EVALUATION OF HARDNESS AND COLOR STABILITY IN THE SOFT LINING MATERIALS AFTER THERMOCYCLING AND CHEMICAL POLISHING

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ABSTRACT

The aim of this study was to evaluate the Shore A hardness and color stability of two soft lining materials after thermocycling and when chemical polishing was used or omitted. Two acrylic-based soft lining materials were tested: Coe-Soft and Soft Confort, 14 specimens were made for each material. They were distributed in four groups according to the treatment performed. The specimens were thermocycled (1000 cycles) and half of the group submitted to chemical polishing (methyl methacrylate). Shore A hardness was determined and color stability was calculated by means of Commission International de l'Eclairage Lab uniform color scale using a spectrophotometer, the measurements were made immediately after deflasked, chemical polishing and thermocycling. Analysis of variance (ANOVA) and Tukey's tests were performed at p< 0,01. Color changes (ΔE) were observed after thermocycling in both soft lining materials: Soft Confort (10.60) showed significantly higher values than Coe-Soft (4.57). Coe-Soft (26.42) showed higher Shore A hardness values than Soft Confort (19.42). Chemical polishing did not influence in the color stability of both materials; however, influenced in the hardness values of Coe-Soft.

Key words: soft lining materials, hardness, color stability, thermocycling, chemical polishing.

AVALIAÇÃO DA DUREZA A ESTABILIDADE DE COR EM MATERIAIS REEMBASADORES MACIOS APÓS TERMOCICLAGEM E POLIMENTO QUÍMICO

RESUMO

O objetivo deste estudo foi avaliar a estabilidade de cor e dureza dos materiais reembasadores macios após polimento químico e termociclagem. Foram confeccionados 14 corpos-de-prova para cada material (Coe-Soft e Soft Confort), em forma de discos com 25 mm de diâmetro e 3 mm de espessura. Estes foram divididos em 4 grupos de acordo ao tratamento realizado (Polimento químico e termociclagem). Os corpos-de-prova de ambos materiais foram submetidos a termociclagem 1000 ciclos (5±1oC e 55±1oC) e a outra metade do grupo foi submetido ao polimento químico por 10 segundos de imersão em metil metacrilato a 80°C, seguido de termociclagem (1000 ciclos). As leituras foram feitas após remoção das muflas, polimento químico e termociclagem. As alterações na cor (ΔE) foram calculadas com o uso da escala de cor (CIE Lab), por meio de um espectrofotômetro de Reflexão Ultravioleta Visível, (Shimadzu UV-visible, Model UV-2450, Kyoto, Japão), e a dureza Shore A foi avaliada por meio do durometro. Os resultados obtidos foram submetidos à análise de variância (ANOVA), seguida da aplicação do teste de Tukey ao nível de 1% de significância (p< 0,01). Observou-se alterações na cor e dureza em ambos materiais após a termociclagem. O material Soft Confort (10.60) apresentou os maiores valores médios em comparação ao material Coe-Soft (4.57), apresentando diferença estatisticamente significativa. Coe-Soft (26.42) apresentou os maiores valores médios de dureza em comparação ao material Soft Confort (19.42.) O Polimento químico não influenciou na estabilidade de cor em ambos materiais e diminuiu a dureza do material Coe-Soft. Já a termociclagem influenciou na alteração de cor e aumentou a dureza dos materiais reembasadores macios.

Palavras chave: material rembasador, dureza, estabilidade de cor, termociclagem e polimento químico.

INTRODUCTION

Soft lining materials are frequently used in prosthodontic treatments. They are used to assist in providing an even distribution of a functional load on the denture bearing area, avoiding local stress concentrations; they usually act as a cushion between the hard denture base and the tissues providing comfort to the patient [1].

The ability to achieve the cushioning effect is related to their resilience and the degree of resilience will depend on the chemical composition and the thickness the material[2].

According to the composition they can be divided into two main groups: plasticized acrylics and silicone elastomers. Plasticized acrylic lining materials are usually supplied in powder/liquid format with the powder consisting of a higher methacrylate polymer (usually polyethyl methacrylate) and a liquid consisting of a higher methacrylate monomer (ethyl, n- butyl); a plasticizer (commonly a phthalate) is also included[1-3].

Table 1: Materials used in this study

Code	Brand name	Type	Manufacturer	Composition	Batch Number
CST	Coe-Soft	Autopolymerized Soft Acrylic-based	GC America Inc. Illinois, EUA	Liquid: Di-n-Butyl phthalate, Ethyl alcohol, Benzyl salicylate.	0311142
				Powder: Polyethyl methacrylate. zinc undecylenate	0310221
SCT	Soft Confort	Autopolymerized Soft Acrylic-based	Dencril, Dentistry Products, Brazil	Liquid: Ethyl alcohol and plasticizer	001/006
				Powder: Polyethyl methacrylate	002/006

The clinical criteria for the indication of these materials are based on: resilience permanency over time, capability to generate a strong bond with the denture base, dimensional stability, adequate tear strength and color stability, inhibition of fungal growth, absence of odor and taste[4].

Among the clinical properties, the color stability is one of the most important for all dental materials, and color changes could be an intelligible indictor to operators of ageing or damaging of the materials[4]. Weathering or changes in physical properties of soft lining materials appear to depend upon their type or composition[5,6]. Also, color stability is a characteristic required for denture base polymers, in resin acrylic or soft lining materials specified in several national and internationals standard specifications like ADA N° 12 (American Dental Association)[7].

To decrease dimensional changes and enhance favorable properties in some soft lining materials sealant application on their surface in order to increase the useful life time[8], to decrease resilience loss[9], and to act as a barrier against water absorption and leaching out of components[10] have been suggested. It is known that resilient denture lining materials are more prone to adhesion of microorganisms than denture acrylic resin due to chemical composition, surface texture and greater porosity[11].

Due to the fact that only some soft lining materials use the application of a "glaze" on their surface, this study attempts to assess soft lining materials without glaze after thermocycling using the chemical polishing like a glaze that could to minimize changes in the properties of these materials.

MATERIALS AND METHODS

The soft lining materials under investigation are listed in Table 1. The name of the manufacturer, the physical presentation and composition of the materials are given. Soft Confort (SCT) (Dencril, Dentistry products, Brazil) and Coe-Soft (CST) (GC America Inc. Illinois, USA), are provided as powder and liquid and they are acrylic-based soft lining temporary materials.

To obtain the specimens, stone molds were prepared by investing condensation silicone (Zetalabor, Zhermack, Rovigo, Italy) disk-shaped patterns (25 mm in diameter x 3 mm thickness)[9] in Type III dental stone (Gesso-Rio, São Paulo, Brazil) in conventional denture flasks. These were submitted to static pressure using a hydraulic press (Midas Dental Products Ltda., São Paulo, Brazil) during 30 minutes. After the setting time of materials (silicone and dental stone) silicone disks were deflasked to obtain 7 moulds with each denture flask.

Soft Confort and Coe-Soft were processed according to the manufacturers' instructions, placed into moulds contained in the denture flask, prepared for this purpose and pressing in the hydraulic press under to 10N during 15 minutes when polymerization/processing concluded, the specimens were removed from the moulds and trimmed with a pair of scissors.

Twenty-eight specimens were made (14 for each material) and divided in groups according the procedure performed (chemical+thermocycling or only thermocycling):

Color stability Test:

Soft Confort with time intervals of readings:

- Group 1-SCT: Specimens of the group without chemical polishing (initial + thermocycling).
- Group 2-SCT: Specimens of the group with chemical polishing (initial + chemical polishing).

- Group 3-SCT: Specimens of the group with chemical polishing (after chemical polishing+ thermocycling).
- Group 4-SCT: Specimens of the group with chemical polishing (initial+chemical polishing+ thermocycling).

Coe-Soft with time intervals of readings:

- Group 1-CST: Specimens of the group without chemical polishing (initial+thermocycling).
- Group 2-CST: Specimens of the group with chemical polishing (initial+chemical polishing).
- Group 3-CST: Specimens of the group with chemical polishing (after chemical polishing+thermocycling).
- Group 4-CST: Specimens of the group with chemical polishing (initial+chemical polishing+thermocycling).

Shore A Hardness Test:

Soft Confort with time intervals of readings:

- Group 1-SCT: Specimens of the group with chemical polishing - after thermoclycling.
- Group 2-SCT: Specimens of the group without chemical polishing - after thermocycling.
- Group 3-SCT: Specimens of the group with chemical polishing - after chemical polishing.
- Group 4-SCT: Specimens of the group with chemical polishing - before chemical polishing.
- Group 5-SCT: Specimens of the group without chemical polishing - before thermocycling.

Coe-Soft with time intervals of readings:

- Group 1-CST: Specimens of the group with chemical polishing - after thermoclycling.
- Group 2-CST: Specimens of the group without chemical polishing - after thermocycling.
- Group 3-CST: Specimens of the group with chemical polishing - after chemical polishing.
- Group 4-CST: Specimens of the group with chemical polishing - before chemical polishing.
- Group 5-CST : Specimens of the group without chemical polishing – before thermocycling

The specimens were thermocycled in a machine of thermal cycle's simulation (Convel, Araçatuba, São Paulo, Brazil) by 1000 cycles to simulate 1 year of clinical use; with 5±1°C and 55±1°C [12] distilled water alternately for 60 seconds.

The chemical polishing was performed in the polishing machine model PQ-9000 (Termotron, São Paulo, Brazil) with fluid for chemical polish (Poli-Quim, Artigos Odontológicos Clássico, São Paulo, Brazil). This process involved the 10-second immersion in methyl methacrylate heated at approximately 80°C, the specimens were removed to room temperature for 15 s and washed in running water for 1 min to eliminate excess fluid, according to the manufacturers' instructions.

Color changes (ΔE) were calculated with the use of Commission Internationale de l'Eclairage L* a* b* (CIE Lab) uniform color scale[13] using a spectrophotometer**,** (Shimadzu UV-visible, Model UV-2450, Kyoto, Japan), to quantify the color and calculate the difference from baseline color of the samples after removed the denture flask, chemical polishing and thermocycling.

The values of the measurements were recorded and the mean of each material was calculated according to the CIE Lab uniform color scale. The color characteristics of 14 samples of each soft lining material were compared to a white standard. This was a pressed powder tablet of barium sulphate. The magnitude of the total color difference is represented by a single number ΔE:

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

Where L* represents lightness, a* redness-greenness and b* yellowness-blueness. This formula is designed to provide numeric data that represents the magnitude of the color difference perceived in between two objects[13]. This system is largely used in dental research[2,4,5]. Color evaluation was also performed by two trained examiners after deflasking; thermocycling and chemical polishing. To standardize the testing conditions the same operator performed all of the tests.

Indentation hardness was evaluated with a Shore A durometer (GSD-709; Teclock Corp, Woltest, São Paulo, Brazil) according to the American Society for testing and materials (ASTM) D-2240 specification[14]. This method is based on the indentation of the specified indenter forced into the material under specified conditions. Durometer hardness numbers, although arbitrary from 0 to 100 from soft to hard, have an inverse relationship to indentation by the indenter in thousandths of an inch. The Shore A durometer is the oldest and best known instrument for testing the indentation hardness of rubber and elastomeric materials[15].

Durometer measurements were made on each specimen immediately after deflasking, chemical polishing and thermocycling; the readings were obtained 1 second after firm contact was achieved. Five readings were taken on each specimen and the results were averaged.

The results were compared by means of analysis of variance (ANOVA) Tukey's test (P<0,01).

RESULTS

Table 2 shows ΔE mean values of soft lining materials. Soft Confort (SCT), presents higher mean values, statistically significant in comparison with Coe-Soft (CST), indicating that change color was higher in the SCT material.

Table 2: ΔE General mean values of soft lining materials

Materials	*ΔE*	*1%*
Soft Confort	10.60	A
Coe-Soft	4.57	B

Mean follow by different letters differ between to the significance level of 1%

Table 3: ΔE mean values of Soft Confort after intervals of readings

Treatment/Material	*Mean*	*SD*	*1%*
Group 1-SCT	14.98	3.66	A
Group 3-SCT	13.40	3.01	A
Group 4-SCT	12.24	2.47	A
Group 2-SCT	1.77	1.10	B

Mean follow by different letters differ between to the significance level of 1%
SCT-Soft Confort
- Group 1: Specimens of the group without chemical polishing (initial + thermocycling).
- Group 2: Specimens of the group with chemical polishing (initial + chemical polishing).
- Group 3: Specimens of the group with chemical polishing (after chemical polishing + thermocycling).
- Group 4: Specimens of the group with chemical polishing (initial + chemical polishing + thermocycling).

Table 4: ΔE mean values of Coe-Soft, after intervals of readings

Treatment/Material	*Mean*	*SD*	*1%*
Group 1-CST	6.32	1.43	A
Group 3-CST	5.48	1.38	A
Group 4-CST	4.61	0.97	AB
Group 2-CST	1.87	0.64	B

Mean follow by different letters differ between to the significance level of 1%
CST - Coe Soft
- Group 1: Specimens of the group without chemical polishing (initial + thermocycling).
- Group 2: Specimens of the group with chemical polishing (initial + chemical polishing).
- Group 3: Specimens of the group with chemical polishing (after chemical polishing + thermocycling).
- Group 4: Specimens of the group with chemical polishing (initial + chemical polishing + thermocycling).

Table 3 shows ΔE higher mean values of SCT (Groups 1, 3, and 4). ΔE values increased immediately after the thermocycling independently of chemical polishing.

ΔE mean values of CST (Group 1, 3 and 4) - shown in Table 4 - after thermocycling were higher, which indicates that this factor influenced color stability independently of chemical polishing.

In Table 3 and 4; ΔE values of chemical polishing (Group 2-SCT: 1,77) and (Group 2-CST: 1,87) show very low mean values without statistically significant differences.

Visual analysis by examiners had over 85% intra- and inter-examiner agreement during training sessions. The examiners observed color changes after thermocycling in both materials and CST showed less color change than SCT. In contrast; perceptible changes color were not observed after chemical polishing in any of the soft lining materials.

Statistical difference ($p<0,01$) on the hardness values between Soft Confort (19.42) and Coe-Soft (26.42) is shown in Table 5. Tables 6 and 7 show

Table 5: Shore A Hardness general mean values of soft lining materials

Materials	*Mean*	*1%*
Coe-Soft	26.42	A
Soft Confort	19.42	B

Mean follow by different letters differ between to the significance level of 1%.

Table 6: Shore A hardness mean values of Soft Con fort after intervals of readings

Treatment/Material	*Mean*	*1%*
Group 1 - SCT	28.28	A
Group 2 - SCT	24.71	A
Group 3 - SCT	15.00	B
Group 4 - SCT	14.85	B
Group 5 - SCT	14.28	B

Mean follow by different letters differ between to the significance level of 1%
SCT – Soft Confort
- Group 1 - SCT: Specimens of the group with chemical polishing - after thermoclycling.
- Group 2 - SCT: Specimens of the group without chemical polishing - after thermocycling.
- Group 3 - SCT: Specimens of the group with chemical polishing - after chemical polishing.
- Group 4 - SCT: Specimens of the group with chemical polishing - before chemical polishing.
- Group 5 - SCT: Specimens of the group without chemical polishing - before thermocycling.

Table 7: Shore A hardness mean values of Coe-Soft after intervals of readings

Treatment/Material	*Mean*	*1%*
Group 2 – CST	34.00	A
Group 1 – CST	28.57	B
Group 5 – CST	27.28	B
Group 4 – CST	26.00	B
Group 3 – CST	16.28	C

Mean follow by different letters differ between to the significance level of 1%
CST - Coe Soft
- Group 1 - CST: Specimens of the group with chemical polishing - after thermoclycling.
- Group 2 - CST: Specimens of the group without chemical polishing - after thermocycling.
- Group 3 - CST: Specimens of the group with chemical polishing - after chemical polishing.
- Group 4 - CST: Specimens of the group with chemical polishing - before chemical polishing.
- Group 5 - CST: Specimens of the group without chemical polishing - before thermocycling

higher Shore A values after thermocycling even if the specimens were submitted to chemical polishing, but these values were higher for Coe-Soft. Chemical polishing did not influence hardness on Soft Confort (15.00); however, it did on Coe-Soft (16.28).
Analyzing table 7, it is seen that hardness values of Coe-Soft were influenced by both treatments, but thermocycling show higher values in comparison to chemical polishing.

DISCUSSION

Many soft lining materials are provided by manufacturers with a glaze while others are not. We attempted to evaluate if chemical polishing could to act like a glaze in order to minimize color changes and loss of resilience of soft lining materials[9,15] after deflasking (initial), and after chemical polishing and thermocycling.
Higher mean values of ΔE values in Soft Comfort (SCT) than in Coe-Soft (CST) could probably be due to differences in chemical composition[2,3]. There were significant color changes in the SCT after thermocycling; this result might reflect the fact that it does not contain benzyl salicylate and while CST does. This chemical product could increase leaching out of components and water absorption and, consequently, color changes.
The results observed in the tables 3 and 4, suggested that the thermocycling influenced in the color stability of both materials, independently of chemical polishing. ΔE for CST was 4,61 to 6,32 and SCT 12,24 to 14,98. According to Craig & Powers[16] a value of ΔE higher than 3,3 can be considered clinically perceptible. Also, color changes were visually perceivable by the examiners, who perceived less color changes in CST. According to Goldstein & Schmitt[17] the highly trained human eye can detect color changes when ΔE is greater than 0.4.
In this study, changes of color were perceivable after 1000 cycles of thermocycling;, this result was consistent with that reported by Park et al.[5] who studied changes in elastic modulus (EM) and color, after thermocycling of three short term-use soft liners.
Some soft lining materials indicate the application of a glaze to improve their properties[8,10]. However, soft lining materials used in this study do not recommend this procedures and chemical polishing was applied as a substitute with the aim to minimize color changes of soft lining materials.
Results indicate that there were no changes in the color of soft lining materials after chemical polishing either by the visual method or spectrophotometer measurements. It can be speculated that chemical polishing creates a superficial film that minimizes leaching out of components that influence color changes. Clinically, the application of chemical polishing could be used to decrease color changes of soft lining materials acting like a barrier against water absorption and leaching out of components that change the properties of these materials[10].
In this study the initial Shore A hardness of the two different soft liners materials were measured and compared with the values after thermocycling and chemical polishing. Coe-Soft material showed higher mean hardness values than Soft Confort. This could be explained by the chemical structures of both soft liners materials[3]. The plasticizer concentration influences on softness and resilience of soft liners materials; consequently, when smaller or greater the contained of plasticizer, smaller or greater will be the hardness value of material[2,3,5]. Presumably Coe-Soft suffered a greater loss of plasticizer than Soft Confort.
Changes in the hardness of both materials were significant and to control the possible undesirable variables, a constant 3 mm thickness was used, which is considered ideal when using resilient materials[9]. There were changes on hardness of both materials after thermocycling (1000 cycles). This result was consistent with that reported by Park et al[5] who studied changes of elastic modulus (EM) and color, after thermocycling of three short term-use soft liners. Their results varied depending on the specific product and properties generally remained unchanged within 1000 to 1500 cycles.

Thermocycling was found to influence on the hardness of both materials. These results were similar with those reported by Qudah et al.[9], on the effect of thermocycling on the hardness of six soft liners. It was concluded that thermocycling contributed to the degradation of materials, mainly in temperatures above 50 C. The decrease of resilience after thermocycling could be due to the fact that some soft lining materials are not stable in an aqueous environment and a greater loss of plasticizer increase the hardness[2]. Chemical polishing was used instead of glaze application to evaluate changes in resiliency loss, water absorption and leaching out of components. No significant differences in hardness values were found after chemical polishing of Soft Confort. However, chemical polishing decreased the hardness of Coe-Soft material. This results may have been influenced by differences in the chemical composition of each material[3,9]. The high temperature required by the chemical polishing fluid (80°C), Poli-Quim (methyl metacrilate) probably produced softness of Coe Soft that contains higher concentrations of plasticizer than Soft Confort.

Although, the results varied depending on the composition of each material; changes on hardness and color of both materials occurred after thermocycling independently of chemical polishing. Chemical polishing did not influence on the hardness of Soft Confort, however, influenced on the hardness of Coe-Soft material. Shore A hardness values were significantly higher to Coe-Soft material than to Soft Confort and chemical polishing did not influence on the color stability of both materials. Behavioral characteristics of each soft lining material were different in the procedures performed.

The clinical implication of this study in relation to chemical polishing, on the hardness and color stability, demonstrate that chemical polishing could be used like a glaze. However, further research about the use of chemical polishing on soft lining materials should be performed with regard to other material properties.

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