munsell Color System and the Standard Commission Internationale de L'Eclairage (CIE Lab) Color System [39]. The later one was used in the present study because it has been widely used for the determination of chromatic differences [32, 40], and it was recommended by ADA [32]. Methods used for studying color stability in different dental materials included exposing specimens to accelerated aging conditions [30, 31, 41, 42], or immersing in different food colorants or beverages [32, 43]. The method used in the present study included immersing specimens in a chemical disinfectant solution. Cleansing prosthesis is a necessary process and is more imperative in patients who suffer from chronic or debilitating diseases or underwent to oral surgery due to high risk of infection [18]. Soft denture lining materials are indicated for those patients, therefore evaluating the effect of cleansing agents on color stability of these materials is very important. Sodium hypochlorite was applied as disinfecting agent for cleansing materials studied, because: (1) it has been commonly used for cleansing prosthesis, (2) it was recommended by Jagger and Harrison [8] for cleansing soft denture liners, (3) clinical trials demonstrated its effectiveness in removing plaque [44], and (4) it is commercially available and cheap. Sodium hypochlorite was used at a level of 5.25 %. The choice of this concentration was based on studies of Rudd et al. [18], and McGowan et al. [45], which indicated that a 5-min immersion of dentures in undiluted sodium hypochlorite (5.25 %) accomplished sterilization against a variety of microorganisms.

Although the mechanism of color change has not understood, but it can be measured. Methods for evaluating color stability include:

1. A visual method, which depends on the macroscopic visual comparison among specimens [43, 46, 47].
2. A digital method, which is based on the digital expression of the color perceived from the object [28, 30–32, 41, 42]

The digital method was applied in this study. It is more accurate than visual one because it is a quantitative analysis, and does not depend on assessors. Color measurements were achieved by applying the lens of the device at the glazed surface of specimen that formed against the glass plate in the mold to avoid the effect of surface roughness which may vary the measurements [32].

The ΔE values were less than 1 when cleansing specimens made of Vertex™ Soft and Vertex Regular by immersing in a solution of sodium hypochlorite (5.25 %) for a period of 24 h; while ΔE values of Molloplast-B specimens were more than 1. This result was particularly important because two colors with a ΔE of less than the value of one being judged were thought to be a color match by more than 50 % of observers [48, 49]. So, the color changes exhibited by all specimens made of Vertex™ Soft and Vertex Regular after immersing for 24 h were at clinically acceptable levels whereas the color change in specimens of Molloplast-B was apparent after immersion in the disinfectant solution for 24 h only. Results related to the denture base acrylic resin (Vertex Regular) at 24 h of immersion were in agreement with those of previous study which showed that the ΔE value of Lucitone 199 (a heat polimerized acrylic resin) did not exceed a value one [28].

When the mean ΔE values of specimens that immersed for 24 h were converted to NBS units, the critical remarks of color difference were slight for Molloplast-B and trace for both Vertex™ Soft and Vertex Regular.

Besides, O'Brien [50] employed another parameter to explain the clinical significance of ΔE values. He stated that when the ΔE value is greater than 3.5, it is no longer within the limits of clinical acceptability because the discoloration becomes visually detectable (Table 6). In accordance with this parameter, all materials studied did not become under good level after immersing in sodium hypochlorite (5.25 %) for 24 h.

The ΔEs of all specimens were more than one after immersing in the disinfectant solution for 7 days. These results indicated that obvious color change had taken place. When the mean ΔE values of specimens that immersed for 7 days were converted to NBS units, the critical remarks of color difference were much for all materials tested. Also, according to O'Brien's parameter ΔEs of all materials expressed on clinical color mismatch (ΔE was more than 3.5) [50]. Thus, the color change that exhibited by all specimens after 24 h (1 day) were clinically acceptable, whereas all of them showed sever discoloration after 7 days. This could be a result of the coloring material leaching out after long time of immersion (7 days).

Molloplast-B with ΔE of 1.54 after immersing for 24 h demonstrated the greatest change and was statistically different from all other materials tested, while Vertex™ Soft with ΔE of 0.53 revealed the smallest change and was not statistically different from Vertex Regular with ΔE of 0.54. After immersion for 7 days, Molloplast-B revealed the greatest change too with ΔE of 9.55 and was statistically different from all other materials tested, whereas the smallest change was demonstrated by Vertex Regular with ΔE of 7.33. Color change in denture base acrylic resin may be caused by monomer leaching out and by water being absorbed [38]. Vertex Regular has a low residual monomer ratio, this may interpret why the disinfectant solution had a small effect on the color stability of this material. Vertex™ Soft showed a moderate change, it could be a result of the plasticizers leaching out. The results are incompatible with study of Jin et al. [12], which revealed that silicone materials were more stable chromatically than acrylic materials when immersed in cleansing solutions. It may be attributed to the difference between cleansing agents used.

The effect of period of immersing in disinfectant solution was studied. It was concluded that color change tended to increase with longer immersion times. This finding was supported by visual evaluation, and may be due to water sorption and the solubility of the materials [43, 47].

L* represents the lightness or darkness of the object. When L* value increases that means the material exposed to bleaching or whitening. So, this value has clinical importance especially for soft denture lining materials. Molloplast-B suffered from bleaching more than the two other materials tested when immersing in the disinfectant solution for 1 day, while Vertex™ Soft and Vertex Regular exposed to bleaching identically. After 7 days of immersion, Molloplast-B also exposed to bleaching more than two other materials tested, but Vertex™ Soft revealed more bleaching than Vertex Regular. As a result, All materials tested exposed to bleaching increasingly after 7 days of immersion. These findings were in agreement with studies of Saraç et al. [24] and Purnaveja et al. [38]. Bleaching may be due to a chemical reactions occurred at the surfaces of a specimen. L* values range between 0 and 100 in CIE L* a* b* system, so when ΔL* is smaller than one, it has minimal importance clinically [28]. Accordingly, bleaching of Vertex™ Soft and Vertex Regular with ΔL* of (0.24) (0.20) respectively after immersing for 1 day had not clinical importance. For Molloplast-B ΔL* was more than one, so it could be concluded that sodium hypochlorite (5.25 %) lead to significant bleaching or whitening after immersing this material for 1 day. ΔL* values of all materials tested became more than one after immersion for 7 days. Consequently, the disinfecting solution was very effective in bleaching all of them. Thus, it could be concluded that the bleaching effect of sodium hypochlorite 5.25 % on Molloplast-B was the greatest one throughout periods of study. On the other hand, its bleaching effect on Vertex™ Soft and Vertex Regular was the same after a short period of immersion (1 day), and after 7 days the bleaching effect became greater on Vertex™ Soft in comparison with Vertex Regular.

Limitations of the present in vitro study include that variation of the concentration of sodium hypochlorite was not investigated. Schaefer [51] recommended a 1:5 dilution (1 % solution), but Rudd et al. [18] immersed all acrylic resin dentures in full strength sodium hypochlorite for 15 h and found no discoloration, so 5.25 % sodium hypochlorite was applied in this study. Colorimetric measurements for each specimen were taken before immersion, and after 24 h and 7 days of immersion. Soaking materials for 7 days produces the equivalent of 3 years of clinical use nearly with immersing in sodium hypochlorite for 10 min daily. It means that the test gave an index about the accumulative effect of sodium hypochlorite when these materials used for a long time. The findings of this study revealed that 5.25 % sodium hypochlorite has apparent effect on color stability of materials tested. There also seems to be a need for further research to understand the mechanism by which chemical disinfectants affect on the color stability of denture base resins and various denture soft lining materials.

Conclusions

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

- The effect of sodium hypochlorite (5.25 %) on color stability of the silicone type soft lining material after immersion for one day was perceivable by the human eye ($\Delta E > 1$); however, the color difference of this material was clinically acceptable ($\Delta E < 3.5$).
- The effect of sodium hypochlorite (5.25 %) on color stability of acrylic type soft lining material and denture base acrylic resin after immersion for one day was insignificant ($\Delta E < 1$).
- Color changes in all materials tested tended to increase with longer immersion times; whereas, all of them revealed sever discoloration after 7 days of immersion.
- The silicone type soft lining material was less resistant to color change caused by immersion into sodium hypochlorite (5.25 %) than two other materials tested.
- The denture base acrylic resin was more resistant to bleaching effect of sodium hypochlorite 5.25 % than the other two materials tested, while the silicone type soft lining material was the least resistant one.
- The results revealed that the color stability of soft denture liner was influenced by its chemical type.

Acknowledgments I would like to express my appreciation to all those who gave me the possibility to complete this study. I acknowledge Damascus University for the financial support of the study. I would like to deeply thank the statistician Muhammad Zaino who helped to perform the statistical study of the research.

Conflict of interest The current research is free of conflict of interest.

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