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ORIGINAL ARTICLE

DETERMINATION OF SURFACE ROUGHNESS AND HARDNESS OF MOLLOSIL-SILICONE- BASED CHAIRSIDE SOFT LINER INCORPORATED WITH BERGAMOT ESSENTIAL OIL

Determinación de la rugosidad y dureza de la superficie de un revestimiento blando a base de silicona mollosil incorporada con aceite esencial de bergamota

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ABSTRACT

Background: Recently, the incorporation of medicinal plant extracts into biomaterials has gained attention as a natural alternative with significant antifungal properties. The objective of the current study is to assess the impact of adding two different concentrations of Bergamot essential oil (BEO) on the surface roughness and surface hardness of silicone-based cold-cured soft liner material.

Materials and Methods: The study consisted of three groups of silicone cold cured soft liner material mollosil, each group consists of 10 specimens: group1 (control) soft liner alone; group 2 with 5% BEO added to the catalyst of silicon soft liner; and group 3 with 6% of BEO added to the catalyst of silicon soft liner. Thirty samples were prepared for the different tests used in this study. The samples were divided according to tests into two main groups: surface hardness and surface roughness tests.

Results: Surface roughness tests showed that control and 5% BEO groups had a lower mean value than the 6% BEO group which showed a higher roughness, and the experimental group with 5% BEO showed the lowest mean value, with non-significant difference among the groups. The results of shore A hardness test showed that the highest mean value was found for the control group and both 5% and 6% BEO groups showed lower mean values of hardness.

Conclusion: The incorporation of bergamot essential oil had no effect on the surface roughness of soft liner while lowering the surface hardness of the liner material.

Keywords: Denture liners; Silicone; Oils; Citrus; Surface properties; Hardness.

RESUMEN

Antecedentes: Recientemente, la incorporación de extractos de plantas medicinales en biomateriales ha ganado atención como una alternativa natural con importantes propiedades antifúngicas. El objetivo del presente estudio es evaluar el impacto de la adición de dos concentraciones diferentes de aceite esencial de bergamota (AEB) en la rugosidad y dureza superficial de material de revestimiento blando curado en frío a base de silicona.

Materiales y métodos: El estudio consistió en tres grupos de material de revestimiento blando curado en frío de silicona mollosil, cada grupo consta de 10 muestras: grupo 1 (control) revestimiento blando solo; grupo 2 con 5% de AEB añadido al catalizador de revestimiento blando de silicona; y grupo 3 con 6% de AEB añadido al catalizador de revestimiento blando de silicona. Se prepararon treinta muestras para las diferentes pruebas utilizadas en este estudio. Las muestras se dividieron según las pruebas en dos grupos principales: dureza superficial y pruebas de rugosidad superficial.

Resultado: Las pruebas de rugosidad de la superficie mostraron que los grupos de control y 5% AEB tuvieron un valor medio más bajo que el grupo 6% AEB que mostró una rugosidad más alta, y el grupo experimental con 5% AEB mostró el valor medio más bajo, con una diferencia no significativa entre los grupos. Los resultados de la prueba de dureza Shore A mostraron que el valor medio más alto se encontró para el grupo de control y los grupos 5% y 6% AEB mostraron valores medios de dureza más bajos.

Conclusión: La incorporación de aceite esencial de bergamota no tuvo efecto sobre la rugosidad de la superficie del revestimiento blando mientras que redujo la dureza de la superficie del material del revestimiento.

Palabras Clave: Alineadores dentales; Silicone; Aceites; Citrus; Propiedades de superficie; Dureza.

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INTRODUCTION

Soft denture lining materials have been used in dentistry for over a century.[1] These materials, often referred to as flexible liners, are polymeric substances that function as *"shock absorbers"* between the occlusal surfaces of dentures and the underlying oral mucosa. This helps to absorb chewing forces and distribute them through viscoelastic behavior.[2]

Soft denture liners create a comfortable interface between the denture and oral tissues, alleviating the painful distribution of occlusal pressures in areas with poorly resorbed alveolar ridges or in tissues healing after surgical procedures.[3] They are particularly beneficial for patients with significant undercuts, fragile supporting mucosa, excessive residual ridge resorption, or extensive trauma or diseased tissue loss.[4]

Fungal infections, particularly those caused by *Candida*, have become increasingly prevalent worldwide. *Candida spp* have many virulence factors that promote colonization, and under the right conditions, have the potential to infect host organisms. *Candida albicans* is recognized as the leading cause of oral mucosal infections, including oral candidiasis and denture stomatitis.[5] Previous studies have demonstrated that plant oils and herbal supplements exhibit effective antifungal properties against *Candida albicans*, and the findings demonstrate that these oils are a viable treatment option. They have potent antifungal effects and have the strong impact to cure denture stomatitis.[6,7]

The *Citrus bergamia Risso* & Poiteau, more commonly referred to as bergamot, is thought of as a hybrid between lemon and sour orange or a modification of the latter. Some writers thought it was a mixture of lemon and sour orange,[8] with bergamot essential oil used in various products such as candy, Earl Grey tea, and perfumes.[9] The yellowish-green oil known as bergamot essential oil (BEO) is composed of both volatile and non-volatile compounds, including bergamottin, citro ptene, and bergaptene.[10] Research has shown that BEO possesses anti-microbial properties, including activity against dermatophytes, *Listeria monocytogenes, Staphylococcus aureus, Bacillus cereus, Escherichia coli,* and *Campylobacter jejuni.*[11]

BEO has also demonstrated *in vitro* activity against various *Candida* species, suggesting its potential as a topical treatment for *Candida* infections.[12] The health of the prosthesis-bearing area and the comfort of the individual are affected, compromising the durability of the material. The surface roughness of the lining material is particularly important, as it directly or indirectly facilitates the adhesion and colonization of microorganisms, contributing to the proliferation of fungal and bacterial species, as well as the accumulation of plaque and staining.[13]

Therefore, whether the material is of long or short use, the optimum softness of lining materials is important and this softness must ensure the material's functional functionality and longevity.[14]

One of the biggest aspects of using full denture liners is stiffness, as most liner materials are unstable in a moist environment such as the mouth. Another feature expected from flexible linings is increased sleekness with long-term sleekness. Rigidity may cause the underlying mucosa to be subjected to stronger occlusal forces, which may increase the number of clinical symptoms experienced by patients.[15]

It is important to identify a disinfectant material that not only minimizes side effects in the patient's mouth but has a positive effect on the soft lining properties in terms of surface roughness and hardness. The objective of the current study is to evaluate the surface hardness and roughness of soft liners impregnated with bergamot oil extract (BEO).

MATERIALS AND METHODS

Specimen Grouping

In the study, three groups of silicone-based, chairside auto-polymerizing soft liner material (Mollosil, DETAX, Germany) were used for both tests: surface roughness and hardness (10 samples in each group).

Group 1 (control): Soft lining alone,

Group 2: Soft lining with BEO added at a concentration of 5% to the soft lining catalyst, and;

Group 3: Soft lining with BEO added at a concentration of 6% to the soft lining catalyst.

Specimen preparation

A discshaped sample model with dimensions (30 mm diameter and 3 mm thickness) is provided for both tests[4,16] (Figure 1A). First, a mold was made by creating a dental stone that was hand blended according to the manufacturer's instructions at the rate of 100 g of powder to 20 ml of water. The mixture was poured into the bottom of the flask with a creamy consistency, and then the sample patterns were placed in a certain position along with the dental stone in the lower half of the dental flask.

Once the stone had hardened, the top half of the dental flask was placed over the bottom half. The lid is then occluded and it is left to stand for half to one hour in accordance with the manufacturer's instructions.[17] Then, the patterns were removed from the mold and made ready for soft liner application (Figure 1B).

Incorporation of Bergamot Essential Oil composite in cold cure soft liner silicon

As previous studies, BEO was used at 5% and 6% by weight.[9,18] The density of the cold-curing silicone soft liner according to the manufacturer's instructions is 1 g/ml.

On the other hand, the volume of the sample prepared for this study was 3 ml, assessed with a dental syringe. Mass was estimated using the equation as follows[19]:

Weight of cold cured silicone sample 3 x 1 = 3 g

Weight of Bergamot Essential Oil 5%: 3 x 5 /100 = 0.15 g

Weight of Bergamot Essential Oil 6%: 3 x 6/100 = 0.18g

Preparation of cold cured silicon soft liner materials (mollosil)

For control samples, cold-curing silicone was made into two pastes (base and catalyst) by mixing 1.5 ml of the base and 1.5 ml of the catalyst according to the manufacturer's instructions, the same amount of both base and catalyst paste was distributed on the glass slide. It was mixed until a unisonous mixture was obtained (30 seconds), painted with a release agent for easy separation of the mold, then placed in the mold with the help of a spatula.

Then, the excess material was removed with the help of a wax knife and the sample was placed in place under 2kg and left for stability.[19] After that, the mixture was put into the mold and was pressed with the help of a clump to obtain a smooth and modified mold until the liner fully sets (5 minutes).

While mixing the base, catalyst pastes and Bergamot Essential oil in the test samples according to Table 1, bergamot essential oil was added to the catalyst paste and manually mixed continuously with a spatula for 3 minutes by the same operator mix on the paper pad or glass slide and complete the same steps with the rest of the samples. The final form of all samples is presented in Figure 1C.

Surface roughness test

A portable digital roughness tester (Profilometer tool, Portable surface roughness meshes, Mahrfederal Inc., Germany) was used

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to evaluate whether the addition of BEO affected the micromorphology of the silicone soft liner surface. This tool's diamond stylus, used as an analyzer to monitor the profile of irregularities, is sharp and precise (Figure 1D). Testing procedures followed Profilometer instructions.

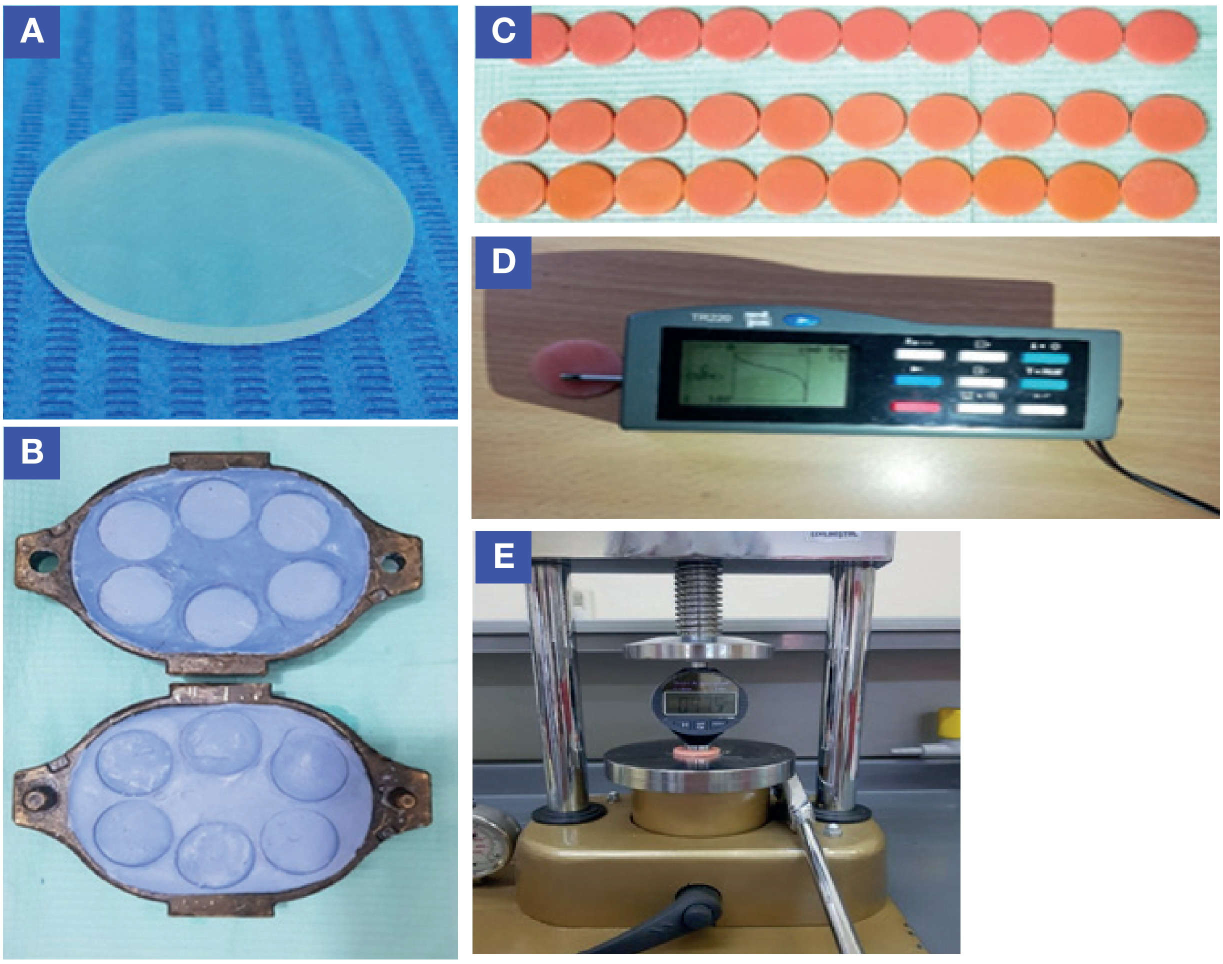
The probe contacted three standardized different regions in the sample (each sample was divided into three equal regions), corresponding to three readings for each sample. The probe contacts the sample 5 mm in each area. When the probe was allowed to touch the first area of the sample, the reading on the digital scale appeared on the screen. The average score of the three readings was then calculated.[9]

Surface hardness test

The hardness of the soft liner was determined using a hardness tester (Shore A durometer, China) (Figure 1E). The test value was calculated as the average of three readings obtained directly from the scale reading of the durometer.

The distance between the sample surface and the indentation was fixed at 20 mm, and the contact time after penetration was 5 seconds, which was used for the hardness test, which required placing a fifty-gram load on the surface of each sample for ten seconds. They were examined in triplicate (right, middle, and left) and average readings were

Figure 1. Materials and instruments used in this study.



A: Specimens pattern with shaped discs.
B: Mold preparation
C: The final form of the specimens.
D: Specimen under the portable digital roughness tester.
E: Specimen under Shore A durometer hardness tester.

recorded for each one.[4] For the statistical analysis, SPSS software (Chicago, Illinois, USA), was employed. The information was shown as descriptive statistics. Using the ANOVA and Tukey-HSD test to compare surface roughness and hardness between the three groups, a *p*-value of 0.05 was evaluated to represent a statistically significant difference.

RESULTS

Surface roughness test

The results revealed that the experimental group with 5% BEO had the lowest mean value in the surface roughness test of descriptive statistics, while the group with 6% BEO had the highest roughness mean values, as shown in Figure 6 and Table 2.

Table 1. Percentages of bergamot essential oil, base and catalyst of cold cured silicon (mollosil) used in this study.

Groups	Percentege of BEO	Amount of BEO (g)	Amount of base (g)	Amount of catalyst (g)
Group 1	0.0	0.0	1.5	1.5
Group 2	5.0	0.15	1.5	1.5
Group 3	6.0	0.18	1.5	1.5

Table 2. Descriptive statistics of the surface roughness test.

Groups	N	Mean	Standard Deviation	Standard Error	Minimum	Maximum
Group 1	10	3.4670	1.36418	0.43139	2.35	6.98
Group 2	10	2.8262	0.36520	0.11549	2.33	3.55
Group 3	10	3.8888	1.194488	0.37773	2.34	6.05

Table 3. ANOVA test for all groups of surface roughness.

	Sum of Squares	degrees of freedom	Mean Square	F-value	*p*-value
Between Groups	5.7258	2	2.863	2.510	0.100 ns
Within Groups	30.790	27	1.140	---	---
Total	**36.790**	**29**	---	---	---

***:** Non-significant at *p*-value>0.05.

Table 4. Descriptive statistics of the surface hardness test.

Groups	N	Mean	Standard Deviation	Standard Error	Minimum	Maximum
Group 1	10	15.5833	0.82121	0.25969	14.17	17.17
Group 2	10	8.8500	1.12614	0.35612	7.50	10.83
Group 3	10	8.4833	0.70471	0.22285	7.67	10.17

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Table 5. ANOVA test for all groups of surface roughness.

	Sum of Squares	degrees of freedom	Mean Square	F-value	*p*-value
Between Groups	319.608	2	159.804	196.545	0.000*
Within Groups	21.953	27	0.813	---	---
Total	**341.561**	**29**	**---**	**---**	**---**

*: Non-significant at *p*-value>0.05.

Table 6. Tukey-HSD test for comparison among the surface hardness groups.

Groups		Mean Difference	Standard Error	*p*-value
Group 1	Group 2	6.73335	0.40325	0.000 *
	Group 3	7.10000	0.40325	0.000*
Group 2	Group 3	3.66650	0.40325	0.639**

*: Significant at p-value ≤ 0.05 **: Non-significant at *p*-value>0.05.

The comparison among the three groups of the surface roughness by using the ANOVA test, indicated there were no significant differences (Table 3).

Surface Hardness test

The descriptive statistics outcome of shore A hardness test revealed that the control group had the greatest mean value, whereas the 5% and 6% BEO groups had lower mean values, Figure 7 and Table 4.

The ANOVA-test of surface hardness for comparing among three groups revealed a significant difference between all groups, Table 5. The need for further analyses so the Tukey-HSD test was run. It was indicated that there was a significant difference between the control group and the 5% BEO group, also a significant difference between the control group and the 6% BEO group. While, there was a non-significant difference between the 5% and 6% BEO (Table 6).

DISCUSSION

Soft denture lining materials serve as a cushioned layer between the rigid denture base and the oral mucosa. These liners absorb chewing forces, helping to distribute stresses more evenly across the underlying tissues. Patients who wear dentures and have small ridge tissues, thin or inelastic mucosa, bony undercuts, or bruxism may find these lining materials particularly beneficial for enhancing comfort.[20]

Candida albicans colonization of the soft liner surface has been one of the most problematic concerns. Studies have shown that some types of bacteria and yeast can infiltrate the porous areas of soft lining substance, and their colonization can shorten the intraoral life of the material.[21] It is necessary to use more modern, all-natural treatments that can stop a biofilm of microorganisms from forming and growing.

Recently, it has been found that incorporating plant-based products into biomaterials offers a natural alternative with strong antifungal properties.[22]

Scientists' preference for plantbased therapies has been driven by the fact that medicinal plant extracts serve as effective alternatives to anti-microbial drugs, often with fewer or no side effects.

Consequently, numerous studies have been conducted to enhance herbal therapies that are biologically safe and exhibit strong anti-fungal activity.[23,24] Extracted liquids that are concentrated hydrophobic products from plants and have a wide range of pharmacological actions, are examples of organically derived herbal medications.[25] These substances are thought to be a promising therapeutic option for treating oral infections.

Over the past few decades, a variety of oils have been tested for their activity against *Candida albicans*, and each has unique active ingredients that work against the fungus in a specific manner.[26,7] Bergamot fruit and its oil are among the most commonly used plants for their essential oils, which are primarily derived from the peel of the fruit.[27] Bergamot essential oil has been utilized for its antimicrobial, anti-inflammatory, diaphoretic, and analgesic properties.[11]

The surface roughness of a material is indicated as Ra parameters that are obtained by using a profilometer device. It provides a description of all the surface roughness and is defined as "arithmetical mean values of the whole roughness profile absolute distance from the center line within the measurement lengths".[28]

The material's surface roughness is an essential characteristic that influences whether an object interacts with its environment.[9] Maintaining a smooth surface without or with very small surface scratches is one of the main goals of soft liner restoration because surface roughness can have a negative impact on denture aes-thetics while smooth shiny surfaces can resist stains, dirt, and plaque formation.[29]

Most micro-organisms, particularly those responsible for denture stomatitis, caries, and periodontal disease, can only survive in the mouth by adhering to a non-shedding oral surface, where they begin to form colonies. As a result, this colonization negatively impacts the health of the tissues in direct contact with the denture.[30]

Based on the literature, the key factors influencing the surface roughness of soft liners are the material's intrinsic characteristics, the polishing method, and the operator's expertise.[31] This resulted in accordance with previous research who found lemongrass essential oil reduced surface roughness values when compared with the control group without lemongrass essential oil.[32] Furthermore, this outcome is similar to a study by Muttagi *et al.,*[33] who discovered that adding seed oils to the soft liner material considerably reduced its surface roughness. A study incorporated Origanum essential oil into a tissue conditioner and demonstrated that this addition minimized the surface roughness of the material.[34]

Surface hardness is a crucial component of soft materials, and to fulfill its role effectively it must remain consistent over time, depending on the type of material used, whether permanent or temporary.[35] Compared with the BEO groups, the average hardness value increased significantly in the control group. This result is consistent with a previous study that found that the addition of lemongrass essential oil significantly reduced Shore hardness and reduced the surface hardness of the soft liner compared to the control group.

This result is consistent with a previous study that found that the addition of lemongrass

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essential oil significantly reduced Shore hardness and reduced the surface hardness of the soft liner compared to the control group.[32]

Additionally, in line with the results of the study by Alamen *et al.,*[36] who showed that adding coconut oil to soft liners reduced their stiffness at all concentrations, a possible explanation for such an effect is that the oil would coat the polymer particles. This coating will reduce the conversion of monomer to polymer, leaving behind a significant amount of it.[37]

CONCLUSION

In the present study, the addition of Bergamot essential oil to the cold-cured silicone soft liner (mollosil) did not affect the surface roughness compared to the control group.

However, a decrease in surface hardness was observed in the mollosil soft liner, as the control group exhibited higher hardness values than the groups with 5% and 6% BEO incorporation.

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

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