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| ORIGINAL

Hardness, compressive strength and resilience of complete denture lining materials: an in situ study

Dureza, resistência à compressão e resiliência de materiais de reembasamento para próteses totais: estudo in situ

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ABSTRACT

Objective: The aim of this study was to evaluate the in situ hardness, compressive strength and resilience of soft lining materials used in total removable prostheses in different time intervals. **Methods**: A total of 48 rectangular test specimens (10 x 3 x 2 mm) were fabricated of each of the polyvinylsiloxane-based soft liner (Mucopren Soft) and acrylic resin-based material (Trusoft), which were placed on total removable prostheses bases of 12 volunteers (n = 12). The hardness (Shore A), compressive strength (in MPa) and resilience (in Kgf/cm^2) were evaluated in different time intervals: 0, 7, 30 and 60 days, at three different locations of the specimens surface. **Results**: The two-way ANOVA and Tukey test showed that the polyvinylsiloxane-based soft liner presented higher hardness values (p = 0.0113) and higher compressive strength (p=0.0252) than the acrylic resin-based material at immediate and 7 days evaluations. The polyvinylsiloxane-based soft liner presented higher resilience values than the acrylic resin-based material at all times (p = 0.0133). Hardness and compressive strength were similar for both materials at 30 and 60 days evaluations. **Conclusions**: For both materials, there was a tendency for an increase of hardness, compressive strength and resilience over time, influenced by the composition of the tissue conditioner. The polyvinylsiloxane-based soft liner presented higher hardness, compressive strength and resilience than the acrylic resin-based material, specially considering a long-term evaluation up to 60 days.

Indexing terms: Dental prosthesis. Hardness. Material resistance.

RESUMO

***Objetivo**: O objetivo deste estudo foi avaliar in situ a dureza, resistência à compressão e resiliência de materiais para reembasamento utilizadas em próteses totais removíveis em diferentes intervalos de tempo. **Métodos**: Um total de 48 corpos de prova retangulares (10 x 3 x 2 mm) foram confeccionados de cada uma dos reembasadores a base de polivinilsiloxano (Mucopren Soft, Kettenbach GmbH & Co) e resina acrílica (Trusoft, Bosworth), os quais foram posicionados na base de próteses totais removíveis de 12 voluntários (n = 12). A dureza (Shore A), resistência à compressão (em MPa) e resiliência (em Kgf/cm^2) foram avaliadas em diferentes intervalos de tempo: 0, 7, 30 e 60 dias, em três diferentes localizações da superfície do corpo de prova. **Resultados**: A ANOVA a dois critérios e o teste de Tukey mostraram que o reembasador a base de polivinilsiloxano apresentou maiores valores de dureza (p =*

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0,0113) e maior resistência à compressão (p=0,0252) do que o a base de resina acrílica nas avaliações nos tempos imediato e 7 dias. O reembasador a base de polivinilsiloxano apresentou maior resiliência que o a base de resina acrílica em todos os tempos (p = 0,0133). Dureza e resistência à compressão foram semelhantes para ambos os materiais nos tempos 30 e 60 dias de avaliação. ***Conclusões****: Para ambos os materiais, houve tendência de aumento da dureza, resistência à compressão e resiliência com o passar do tempo, influenciado pela composição dos materiais de rembasamento tecidual. O reembasador a base de polivinilsiloxano apresentou maior dureza, resistência à compressão e resiliência que o a base de resina acrílica, considerando-se especialmente o tempo de avaliação de 60 dias.*

Termos de indexação: *Prótese dentária. Dureza. Resistência de materiais.*

INTRODUCTION

The use of resilient lining materials in complete dental prostheses is indicated in immediate complete dental prostheses, with the purpose of improving problems of diction related to cleft palate and immediate ferrulization after surgeries [1-6] and to stabilize complete dental prostheses used as healing guides, avoiding the recurrence of hyperplasias caused by poorly fitting dentures removed by surgical procedures [5,7,8]. In implant dentistry, during the time of healing, the ridges that were recently operated for the placement of implants, these materials may be used in the maintenance of temporary or transitory complete dental prostheses [4,8]. Resilient reliners are more advantageous in comparison with acrylic resin-based materials, because they form a soft layer between the rigid base of the complete dental prosthesis and the oral mucosa, with the potential to improve the comfort of complete denture wearers [5,6,9,10]. The fact of being resilient make the tissue conditioners ideal for offering a better distribution of the functional loads over the complete denture base area, restoring the health of inflamed and/or injured tissues [9-11].

The complete denture lining materials are presented in a rigid or resilient form and may be polyvinylsiloxane- or acrylic resin-based products [1,6,12]. The polyvinylsiloxane-based materials have advantages compared with those of acrylic resin, such as maintaining their resilience for periods longer than six months [5,13] in addition to improving the performance in thin and irregular areas of the mucosa [5,6,9,11]. On the other hand, their main disadvantage is lack of adhesion to the conventional acrylic resin base of the dental prosthesis [14-16].

The study of dental materials by means of laboratory tests to evaluate their longevity and maintenance is necessary to facilitate adequate indication in these clinical situations for which they are proposed, with the purpose of reducing the chances of possible changes on the mucosa. One way of evaluating the physical and mechanical properties of these materials is to submit them to an in vitro simulation of the aging that would occur in the intraoral medium, by means of accelerated aging tests by thermal cycling [17] or xenonium-based ultra violet light [14]. The method most cited in the literature - thermal cycling - is performed with the purpose of promoting successive volumetric contractions and expansions of the materials by means of heat treatments, resulting in aging [5,18]. Thus, important properties, such as absorption, solubility, tensile strength and hardness [19] can be evaluated.

The process of water absorption and soluble component loss (plasticizers and ethyl alcohol) [20] changes the physical and mechanical properties of these resilient materials [21]. There is an increase in the material hardness which may cause lack of adhesion of the material to the acrylic resin base, chemical decomposition, and predisposition to fracture, also promoting oral mucosa lesions [5,22], and changing the clinical longevity [5,23,24]. Compressive strength is also an important property in the evaluation of these materials, because it determines the values of permanent deformation in resilient materials, and indicates their deficiency in elastic recovery after having been submitted to compressive stresses [24,25]. Resilience is the capacity of the material to absorb part of the energy generated during mastication is related to their viscoelastic properties, such as the modulus of elasticity. The use of resilient materials is associated with strict clinical control, because the characteristic of resilience of the material may be lost over time, making it rigid, and capable of leading to undesirable tissue changes: an effect opposite to that originally intended [25-27].

However, there is no clinical or in situ studies showing the interaction of the oral medium with the soft-lining materials mechanical properties (as hardness, compressive strength and resilience), considering the constant presence of saliva and food, changes in temperature and the pH level in the oral cavity. Although these materials are not indicated to be used for more than

30 days, some patients impossibilities may prolong the use of this soft liner for more days. Therefore, a material that has greater hardness and resilience may lead to an excessive distribution of load on certain sites in the oral cavity, capable of causing the patient discomfort and harming the rehabilitative treatment. In view of the foregoing discourse, it was interesting to evaluate the hardness, compressive strength and resilience of different tissue conditioners in an in situ study during 60-days long-term evaluation. The null hypothesis to be tested was that there were no differences in hardness, in compressive strength, and in resilience of different tissue conditioners in an in situ study during 60-days long-term evaluation.

METHODS

After approval of the project by the ethics committee (CAAE 62025316.1.1001.5374), 12 patients with a completely edentulous maxillary and mandibular dental arch were selected at random from the patients of the Dental Clinic of the Dental School of Federal University of Goiás (Goiânia, GO, Brazil), who were seeking a new denture. Informed consent was obtained for experimentation with human subjects. The inclusion criteria were: patients who needed maxillary complete dental prostheses, or its replacement; who had good general and oral health; and would be available for the control period. The exclusion criteria were: presence of fibrous hyperplasia, stomatitis, palatine tori, hyposalivation, and systemic conditions such as xerostomia;

This study used the same methodology described by Araújo and Basting [27]. Twelve total removable dental prostheses were fabricated for each one of the patients by taking anatomic impressions with high fusion godiva (Godibar, Lysanda, São Paulo, SP, Brazil), fabrication of individual tray and functional impressions taken with zinc oxide and eugenol paste (Lysanda, Produtos Odontológicos, São Paulo, São Paulo, Brazil) to obtain the final casts. Only for the maxillary dental prosthesis, niches were created to accommodate the specimens of both lining materials. Therefore, only for the maxillary total removable prosthesis, the try-in bases were fabricated with light polymerizable resin (Supertec, DMG, Hamburg, Germany) with a thickness of 3 mm (higher than the usual with 2 mm) with the purpose of being a thickness that would be capable of accommodating the niches for the materials to be tested. The try-in mandibular try-in base was fabricated with the usual 2 mm thick.

The wax planes were fabricated for the upper and lower try-in bases to obtain the intraoral records of the maxillomandibular relation. Afterwards, the teeth for the mandibular and maxillary total removable dental prostheses were mounted and the functional and aesthetic tests were performed in the patients.

To make the niches at the maxillary dental prosthesis to accommodate the lining materials, silicone molds were made for later placement of the test specimens (Zetalabor, Zermack, Rovigo, Italy) measuring 10 mm long, 3 mm wide and 2 mm thick. In total 96 silicone molds were made. Before denture acrylization, each upper cast received 8 silicone molds fixed onto the palatine cavity of the maxillary model with cyanoacrylate-based adhesive (Super Bonder, São Paulo, São Paulo, Brazil). Therefore, the dentures were acrylized in a microwave oven, using the technique recommended by Tomaz Gomes, after manipulating the heat-polymerised acrylic resin (VipiFlash, Vipi Comércio, Pirassununga, SP, Brazil).

After cleaning the total removable dental prostheses, the niches at the maxillary prothesis were filled with different lining materials to be tested. Four niches were filled with the polyvinyl-siloxane-based Mucopren Soft (M) tissue conditioning material, and the other four were filled with the resin-based Trusoft (T) tissue conditioning material: one niche, corresponding to each material (M or T) and for each time interval studied (0, 7, 30 and 60 days). The soft lining materials were manipulated in accordance with each manufacturer's recommendations (table 1). After this, the dental prosthesis was inserted in the patient's mouth (figure 1). The total removable prostheses were delivered to the participants and they were instructed on how to use and clean them. They were instructed to wear the denture through the entire day and night, not to remove it when going to sleep, and to clean it 3 times a day (after breakfast, lunch and dinner) with a toothbrush for complete dentures (Dentalclean, Londrina, PR, Brazil) and toothpaste (Colgate Total 12, São Paulo, SP, Brazil). The patients's adaptation with the new prostheses were accomplished by the researcher during all the required time. Only two patients returned after 24 hours requiring minor adjustments of the new prostheses, which have not influenced the correct use of the dentures.

Table 1. Materials, manufacturers and compositions of each soft lining material.

Soft lining material	Commercial brand (manufacturer, state, country)	Composition	Lot number
Polyvinyl-siloxane-based material	Mucopren Soft (Kettenbach GmbH & Co. KG), Eschenburg, Germany	Base: polyvinylsiloxane Adhesive: ethyl acetate Sealant: polyvinylsiloxane	20907/1903
Acrylic resin-based material	Trusoft (Bosworth Company), Illinois, United States of America	Powder: pigmented polyethylmethacrylate, cadmium pigments (pink pigment) Liquid: ethyl alcohol, plasticizer	1211-495

Figure 1. Dental prostheses with the tissue conditioning materials specimens.

In a randomized manner, one test specimen of each material was removed from the denture to evaluate the Shore A hardness, compressive strength and resilience at different time intervals: immediate, 7, 30 and 60 days. The same specimen was used for perform all the mechanical evaluations at each time; however different locations of the specimens surface were used to conduct the tests to not influence the results obtained. For the immediate evaluation, the test specimens of the respective materials were removed approximately 5 minutes after the setting time and did not remain in the participant's mouth. The test specimens were stored in a receptacle with a 3 mm thick sponge imbibed with distilled water and kept at an ambient temperature of approximately 23°C. The site from which the test specimen had been removed was filled with self-polymerizing acrylic resin (Jet, Clássico, São Paulo, São Paulo, Brazil). On conclusion of the study (after all the test specimens of the 60-day time interval had been removed), a new complete dental prosthesis was fabricated for each volunteer patient, free of charge to the patient.

For the Shore A hardness measurement an analog microdurometer HVS 1000 (PanTec, São Paulo, SP, Brazil) was used three indentations were made on the surface of each test specimen. To standardize the force to be applied by the microdurometer, for the purpose of avoiding variations of the forces on the test specimen, a cylindrical artifact weighing 1 kg was fabricated, with a centralized perforation, which was adapted to the top part of the mobile vertical shaft of the delineator (figure 2). Pressure was applied to the appliance, using the artifact, until the bottom surface of the microdurometer, from which the penetrator emerges, touched the test specimen in a uniform manner. At this time, the pointer of the analog display indicated the Shore A hardness. This process was performed three times in different places for each test specimen, and a mean value of the three measurements was obtained, which was considered the Shore A hardness value for the test specimen.

The compressive strength and resilience evaluations were performed by means of a mechanical universal test machine (Instron, Norwood, MA, USA) with a blunt tipped load applicator, 3 mm in diameter, and total length of 5 cm. As the diameter of its shaft was 5 mm, it was adapted

to the "push out" or socket device of the mobile top bar of the equipment, using a load cell of 2 kN and speed of 1 mm/min. The compressive strength data were measured in megapascal (MPa), while the resilience data were obtained in Kgf/cm^2; these data were collected in three different places on each test specimen.

For statistical analysis, the analysis of variance (ANOVA) with a 2 x 4 factorial scheme (material x time) was applied in a random block design. The multiple comparisons were made by the Tukey test considering a level of significance of 5%.

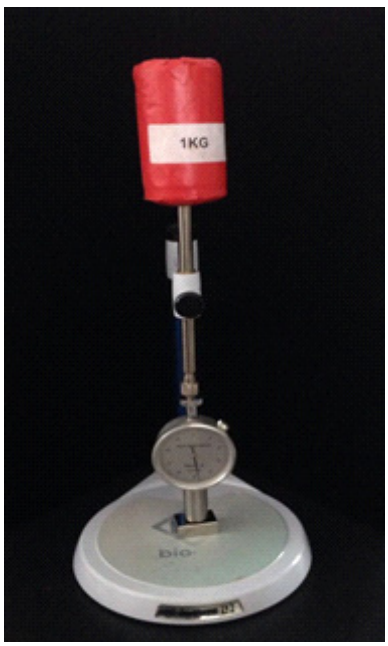

Figure 2. Device used to perform the Shore A hardness evaluation.

RESULTS

Mucopren showed higher hardness than Trusoft at immediate and 7 days evaluations (p<0.0001) (table 2). Higher hardness values were demonstrated by Mucopren at 30 days, which differed from immediate evaluation (p<0.0001). Trusoft showed higher hardness values at 30 days (p<0.0001). Mucopren did not present statistical significance differences between immediate and 60-days evaluations (p>0.0001). There was significant interaction between the factors "material" and "time" (p = 0.0029).

Mucopren demonstrated higher compressive strength than Trusoft at immediate and 7 days evaluations (p=0.0252) (table 2). Mucopren showed higher compressive strength at 60 days than other times evaluations (p<0.0001). Trusoft did not demonstrate significant differences at 30 and 60 days evaluations, but higher means were observed at 60 days than at immediate and 7 days evaluations. There was significant interaction between the factors "material" and "time" (p = 0.0112).

Mucopren demonstrated higher resilience values than Trusoft at all times (p=0.0133) (table 3). For both materials, there was an increase in resilience over time (p<0.0001). The interaction between the factors under study "material" and "time" was not significant (p = 0.1284).

DISCUSSION

The addition of relining material on the internal surface of complete dental prostheses promotes relief of stresses applied on the alveolar ridge [2,5,6], making the prostheses more comfortable to use than those made of acrylic material [3-5]. This comfort is accompanied by

Table 2. Means (standard deviation) of Shore A hardness (in Shore A unit) and compressive strength (in MPa) of each material at each time.

Mechanical property	Material	Time			
		Immediate	7 days	30 days	60 days
Shore A hardness	Mucopren	44.03 (4.91) Ba	48.35 (3.89) ABa	49.29 (4.43) Aa	47.33 (5.70) ABa
	Trusoft	37.23 (6.47) Cb	43.33 (3.61) Bb	50.84 (4.60) Aa	43.49 (3.83) Ba
Compressive strength	Mucopren	5.74 (3.98) Ba	6.52 (1.30) Ba	5.62 (2.82) Ba	10.52 (3.83) Aa
	Trusoft	3.74 (0.90)Cb	4.70 (1.23) BCb	6.79 (2.28) ABa	8.35 (2.97) Aa

Note: Means followed by different letters (capitals in the horizontal and lower cases in the vertical for each mechanical property) differ among them (p≤0.05).

Table 3. Means (standard deviation) of resilience (in Kgf/cm2) of each material at each time

Material	Time				Tukey
	Immediate	7 days	30 days	60 days	
Mucopren	0.03 (0.02)	0.03 (0.01)	0.04 (0.02)	0.06 (0.02)	a
Trusoft	0.02 (0.01)	0.02 (0.01)	0.04 (0.01)	0.04 (0.02)	b
Tukey	C	BC	B	A	

Note: Means followed by different letters, (capitals in the horizontal and lower case in the vertical) differ among them ($p \leq 0.05$).

improved speech; chewing ability; significant reduction in feeling pain; improved retention and stability of dental prostheses, and consequent psychological comfort [2,6,10,14]. Nevertheless, these materials present changes over the course of time due to the degradation inherent to use [2,6,10,19,21,24].

In this study, the null hypothesis that there were no differences in in hardness, in compressive strength, and in resilience of different tissue conditioners in an in situ study during 60-days long-term evaluation was rejected. An increase in hardness was observed for both materials, especially in the time interval of 30 days, in which significantly higher values were recorded than those in the initial time interval. The stability of hardness is a desirable characteristic of resilient relining materials, because any increase may change the distribution of masticatory load, and diminish the absorption of elastic energy that is transmitted to the mucosal tissues under the complete dentures [2,6,10,19]. The Shore A hardness values for resilient relining materials are recognized to range from 25 to 50 units after 24h of aging in distilled water at 37°C, and diminish after 28 days of storage, and these values must not be shown to be higher than 35 units [3,26]. In the present study, the hardness of the materials evaluated ranged between 37 and 50 units in the initial time interval, but no reduction in the hardness values below 35 units was verified in the different time intervals. Laboratory studies have verified increases in the hardness of acrylic resin-based resilient relining materials of up to 150% in the first six months of storage in distilled water [2,6,10]. On the other hand, the hardness of polyvinylsiloxane-based resilient relining materials increase a maximum of 64%, or remained unchanged [14,25,26]. In this study, an increase in hardness was observed for the two materials, irrespective of the composition, however, at a significantly lower percentage for the polyvinylsiloxane-based material.

The increase in hardness may be attributed to the loss of plasticizers and percolation of liquid, or absorption of water by the resilient reliners in long term storage [2,5,6,10,17]. This increase in hardness may lead to the loss of elasticity and shock-absorber effect of the reliners. The results of this study corroborated the results found by Pisani et al. [15] and Kubo et al. [16] in which the changes in hardness increased gradually over time. The authors explained that this occurred as a result of degradation of the resilient relining materials. These changes could be related to the breakdown of polymer chains, water absorption, bonds with free oxygen and release of plasticizers. The breakdown of the polymer chains may increase the freedom of movement of the molecules, and water absorption could act as the addition of plasticizers that improve the elasticity of the material. However, the latter two factors indicated a reduction in the movements of molecules and reduction in the elasticity of the material [2,6,24]. As regards differences between the materials, the hardness values were higher for the acrylic resin-based reliners (Trusoft) due to the increased loss of their plasticizing component [16]. These findings were in agreement with those of the present study, in which the authors verified significant increase in hardness for Trusoft when compared with the polyvinylsiloxane-based reliner (Mucopren), especially in the time interval of 30 days.

In the 60-day time interval, the authors verified that the acrylic resin-based material showed a significant reduction in hardness values in comparison with the 30-day time interval, while the polyvinylsiloxane-based material presented stable hardness in this time interval. This result may be explained by the fact that Trusoft presented a small quantity of plasticizers and alcohol in its composition, which allowed an initial stability of hardness and hardening after 30 days. Whereas, the majority of silicon-based

materials are composed of dimethyl siloxane polymers that do not need the addition of alcohol and plasticizers for them to have resilience [6]. The authors suggest that Trusoft should be indicated for a shorter time of use [11,13], while Mucopren may be indicated for prolonged use if necessary, as well as for relining traditional dental prostheses, because the polyvinylsiloxane-based materials undergo few cohesive changes and therefore, remain unchanged for long periods [2,6,19].

The determination of permanent deformation values in resilient materials indicates their deficiency in elastic recovery after having been submitted to compressive stresses [2,6]. The present study showed that the material Mucopren presented greater compressive strength than Trusoft in the immediate time interval. The higher compressive strength in the initial times represented the greater flexibility of the material, which would lead to greater tolerability by the mucosa and ridge, generating more comfort for the patient. However, in the later time intervals of evaluation, no significant differences were observed between the materials, apart from an increase in compressive strength of the material Trusoft over time. This may be explained by the fact that acrylic resin-based materials have plasticizers in their composition, which are responsible for the resilience of the material, and the leaching of these components results in its stiffening. Whereas, the polyvinylsiloxane-based materials do not have plasticizers, but have a filler in their composition; and water sorption by the presence of this component promotes an increase in the hardness of resilient materials [2,6,23]. Some authors [2,6,10,24] have suggested that the useful life of these materials could be longer than 180 days; however, clinically it has been observed to be more comfortable to change the material in up to 30 days of use due to the loss of resilience [6,10,19].

In evaluating the influence of the factor time, the authors verified an increase in the resilience of the materials from the immediate up to the 60-day time interval. These results may be explained by the fact of the time being considered short. Mucopren, because of being a polyvinylsiloxane-based reliner, suffers little impact on its composition. These materials present a large quantity of crosslinks, absence of or small quantity of plasticizers, and have good elastic recovery. The acrylic resin-based materials present a high percentage of permanent deformation due to the fact of releasing plasticizers into the oral medium, generating a reduction in resilience and deterioration of their properties [10,17].

The resilient relining materials undergo many changes in hardness, compression strength and resilience resulting from the natural process of aging of the materials. In addition to the loss of components, there are the factors resulting from the daily activities such as the daily intake of coffee, use of cigarettes, among others. In view of these factors, in vivo studies will be necessary for determining the best maintenance and clinical use of these materials.

CONCLUSION

The polyvinylsiloxane-based soft liner presented higher hardness, compressive strength and resilience than the acrylic resin-based material, specially considering a long-term evaluation up to 60 days.

Collaborators

H CARVALHO JUNIOR performed the clinical and laboratorial evaluations, and wrote de paper. VHM CARVALHO performed the clinical evaluations and drafted the paper. RT BASTING developed the experimental design, and wrote de paper.

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