Effect of Denture Cleaning Solutions on Water Sorption, Solubility and Color Stability of Resilient Liners

Jadesada Palasuk[1]*, Dalanporn Kaewkumnerd[1], Kunlanun Sangchanpakdee[1], Thanchanok Saengkhiaw[1], Suchanart Yuthavong[1], Nawaporn Jittapiromsak[1]

1. Department of Restorative Dentistry, Faculty of Dentistry, Naresuan University, Phitsanulok, Thailand.

Abstract

This study compared water sorption (Wsp), solubility (Wsl) and color stability of an acrylic based (Soft Liner®) and a silicone based resilient liners (Soft Liner Tough M®) that were undergone daily cleaning and using cycles as follows: soaking in artificial saliva, cleaning solution and distilled water, respectively. Three factors (types of resilient liners, cleaning solution and time) were evaluated.

Ninety six disk shaped specimens were fabricated and divided into 8 groups (n=4) according to types of resilient liners, cleaning solutions (distilled water, 0.1% sodium hypochlorite (NaOCl), 0.2% chlorhexidine gluconate and Polident®) and time. Color and weight were measured after 24 h, day 7 and 14. Wsp and Wsl and color change (ΔE) were calculated. Data were analyzed using ANOVA and Tukey test ($P<0.05$).

Soft Liner® showed significant higher Wsp, Wsl and ΔE than Soft Liner Tough M®. “Time” and “cleaning solution” showed no significant effect on Wsp. Cleaning Soft Liner® in NaOCl increased Wsl than cleaning in Polident® ($P<0.05$). ΔE was significantly increased from 24 h to day 7 and to day 14, respectively. Polident® increased ΔE of resilient liners than NaOCl ($P<0.05$). Silicone based resilient liners is more stable in terms of Wsp, Wsl and color stability than acrylic based resilient liners.

Experimental article (J Int Dent Med Res 2019; 12(1): 12-18)

Keywords: Resilient liners, Water sorption, Solubility, Color stability.

Received date: 06 June 2018 **Accept date:** 19 August 2018

Introduction

Currently, different kinds of resilient liners have been widely used clinically. Based on their composition, they are simply classified into two main categories: acrylic based resilient liners (ABLs) and silicone based resilient liners (SBLs).[1] The ABLs are composed of methacrylate polymers, a radical initiator (i.e. organic peroxide), cross-linking agents (i.e. ethylene glycol dimethacrylate), and external plasticizers (i.e. dibutyl phthalate, ethyl acetate or alcohol).[2] On the other hand, SBLs are basically polydimethylsiloxanes which is elastomer in nature.

***Corresponding author:**
Dr. Jadesada Palasuk
Department of Restorative Dentistry,
Faculty of Dentistry, Naresuan University,
Phitsanulok, Thailand
E-mail address: jpalasuk@gmail.com

Resilient liners are used to equally distribute occlusal forces to the denture bearing mucosa for restoring health of inflamed mucosa such as denture stomatitis or recurrent soreness. Since these materials are elastic in nature, they are also beneficial for patients with sharp or advancing alveolar bone resorption,[3,4] congenital or acquired oral defects requiring obturation, and xeostomia.[5] Additionally, these materials improve retention and stability of removable partial dentures such as in the case of poor fitting denture.[1,2]

To achieve those purposes, they are advisable to maintain their properties in clinical setting. However, deterioration occurs continuously.[2,3] They encounters dimensional and mechanical changes during the function in oral cavity or even in the daily cleaning. Denture cleaning techniques can be mechanical and chemical cleaning. Chemical cleaning solutions are based on alkaline peroxides (i.e. Polident®)[6], alkaline hypochlorites (i.e. sodium hypochlorite /NaOCl)[7], disinfectants (i.e. chlorhexidine/CHX)[8], enzymes and acids.[9,10] These chemicals are beneficial for disinfecting candida infected dentures especially for treatment denture stomatitis.[11-15] Through the course of daily changes, water sorption (Wsp) and solubility (Wsl) of the resilient liners are associated with the most common problems of these materials.[16] Sorption is defined as the simultaneously liquid diffusion into the materials from the surrounding environments, occupying the spaces/voids within the polymer structures. Wsl refers to the loss of the soluble components to the surrounding medium. These result in expansion and distortion of the materials, reduction of mechanical strength, increase in roughness and hardness, color changes, loss of superficial integrity, unpleasant smell, as well as bacteria colonization.[16,17]

Currently, in vitro studies are limited on their ability to fully simulate the effect of cleaning solution as daily using/cleaning cycles on the properties of resilient liners. Therefore, the current study aims to compare Wsp, Wsl and color stability of two resilient liners that undergone daily cleaning and using cycles for 14 days. The null hypothesis was that there was no significant difference in Wsp, Wsl and color stability of resilient liners. Three main factors were evaluated as follows: types of resilient liners, cleaning solution and time.

Materials and methods

Water sorption (Wsp), solubility (Wsl) were determined by the method described in American Dental Association (ADA) specification no 12 for denture base polymers. Two types of resilient liners were used in this study: an acrylic based resilient liner/ABL (Soft Liner®, GC Corporation, Tokyo, Japan), a silicone based resilient liner/SBL (Soft Liner Tough M®, Tokuyama, Yamaguchi, Japan).

Specimen fabrication. Ninety six disk shaped specimens (50 mm × 3 mm) were fabricated using custom made plastic molds. Briefly, plastic molds were coated with a thin layer of petroleum jelly and placed on the glass slap. Resilient liners were prepared according to manufacturer's instruction. Soft Liner® was mixed with powder: liquid ratio of 2.2 g: 1.8 g and packed into the mold. Soft Liner Tough M® supplied as a cartridge was directly injected directly into the mold. Then, a glass slap was placed on the top of the mold. Specimens were left into the mold as recommended by manufacturer (5 minutes for Soft Liner® and 20 minutes for Soft Liner Tough M®). Then, the excess materials were removed.

Water sorption and solubility. Specimens were transferred to a desiccator containing dry silica gel and weighted daily to an accuracy of 0.001 g using an analytical balance (Mettler Toledo International Inc., AB204-S, Greifensee, Switzerland) until the constant weight (W1) was reached (Figure 1). The dry specimens were then randomly divided into 8 group (n=4) based on the types of resilient liners, time, and cleaning solution as follows: control: distilled water, 0.1% sodium hypochlorite (NaOCl), 0.2% chlorhexidine gluconate (CHX), and Polident® (Block Drug Company, Memphis, USA). Specimens were individually soaked in artificial saliva (pH 7.2)[18] for 12 hour (37°C) and then rinsed with distilled water for 1 minute. Then, they were immersed in 30 ml of cleaning solution for 20 minutes, rinsed again with distilled water for 1 minute and kept in distilled water overnight at room temperature. These processes were repeated daily (Figure 1). Notably, soaking specimens into artificial saliva and distilled water represents the daily use cycle of dentures that are exposed to saliva during the day and kept in the water overnight except the control group in which specimens were kept in distilled water at all times until the weight was measured.

At 24 h, day 7 and 14, specimens were removed from distilled water, gently wiped until no visible moisture was observed and then weighed (W2). After this reading, the specimens were reconditioned in a desiccator containing dry silica gel in order to obtain a constant dry weight (W3), following the cycle described for W1. The water sorption (Wsp) and solubility (Wsl) were calculated as follows:[5,19]

$$\text{Water sorption (Wsp, \%)} = \frac{W2-W3}{W1}\times 100$$

$$\text{Solubility (Wsl, \%)} = \frac{W1-W3}{W1}\times 100$$

Where,
W1: The initial weight
W2: The weight after absorption
W3: The final weight after desiccation

Color stability. CIE L*a*b* system was used to determine the color of resilient liners immediately after specimen fabrication (C0, baseline color) using Color meter (ColorQuest® XE, HunterLab, Reston, VA, USA). Color measurement was obtained again at 24 h, day 7 and 14 after W2 weighing (C1). Color change (ΔE) which is the change in the position of a point in the 3-dimensional CIE L*a*b* space represented total color different compared to the baseline (color of specimens immediately after fabrication) were calculated based on the following equation:[20,21]

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

where, $\Delta L^* = L^*_{C1} - L^*_{C0}$ (difference in lightness and darkness, $-L^*$ = dark, $+L^*$ = light)
$\Delta a^* = a^*_{C1} - a^*_{C0}$ (difference in red and green, $-a^*$= green, $+a^*$= red)
$\Delta b^* = b^*_{C1} - b^*_{C0}$ (difference in yellow and blue, $-b^*$= blue, $+b^*$= yellow)

Statistical analysis. The data were analyzed using analysis of variance (ANOVA) followed by Tukey test for multiple comparisons. A significance level was set at α=0.05.

Results

Generally, ANOVA detected statistical significance for the factors “types of materials” (Soft Liner® or Soft Liner Tough M®, *P*=0.000) on three parameters (Wsp, Wsl and ΔE) regardless of time and cleaning solution (Table 1). Soft Liner® had significant higher Wsp, Wsl and ΔE than those of Soft Liner Tough M® (*P*=0.000). By excluding the effect of types of materials, the remaining factors (time and cleaning solution) analyzed by two-way ANOVA differ from one to others and are described as follows:

Parameters	Materials	
	Soft Liner®	Soft Liner Tough M®
Water sorption (%)	1.20±1.23	0.18±0.36
Solubility (%)	0.89±0.30	0.05±0.60
Color change (ΔE)	19.24±3.34	3.48±1.82

Table 1 Descriptive Statistics (mean±SD) of Water Sorption (%), Solubility (%) and Color Change (ΔE) of Soft Liner® and Soft Liner Tough M®

Water sorption. Figure 2A and 2B showed Wsp of Soft Liner® and Soft Liner Tough M®. Statistical analysis revealed that time and cleaning solution showed no significantly effect on Wsp.

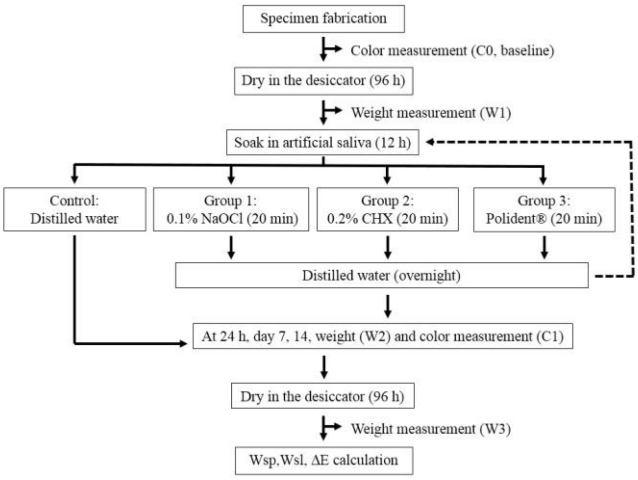

Figure 1. Experimental Protocol. CHX: Chlorhexidine.

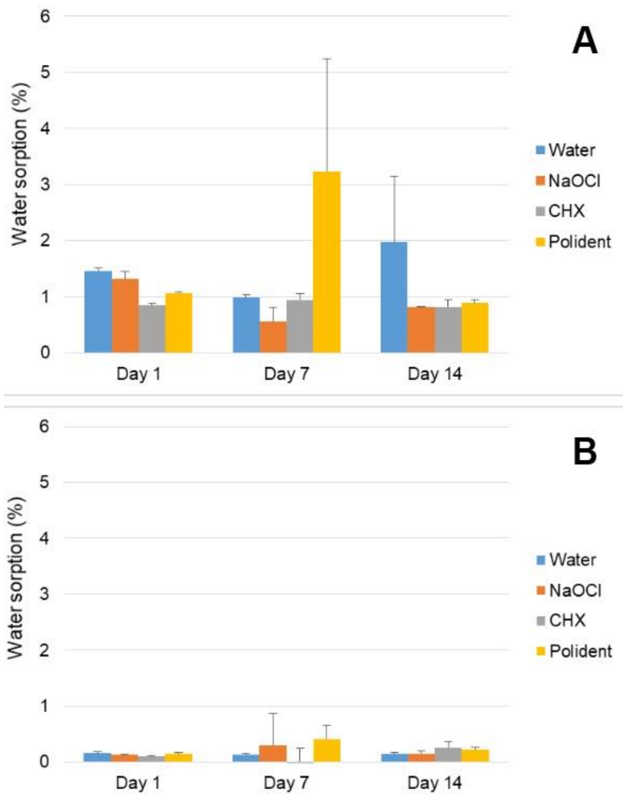

Figure 2. Mean Water Sorption (Wsp, %) of Soft Liner® (A) and Soft Liner Tough M® (B). Statistical Analysis Revealed that Factors “Duration” and “Soaking Solution” Had No Significant Effect on Wsp.

Solubility. Wsl of Soft Liner® and Soft Liner Tough M® are shown in Figure 3A, 3B, respectively. Compared within each type of materials (either Soft Liner® or Soft Liner Tough M®), time (*P*=0.000) and cleaning solution (*P*=0.017) significantly affected on Wsl of Soft Liner®, these results were not observed in Soft Liner Tough M®. Multiple comparison showed significantly different among "time" (24h, day 7 and day 14, *P*<0.05) where the highest Wsl was day 14. Cleaning Soft Liner® in NaOCl significantly increased Wsl than cleaning in Polident® (*P*=0.02). Other significant differences were not observed in Soft Liner Tough M®.

Color change (ΔE). Delta E (ΔE) represented color change of Soft Liner® and Soft Liner Tough M® is shown in Figure 4A, 4B, respectively. ANOVA detected significant difference on both factors (time: *P*=0.00, and cleaning solution: *P*=0.047). Over the 14 days of this study, it was found that ΔE was significantly increased from 24 h to day 7 (*P*=0.00) and to day 14 (*P*=0.00) but no significant difference was found between ΔE of day 7 and day 14 (*P*=0.933). Moreover, soaking resilient liners in Polident® significantly increased ΔE (higher color change) than that of NaOCl (*P*=0.044). No other significant differences were found.

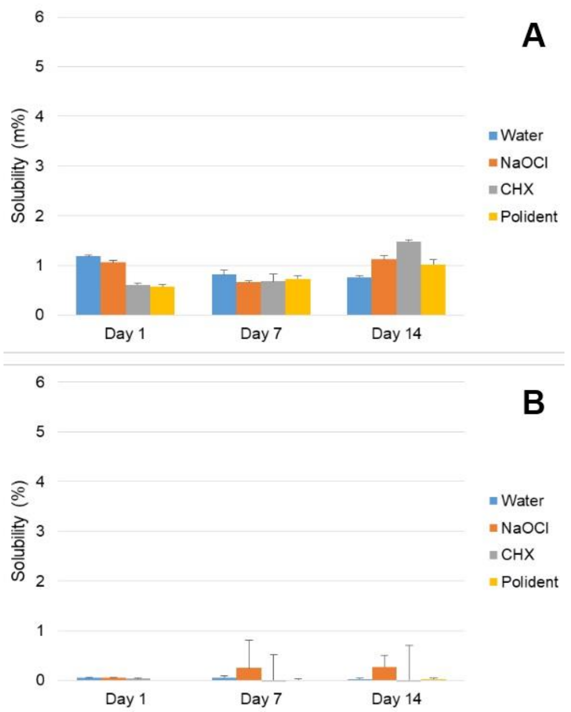

Figure 3. Mean solubility (Wsl, %) of Soft Liner® (A) and Soft Liner Tough M® (B). Factors "time" and "soaking solution" significantly influenced on Wsl of Soft Liner®, not Wsl of Soft Liner Tough M®. Statistical significant differences among 24 h, day 7 and day 14 were observed where the highest Wsl was day 14. Soaking resilient liners in NaOCl showed significant higher Wsl than that of Polident.

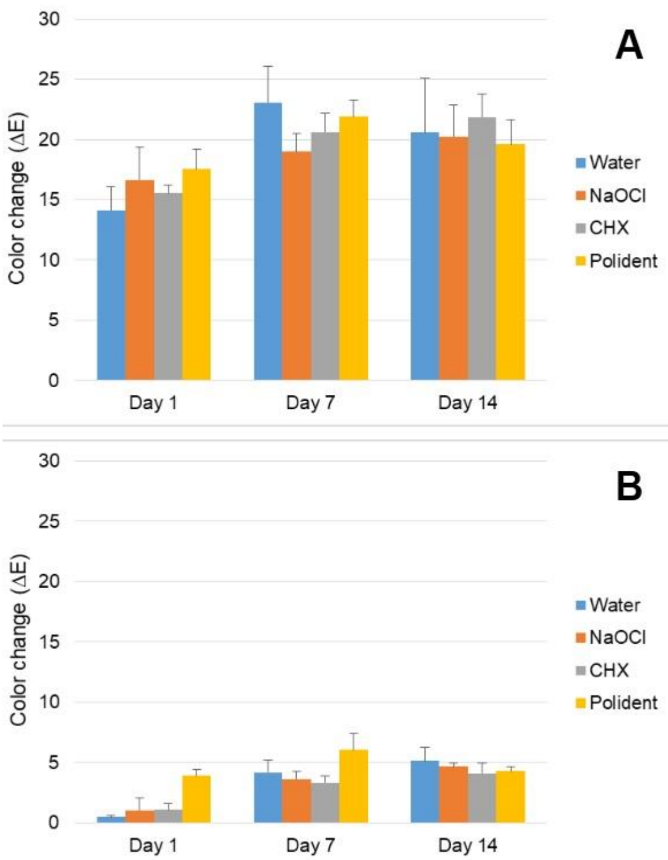

Figure 4. Mean Color Change (ΔE) of Soft Liner® (A) and Soft Liner Tough M® (B). Factors "time" and "soaking solution" Significantly Increase ΔE Values from 24 h to day 7 and Day 14. Soaking Resilient Liners in Polident Significantly Increased ΔE than that of NaOCl.

Discussion

During clinical use, resilient liners are immersed in saliva and exposed to foods and beverages. At night, they are usually soaked in water or cleansing agents. As a result, water are simultaneously diffused into the polymer causing deterioration of materials.[22] This study was conducted to simulate the daily using/cleaning cycles of resilient liners for 14 days and to compare Wsp, Wsl and ΔE. The results led to rejection of null hypothesis since a significant differences of Wsp, Wsl and ΔE were observed.

The average Wsp and Wsl of Soft Liner® were 6-folds and 16-folds higher than those of Soft Liner Tough M® (*P*<0.000, Table 1). High Wsp and Wsl of ABLs are related with swelling, distortion, hardening, absorption of odors, and color changes.[22] This finding suggested the less stable of ABLs (i.e. Soft Liner®) in aqueous environment compared to the SBLs (i.e. Soft Liner Tough M®). This results are supported by various studies.[23,24] This was due to the role of plasticizers and other soluble chemicals such as aromatic esters (i.e. dibutylpthalate), ethyl acetate or ethyl alcohol.[25] The plasticizers can lower the glass transition temperature by separating polymer chains and make the materials softer.[26] However, such plasticizers are not bonded to the methacrylate resin of ABLs, and therefore, they leach out in overtime.[16,23]

Regarding the factor "time", time was significantly affected only on Wsl of Soft Liner® (Figure 3) where the highest Wsl was day 14. This finding is reasonable because the longer materials immerses in the aqueous solution, the more water diffuses into the materials causing high solubility. For the cleaning solution, NaOCl had significantly higher Wsl that of Polident® (p=0.02). The rational related to this finding is unclear. Kazanji and Watkinson[27] reported that Na^+, K^+ ion can speed up the release of plasticizers from ABLs creating high Wsl. However, Na^+, K^+ concentrations in both cleaning solutions were not measured and should be further investigated.

On the other hand, "time" and "cleaning solution" has no adverse effect on Wsp and Wsl of Soft Liner Tough M®. This may be because Soft Liner Tough M® is an elastomer and it is not required to have plasticizers to maintain its elasticity. In other words, less soluble chemicals leach out and therefore, the significant weight change was not observed. In addition, the mixing technique should be considered. The injectable SBLs create more homogenous, less porosity in the specimens compared to the hand mixed ABLs. As a result, such space/voids are less occupy by water resulting in insignificant difference of Wsp and Wsl.

Regarding the ΔE, it is obviously that "types of resilient liners", "time" and "cleaning solution" significantly deteriorated color of resilient liners. As human eyes can detect, it is considered undetectable if ΔE is less than 1, "clinically acceptable" if ΔE ranges between 1-2, and "clinically noticeable/unacceptable" if ΔE is more than 3.3.[28] In this study, ΔE of the Soft Liner® is remarkably higher than 3.3 even at 24 h (ΔE >14). Conversely, ΔE of Soft Liner Tough M® are approximately at the unnoticeable level at 24 h and clinically noticeable at day 14 (ΔE < 5). These results suggest that SBLs like Soft Liner Tough M® have higher color stability than ABLs.

Color change is related with intrinsic and extrinsic factors.[29] The intrinsic factor is the discoloration due to the matrix change of the polymer. Extrinsic factors is the absorption of external staining.[29] The significant color change between two resilient liners is mainly due to the individual characteristics of each material associated with Wsp[30] and led to the absorption and accumulation of stain. First, plasticizers used to improve chain stretching of the polymer make penetration of colorants easier and faster. Second, staining agent may penetrate into the space produced by the leaching out of plasticizers. Third, the hydrophobicity of SBLs[31] such as Soft Liner Tough M® make it more difficult to absorb water or colorants as noticed by the low Wsp and Wsl. Generally, high Wsp and Wsl is associated with high ΔE and material aging.[32,33]

Post-hoc analysis showed significant higher ΔE of Polident® than NaOCl. This is possibly due to the high ionic concentration of Polident® which accelerates the release of soluble chemicals,[27] changes polymer structure and finally, declines material properties.[23] Moreover, the extrinsic factors should be taken into the consideration. Whereas NaOCl is colorless, the Polident® is light green so that the high ΔE of Polident® group could result from external staining of this solution. Interestingly, CHX solution which is slightly yellowish color did not significantly darken color of both resilient liners. This may be because of the stronger greenish color of Polident® compared to the light yellowish color of CHX, and the short soaking time (only 20 minutes/day). The longer duration may show significant change in ΔE compared to the control (water).[34]

Even though this study simulate the daily cleaning/cycles of resilient liners, this in vitro study did not simulate the real functional use. In other words, the materials did not expose to the functional stress, bacteria and their products, temperature change, diet, and dynamic/diurnal saliva flow. Moreover, more materials, higher concentration of cleaning agents or the longer experimental time may be beneficial to further investigate the changes particularly for SBLs that did not show significant change in Wsp and Wsl in this study.

Conclusions

Within the limitations of this in vitro study, it can be concluded that SBLs (Soft Liner Tough M®) is more stable in terms of Wsp, Wsl and color stability than ABLs regardless of cleaning solutions and time.

Acknowledgements

This study was supported in part by Faculty of Dentistry, Naresuan University.

References

1. Mohammed HS, Singh S, Hari PA, et al. Evaluate the effect of commercially available denture cleansers on surface hardness and roughness of denture liners at various time intervals. Int J Biomed Sci 2016;12(4):130-42.
2. Chladek G, Zmudzki J, Kasperski J. Long-term soft denture lining materials. Materials (Basel) 2014;7(8): 5816-42.
3. Kimoto S, Kimoto K, Murakami H, Gunji A, Ito N, Kawai Y. Survival analysis of mandibular complete dentures with acrylic-based resilient liners. Gerodontology 2013;30(3):187-93.
4. Ogawa A, Kimoto S, Saeki H, Ono M, Furuse N, Kawai Y. The influence of patient characteristics on acrylic-based resilient denture liners embedded in maxillary complete dentures. J Prosthodont Res 2016;60(3):199-205.
5. Dinckal Yanikoglu N, Yesil Duymus Z. Comparative study of water sorption and solubility of soft lining materials in the different solutions. Dent Mater J. 2004;23(2):233-9.
6. Iseri U, Uludamar A, Ozkan YK. Effectiveness of different cleaning agents on the adherence of Candida albicans to acrylic denture base resin. Gerodontology. 2011;28(4):271-6.
7. Mahboub F, Salehsaber F, Parnia F, Gharekhani V, Kananizadeh Y, Taghizadeh M. Effect of denture cleansing agents on tensile and shear bond strengths of soft liners to acrylic denture base. J Dent Res Dent Clin Dent Prospects 2017;11(3):183-88.
8. Bertolini MM, Portela MB, Curvelo JA, Soares RM, Lourenco EJ, Telles DM. Resins-based denture soft lining materials modified by chlorhexidine salt incorporation: an in vitro analysis of antifungal activity, drug release and hardness. Dent Mater. 2014; 30(8):793-8.
9. Duyck J, Vandamme K, Krausch-Hofmann S, et al. Impact of Denture Cleaning Method and Overnight Storage Condition on Denture Biofilm Mass and Composition: A Cross-Over Randomized Clinical Trial. PLoS One. 2016;11(1):e0145837.
10. Moffa EB, Giampaolo ET, Izumida FE, Pavarina AC, Machado AL, Vergani CE. Colour stability of relined dentures after chemical disinfection. A randomised clinical trial. J Dent. 2011; 39Suppl 3:e65-71.
11. Kaomongkolgit R, Wongviriya A, Daroonpan P, Chansamat R, Tantanapornkul W, Palasuk J. Denture stomatitis and its predisposing factors in denture wearers. J Int Dent Med Res. 2017;10(1): 89-94.
12. Aoun G, Cassia A, Berberi A. Effectiveness of a Chlorhexidine Digluconate 0.12% and Cetylpyridinium Chloride 0.05% Solution in eliminating Candida albicans Colonizing Dentures: A Randomized Clinical in vivo Study. J Contemp Dent Pract. 2015;16(6): 433-6.
13. Barnabe W, de Mendonca Neto T, Pimenta FC, Pegoraro LF, Scolaro JM. Efficacy of sodium hypochlorite and coconut soap used as disinfecting agents in the reduction of denture stomatitis, Streptococcus mutans and Candida albicans. J Oral Rehabil. 2004;31(5):453-9.
14. Montagner H, Montagner F, Braun KO, Peres PE, Gomes BP. In vitro antifungal action of different substances over microwaved-cured acrylic resins. J Appl Oral Sci. 2009;17(5):432-5.
15. Emami E, Kabawat M, Rompre PH, Feine JS. Linking evidence to treatment for denture stomatitis: a meta-analysis of randomized controlled trials. J Dent. 2014; 42(2):9-106.
16. Lima JF, Maciel JG, Arrais CA, Porto VC, Urban VM, Neppelenbroek KH. Effect of incorporating antifungals on the water sorption and solubility of interim resilient liners for denture base relining. J Prosthet Dent. 2016; 115(5)611-6.
17. Zankuli MA, Devlin H, Silikas N. Water sorption and solubility of core build-up materials. Dent Mater. 2014;30(12):e324-9.
18. Pashley DH, Tay FR, Yiu C, et al. Collagen degradation by host-derived enzymes during aging. J Dent Res. 2004;83(3):216-21.
19. Chladek G, Kasperski J, Barszczewska-Rybarek I, Żmudzki J. Sorption, solubility, bond strength and hardness of denture soft lining incorporated with silver nanoparticles. Int J Mol Sci. 2012; 14(1):563-74.
20. Perez Mdel M, Saleh A, Yebra A, Pulgar R. Study of the variation between CIELAB delta E* and CIEDE2000 color-differences of resin composites. Dent Mater J. 2007;26(1):21-8.
21. Kim JG, Yu B, Lee YK. Correlations between Color Differences Based on Three Color-Difference Formulas Using Dental Shade Guide Tabs. J Prosthodont. 2009;18(2):135-40.
22. Leon BL, Del Bel Cury AA, Rodrigues Garcia RC. Water sorption, solubility, and tensile bond strength of resilient denture lining materials polymerized by different methods after thermal cycling. J Prosthet Dent. 2005;93(3):282-7.
23. Brozek R, Koczorowski R, Rogalewicz R, Voelkel A, Czarnecka B, Nicholson JW. Effect of denture cleansers on chemical and mechanical behavior of selected soft lining materials. Dent Mater. 2011;27(3):281-90.
24. Sudhapalli S, SuDhapalli S. Time Dependent Effect of a Denture Cleanser on the Sorption and Solubility of Four Soft Liners-An Invitro Study. J Clin Diagn Res. 2016;10(4):ZC100.
25. Shanmuganathan N, Padamanabhan T, Subramaniam R, Madhankumar S. The compliance of temporary soft lining materials-an in vivo & vitro study. Int J Sci Res Publ. 2012;2(6):1-7.
26. Jones DW, Sutow EJ, Hall GC, Tobin WM, Graham BS. Dental soft polymers: plasticizer composite and leachability. Dent Mater. 1988;4(1):1-7.
27. Kazanji MN, Watkinson AC. Soft lining materials: their absorption of, and solubility in, artificial saliva. Br Dent J. 1988;165(3):91-4.
28. Vichi A, Ferrari M, Davidson CL. Color and opacity variations in three different resin-based composite products after water aging. Dent Mater. 2004;20(6):530-4.
29. Goiato MC, Zuccolotti BC, Moreno A, dos Santos DM, Pesqueira AA, Dekon SF. Colour change of soft denture liners after storage in coffee and coke. Gerodontology 2011;28(2):140-5.
30. Pisani MX, Leite VMF, Badaró MM, Malheiros-Segundo AdL, Paranhos HdFdO, Silva CHLd. Soft denture liners and sodium perborate: sorption, solubility and color change. Braz J Oral Sci. 2015;14(3):219-23.
31. Aziz T, Waters M, Jagger R. Development of a new poly(dimethylsiloxane) maxillofacial prosthetic material. J Biomed Mater Res B Appl Biomater. 2003;65(2):252-61.

32. Mancuso DN, Goiato MC, Zuccolotti BC, Moreno A, dos Santos DM, Pesqueira AA. Effect of thermocycling on hardness, absorption, solubility and colour change of soft liners. Gerodontology. 2012;29(2):e215-9.
33. Mancuso DN, Goiato MC, Zuccolotti BC, Moreno A, dos Santos DM. Evaluation of hardness and colour change of soft liners after accelerated ageing. Prim Dent Care. 2009;16(3): 127-30.
34. Salloum AM. Effect of 5.25 % sodium hypochlorite on color stability of acrylic and silicone based soft liners and a denture base acrylic resin. J Indian Prosthodont Soc.2014;14(2)179-86.