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Original Article

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Soft denture liners and sodium perborate: sorption, solubility and color change

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Abstract

Aim: To evaluate the sorption, solubility and color change in two lining materials after 120 days of immersion in either sodium perborate or artificial saliva. **Methods:** Thirty disk-shaped specimens (15×3 mm) of each material, Mucopren® soft (MS) and Elite® soft (ES) were manufactured and divided into two groups. The specimens in the control group (CG, n=15) were stored in artificial saliva at 37 °C. The specimens in the experimental group (EG, n=15) were stored in artificial saliva at 37 °C and immersed in sodium perborate daily for 5 min. The analysis of sorption and solubility was based on the initial dry weight and on the wet and dry weights after immersion. The color was assessed with a portable spectrophotometer and the NBS system. ANOVA and Tukey test (p<0.05) were used to analyze color and sorption. The solubility was analyzed by Kruskal-Wallis test (p<0.05). **Results:** Sorption was higher in the EG group (0.31±0.08) than in the control group (0.26±0.05), and higher in Elite® soft relining (0.34±0.07) than in Mucopren® soft (0.23±0.06). There was no interaction between the factors. Elite® Soft presented a higher solubility when immersed in artificial saliva (CG: 0.16±0.07 and EG: 0.13±0.06; p=0.00). Mucopren® soft showed no solubility in either treatment. Regarding the color changes, there was a significant difference between the groups (CG: 9.2±1.2 and EG: 9.9±1.2; p=0.025) but not between the materials (Mucopren® soft: 9.4±1.3 and Elite® soft: 9.7±1.0; p=0.34). Using the NBS system, we verified that both materials presented a high color change. **Conclusions:** The daily use of sodium perborate promoted changes in the liners' sorption and color. Elite® soft relining was more prone to changes than Mucopren® soft.

Keywords: denture, complete; denture liners; hygiene; physical properties.

Introduction

Heat-polymerized acrylic resin is commonly used as denture base material. However, as the supporting tissues (mucosa and alveolar ridge) are sensitive to the pressure caused by this rigid denture base, soft denture liners can be used as a cushion to overcome this disadvantage[1]. Soft liners are able to distribute the functional load on the denture support area, and improve the denture's retention and adaptation[2]. These characteristics can improve the patient's comfort and quality of life during denture use[2-3].

The resilient denture liners are divided into two groups based on their chemical composition: acrylic polymers and silicone polymers[3-4]. Both have short and long-term use and can be polymerized at room temperature or at high temperatures[5-6].

The structure of the soft lining materials and their surface roughness may promote biofilm accumulation[7], which in turn can create favorable conditions to colonization by microorganisms (*Candida* spp.), which may cause denture

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stomatitis[7-8], unpleasant odor and stains. The risk of infections, such as aspiration pneumonia in immunocompromised patients, is caused by the ingestion of microorganisms from the denture biofilm. These problems may be reduced by an adequate denture biofilm control[7]. Thus, it is extremely necessary to avoid material degradation during the daily use and hygiene procedures[5,9].

Although brushing is the most commonly used method of biofilm control, it may promote adverse effects such as the increase in surface roughness[8] and therefore, it is not the most adequate method for soft liner hygiene.

Chemical disinfectants such as sodium perborate, which are available as solutions and as effervescent tablets, have detergent and antiseptic action that prevent microorganism proliferation on dentures[5-6,10]. However, due to immersion in these disinfectants, the soft lining materials may become stiff and porous. In addition, liquid sorption or the loss of components[11-14] to the environment may occur, and discoloration[15-18] and surface roughness may increase[1]. In this way, it is important to evaluate whether chemical disinfectants may have a negative influence on the physical properties of soft liners used in association with acrylic resin bases[11,19-21].

In the present study, we evaluated the influence of sodium perborate, a alkaline peroxide, on three clinically relevant properties of two different soft liner materials. The specific aims of this research were: 1) To investigate the differences between two soft liner materials and whether sorption takes place after immersion in sodium perborate and 2) To investigate whether there is an increase in their solubility and/or color changes after immersion. The hypothesis to be tested was that sodium perborate would not cause negative effects to the sorption, solubility and color change on the relining denture bases and there would be no difference between the materials.

Material and methods

Experimental design

We evaluated two soft lining materials, Mucopren® soft and Elite® soft relining after immersion in sodium perborate for 120 days. The analyzed quantitative variables were sorption, solubility and color change. Thirty specimens of each material were randomly assigned to one of two groups: the experimental group (EG, n = 15) in which specimens were immersed in sodium perborate and a control group (CG, n = 15) where specimens were immersed in artificial saliva. The soft liner materials, hygiene solution and the used artificial saliva are in Table 1.

Specimen preparation

A stainless-steel matrix with five open disc-shaped molds (15 × 3 mm) was placed on a glass plate and fixed with adhesive strip. To obtain the soft lining specimens, the materials were injected into each mold and the matrix was pressed against another plate until the final polymerization of the materials. Following the manufacturer's instructions, the polymerization time was 10 min at room temperature. After polymerization, the specimens were detached from the molds and the excess material was removed with a stainless steel scalpel (#15 stainless steel scalpel blade; Cirurgica Passos, Curitiba, PR, Brazil). Thirty disc-shaped specimens with a 15 mm diameter and 3 mm thick were obtained from each soft liner material.

Immersion procedures

The specimens in the control group (15 of each material) were stored in a container with 300 mL of artificial saliva, which was changed daily (Table 1). This container was kept in an incubator at 37 ± 2 °C. In the experimental groups, the 15 specimens of each material were immersed in the hygiene solution, which was prepared daily for each immersion, according to the manufacturer's instructions, using 1400 mL water at 50 °C and 7 sodium perborate tablets (200 mL water per tablet). The number of tablets was defined according to the specimens' weight, similar to the weight of a medium-sized denture. The specimens were immersed in the fresh hygiene solution for 5 min per day for 120 days. Prior and after each immersion, the specimens were rinsed in tap water for 10 s and stored in fresh artificial saliva for the next 24 h at 37 °C.

Table 1 – Commercial name, materials and manufacturer used in the study.

Commercial name	*Material	Manufacturer
Mucopren soft	Soft relining (Polyvinylsiloxane) andethyl-acetate adhesive	Kettenbach GmbH & Co. KG, Eschenburg, Germany.
Elite soft relining	Soft relining (Polyvinylsiloxane)and dichloromethane adhesive	Zhermack S.P.A., Badia Polesine, Italy.
Corega Tabs	Effervescent tablet - sodium perborate, pH 6,8	GlaxoSmithKline Brazil Ltd., Rio de Janeiro, Brazil.
Artificial saliva	Potassium phosphate diacid, Potassium phosphate dibasic, Potassium chloride, Sodium chloride, Magnesium chloride (6 H2O), Calcium chloride (2 H2O), Sodium fluoride, Sorbitol 70%, Flavoring and coloring, Preservatives (Nipagin/nipasol), Thickener, Water q.s.p, pH 6,8	Faculty of Pharmaceutical Sciences of Ribeirao Preto - University of Sao Paulo, Ribeirao Preto, Brazil.

* Information according manufacturers.

Sorption and Solubility

The specimens' sorption and solubility were evaluated according to the methodology described by ADA #12 Specification for denture base polymer[22]. All specimens were weighted immediately after being obtained and then placed in a desiccator with silica gel (DPV Chemical Products, Sao Paulo, SP, Brazil) at room temperature. The specimens were weighted daily in an analytical balance until obtaining constant weight (± 0.001 g), which was considered as the specimens' initial weight (W1). After the total immersion period (120 days), the specimens were washed in tap water, dried with filter paper and weighted in an analytical balance. This value was used in the sorption calculation (W2), i. e., $\%\text{Sorption} = (W2 - W3)/W1 \times 100$[11], where W1 is the initial weight, W2 the weight after sorption and W3 the final weight after desiccation. Then, the specimens were placed in the desiccator, weighted daily until stable readings of the dry weight (W3). Solubility (in %) was given by the formula: $\%\text{Solubility} = (W1 - W3)/W1 \times 100$

Color change test

The amount of color change was obtained using a portable colorimeter (Color Guide 45/0; BYK-Gardner GmbH - Geretsried, Germany), calibrated according to the manufacturer's instructions and using the standard Commission Internationale de L'Eclairage (CIE LAB) color system. A white background was used for the measurements, and for each specimen the following readings were obtained: brightness (L*), red-green proportion (a*) and the yellow-blue proportion (b*). The color change (ΔE) was determined as the variation between the values obtained before and after immersion using the formula: $\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{½}$, where ΔL, Δa, and Δb are the differences between the initial and final values of L*, a*, and b*, respectively.

In addition to this analysis, the critical observation of color change was also quantified by the National Bureau of Standards (NBS), which is given by $NBS = \Delta E \times 0.92$ (Table 2).

Table 2 - Classification unit by NBS.

Critical observation of color change	Units NBS
Very Light	0.0 – 0.5
Light	0.5 – 1.5
Remarkable	1.5 – 3.0
Appreciable	3.0 – 6.0
High	6.0 – 12.0
Very High	>12.0

Data analysis

All variables were tested for normal distribution (Shapiro-Wilk test) and homogeneity (Levene test). Once the normality and homogeneity of sorption and color change were confirmed, these variables were analyzed using ANOVA (two-way) and the Tukey HST test. Due to the non-normal distribution of solubility data, the Kruskal-Wallis test was employed. Regardless of the test, significance level was set at $p < 0.05$. All analyses were made using SPSS Statistics Base 18 (SPSS Inc., Chicago, IL, USA).

Results

Sorption and Solubility test

The average values showed that specimens in sodium perborate (0.31 ± 0.08) had a higher average sorption than the ones in saliva (0.26 ± 0.05), with a significant difference ($p = 0.006$). The materials also differed in sorption ($p = 0.0$), where the Elite® soft relining (0.34 ± 0.07) had a higher average sorption than Mucopren® soft (0.23 ± 0.06). There was no interaction between the factors ($p = 0.06$). Elite® soft relining had a higher average solubility when immersed in artificial saliva whereas Mucopren® soft showed no solubility in either group. The comparison of the individual averages and standard deviations (SD) in each group/material are shown in Table 3.

Color change

There was a significant difference in color change ($p = 0.025$) between the control and experimental groups, and EG showed the highest average color change. There was no difference ($p = 0.34$) between the materials and no interaction between the factors ($p = 0.18$). The averages and SD are shown in Table 4. The critical observation of color change by the NBS, revealed that both materials presented color changes independent of the immersion group (Table 4).

Discussion

One of the main disadvantages and even the reason behind the failure of the resilient denture liners is the difficulty in maintaining them clean. In addition, there is lack of information regarding the ideal hygiene products and methods that would not affect negatively the physical properties of soft denture liners[1,5-6].

Sorption, solubility and color stability are important properties for maintaining quality of the materials[23] and these properties can be affected by the denture cleanser and periods of immersion[24-25]. Increase of sorption and solubility may result in dimensional change, discoloration, unpleasant odor, separation from the complete denture base and loss of resilience[11,23,26]. These changes result in a lower sorption of the occlusal impact force and in patient's dissatisfaction[11]. Ideally, a soft liner should have low sorption and solubility[15] but such material is still lacking[26]. Alkaline peroxide (sodium perborate) was used in this study because it has specific indication for denture hygiene and has been largely used in different studies[5-6,10,15,17,19] due to its antiseptic and disinfecting properties, capacity to eliminate stains on the denture surface, and a more favored flavor.

In this study, the hypothesis tested for sorption was rejected, since there was change in this property after use of perborate and there was difference between the materials. For solubility, the hypothesis was partially accepted, since

Table 3 - Comparison of averages (%) and SD of the sorption and solubility of the materials and groups after immersion.

	Sorption			Solubility	
	CG	EG	Material Average	CG	EG
Mucoprem Soft	0.22 (0.04)^{Aa}	0.24 (0.08)^{Ba}	0.23 (0.06)^{a}	0.00^{Aa}	0 .00^{Aa}
Elite Soft	0.30 (0.06)^{Ab}	0.38 (0.08)^{Bb}	0.34 (0.07)^{b}	0.16 (0.07)^{Ab}	0.13 (0.06)^{Bb}
Groups Average	0.26 (0.05)^{A}	0.31 (0.08)^{B}			

Same letters indicate statistical equality; Capital letter: comparison between columns; Lower case: comparison between lines.

Table 4 - Evaluation of the color change in the materials after immersion according the CIE LAB System (Average and SD) and classification of NBS.

	CIE LAB		NBS	
	CG	EG	CG	EG
Mucopren soft	9.07 (1.4)^{a}	9.7 (1.2)^{b}	8.34°	8.92°
Elite soft relining	9.3 (0.96)^{a}	10.04 (1.09)^{b}	8.54°	9.23°

For CIE LAB: Same letters indicate statistical equality.
For NBS: # Remarkable; * Appreciable; High.

there was difference between materials. The sorption was higher after immersion of the materials in the hygiene solution, and the same results were found by Mansoor[24] (2014). Moreover, the solubility was higher when Elite® soft relining was immersed in saliva, whereas for Mucopren®, there was no change in solubility between the immersion groups. It is known that high ionic concentration (potassium and sodium) of denture cleansers, as compared to the water, caused higher dissolution of soluble components[12]. As regards solubility, Goll et al.[21] (1983) and Rodrigues-Garcia et al.[14] (2003) also found loss in weight of resilient materials after 30 days of immersion in water and sanitizer. The results for the control group were as expected, because the saliva contains ions and is based on a polar solvent (water), which may encourage diffusion processes of ionic and polar species from the lining material into the solution[5,11].

Although both analyzed materials in this study were silicone based, differences between them were observed. Water sorption depends on the hydrophobicity and porosity[13] of the material, as well as on the presence of cross-linking agents[11]. Further studies should be conducted to evaluate the hydrophobicity and the cross-linking agents of the materials used here. Micro-structural analysis may identify the differences between the used materials.

According to Hekimoglu and Anil[12] (1999) and Kazanji and Watkinson[11] (1988), in daily use dentures are in contact with saliva and can be kept in a sanitizing solution as a hygiene method. Such situations can increase the denture's solubility, and consequently, water sorption. Soft liners can release chemical compounds such as monomers (methyl methacrylate, ethyl methacrylate, dodecyl methacrylate), plasticizers (dibutyl phthalate, diethyl phthalate, tributyl acetylcitrate), and others (e.g., benzophenone) after immersion in a chemical denture cleanser and in saliva[19].

Color stability is an important physical property for soft denture liners, which besides interfering in the esthetics of the material, also indicates the degree of aging[16]. An ideal soft denture lining material should therefore not easily change in color and/or become stained after long use[23].

In this study, the tested hypothesis was rejected, since there was change color due to hygiene solution and materials. The immersion in sodium perborate caused higher color change than immersion in artificial saliva. Similar results were found by Tan et al.[17] (2000) after immersion for 90 days in a hygiene solution that was also based on sodium perborate. Goll et al.[21] (1983) found different results in color change caused by cleansers with similar composition (sodium perborate). They concluded that quantitative differences in their formulation, pH and in water temperature used with the cleanser solution, apparently influenced the liner color. Saraç et al.[20] (2007) agreed that the oxidant is the cause for color change. Salloum et al.[25] (2014) affirmed that the chemical type influenced soft denture liners' color stability and that the color changes depend on the period of immersion. In this study, both the saliva and sanitizer solution had a 6.8 pH. Therefore, in this case the oxidant action hypothesis would be better accepted.

According to Jin et al.[15] (2003), many factors may contribute to the discoloration of the lining materials; for example, the accumulation of stains, dehydration, hydrolysis and the decomposition chain reaction. The chain reaction is the oxidation of carbon double bonds reacting with peroxide (present in some hygiene solutions) and produce colored compounds. These compounds in turn continue to degrade the colored products. Matsumura et al.[27] (2001) report that color stability is related with the direct polymerization of the material in the oral cavity due to the presence of a low polymerization surface layer, compared to indirect polymerization. No comparison was made with the indirect technique of polymerization, but this fact may have contributed to the color changes observed in this study. Further studies should be performed with this purpose. Although the literature indicates that the color change is related with liquid sorption[18], the present study did not find a relationship between these properties.

Ma et al.[18] (1997) in a laboratory investigation, observed the color changes of four relining materials after immersion in sanitizing solutions and found that, although statistically significant, the results were not clinically detectable. However, in critical analysis of the color changes based on the NBS classification, the present study found that both materials and both groups had high color variation.

Maintaining the material's color is important for patients, and they are more satisfied when the soft liner color is stable and indistinguishable from the color of the denture base material[16]. In our study, both materials showed NBS values higher than 2, demonstrating a clinically noticeable color change, which indicates that the combination of the lining materials with the evaluated hygiene method was not favorable.

In conclusion, daily use of sodium perborate as a chemical denture hygiene method may promote sorption and color alterations in the soft denture liners studied here and Elite® soft relining was more prone to changes compared to Mucopren® soft.

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