

Evaluating the Effect of Lemongrass Essential Oil Addition on Some Properties of Heat Cure Acrylic Soft-Lining Material

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Abstract

Background: Denture liners' viscoelasticity absorbs shocks and relieves tissue pressure. Soft liners must be replaced every 6–12 months because oral conditions destroy elastomers. By adding chemicals to soft liners, researchers have created a new class of flexible, oral-friendly materials. This lowers denture and mucosa pressure. **Objectives:** The aim of the study is to discover if the best two concentrations of lemongrass essential oil (LGEO) added to heat-cured soft denture liner improves the material's hardness, the strength of the peel bond, and surface roughness. **Materials and Methods:** In a pilot study, 2.5 vol.% and 5 vol.% LGEO improved the heat-cured soft-liner material's Shore A hardness and surface roughness. The main study categorized 90 specimens into three groups (Shore A hardness, peel bond strength, and surface roughness). Each of the groups has three subgroups (control, 2.5 vol.% of LGEO additive, and 5 vol.% of LGEO additive). One-way analysis of variance, Dunnett's T3 *post hoc*, Tukey's honestly significant difference, and Fisher's exact test were used for data analysis, which was significant at $P < 0.05$. **Results:** After adding 2.5 vol.% and 5 vol.% of LGEO additives (experimental subgroups), Shore hardness, peel bond strength, and surface roughness of the two experimental subgroups decreased significantly from the control subgroup at $P < 0.05$, except for 2.5 vol.% of the LGEO additive subgroup, which did not differ significantly at $P > 0.05$. When failure mode was assessed, all subgroups varied substantially. The 2.5 vol.% of LGEO addition specimens showed adhesive and cohesive failure with some mixed type, whereas 5 vol.% showed predominantly cohesive failure. **Conclusions:** LGEO enhances the hardness and surface roughness of the soft-lining material, making it more resilient and smoother. This leads to a greater cushioning effect and reduced damage to the oral tissues while decreasing the liner's peel bond strength to an acceptable level. 5 vol.% is the best percentage that improves liner properties.

Keywords: Heat-cured acrylic soft-lining material, lemongrass essential oil, mode of failure, peel bond strength, Shore A hardness, surface roughness

INTRODUCTION

Soft denture liners are cushioned layers that sit between the hard denture foundation and the oral mucosa. By absorbing a part of the masticatory pressures, the liners serve to distribute the forces of mastication more uniformly to the underlying tissues. Denture patients with ridge atrophy, thin and nonresilient mucosa, bony undercuts, and bruxomania may benefit from the soft liners. They are also indicated for individuals with bruxism and xerostomia, as well as for abnormal bone resorption, immediate prosthesis, and healing following implant implantation.^[1]

For maximum benefits for denture wearers, soft denture liners should have several qualities, including biocompatibility, good resiliency, low roughness and

hardness level, and adequate bond strength with the underlying denture base.^[2]

The soft liner has several disadvantages including low abrasion resistance, porosity, and low bond strength.^[1] The mechanical strength of the relined base of the denture is thought to be influenced by the resins used to make the denture liner and denture base.^[3] The strength of peel bond test is the most important approach to anticipate

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material bonding in clinical situations because bond loss often starts via an apparent detachment process at the exposing edge of the soft-lining material.^[4]

Soft materials may be used to provide the perfect hardness or softness that gives the patient more comfort; therefore, hardness is a crucial quality for a resilient liner and should be constant for an extended time so that the material can effectively carry out its tasks.^[5]

Lemongrass is an herbal medicine that is known for its antimicrobial effect, so this study was conducted to produce a soft-lining material with antimicrobial properties with less effect on other properties of the material such as hardness, surface roughness, and peel bond strength.^[6]

MATERIALS AND METHODS

Pilot study

For the purpose of determining the optimum two concentrations of lemongrass essential oil (LGEO) (Now foods, USA) that have to be added to heat-cure soft-lining material (Moonstar, Turkey), hardness and roughness tests were selected, and different concentrations of LGEO were used: 0% control, 2.5%, 5.0%, and 7.5% (v/v), and then mixed with the liquid of heat-cured soft-liner material.

Results of the pilot study

For both Shore A hardness and surface roughness, 2.5 vol.% and 5 vol.% of LGEO were selected to be added to the heat-cure soft-lining material in the main study as these two concentrations showed the best improvement in the hardness and roughness of the material.

Main study

Test for Shore A hardness

Specimen design CNC machine was used to prepare plastic specimen models. To prepare the soft denture lining specimens for Shore A hardness test, the specimens that were shaped in disk-like that is 6 mm thickness and 35 mm diameter were used according to ISO-10139-2 (2016) specification.

Mold preparation The separating medium (BMS Dental, Italy) was applied to the plastic models and left to dry. The extremely hard dental die stone of Type IV (Zermach, Germany) was mixed in accordance with the manufacturer's recommendations (100 g powder to 20 mL water: P/W) and put in the flask's bottom half before being

vibrated to eliminate air bubbles. To prevent the plastic models from getting submerged in the stone, which would make it hard to recover them after opening the flask, half of them were implanted deeply, whereas the other half were left above the level of the stone. After the bottom half was set, a separating medium was used to coat it and left to dry. The flask was then placed on its counterpart, filled with stone, vibrated, and left for 1 h to guarantee the stone was completely set; when the stone was fully set, the flask was separated and the plastic models were removed to create molds for the heat-cured acrylic soft-liner specimens.

For control group

According to the manufacturer's specifications, the soft-liner polymer and monomer were combined in a dry, clean glass container with a lid to prevent the monomer from evaporating.

To prevent soft-liner adherence to the stone, separating media were applied to the top and bottom sections of the dental flask. When the mixture reached the consistency of dough, it was molded with a finger and placed in the mold area of the stone.

Incorporation of lemongrass essential oil (experimental specimens)

LGEO was measured with a micropipette (DRAGON lab, China), then added and mixed with the soft-liner liquid using an electronic mixer, then added immediately to the soft-liner powder to prevent oil separation from the liner liquid, and the amount of oil was decreased from the soft-liner liquid to retain the same manufacture ratio of P/L. An electronically balanced device (accuracy of 0.001) (KERN, Germany) was used to weigh the powder, and a micropipette was used to measure the monomer [Table 1].

Packing

After reaching the dough stage, the soft liner was hand kneaded and placed on the mold. The lid was placed on the polyethylene-coated top piece (JIAO JIE, China). A hydraulic press (China) was utilized to exert 100 kg/cm² of continuous pressure to remove any excess material and evenly distribute the soft-lining material in the mold.

After the press, the flask was unsealed. Using a wax knife (China), the polyethylene film was peeled, surplus material was removed, and the stone's surface was recoated before curing.

Table 1: The mixing ratios of LGEO, soft-liner powder, and soft-liner monomer

Selected percentage	Lemongrass oil amount in milliliter	Polymer amount in grams	Monomer amount in milliliter
Control	0	3.5	2.5
2.5 vol.% (LGEO additive)	0.062	3.5	2.437
5 vol.% (LGEO additive)	0.125	3.5	2.375

The flask was clamped for 5 min at 100 kg/cm² pressure to prepare for curing.^[7]

Curing and finishing

The dental flask was placed in a digitally thermostatically managed bath of water (HH-2, China). According to manufacturer's recommendations, the flask was placed in room-temperature water and heated to 100°C for 20 min.^[8]

After curing, at room temperature, the flask cooled for 30 min before 15 min chilling under running tap water. After the flask cooled, the specimens have been removed.^[9]

After removing the excess material with a sharp blade, the specimens were finished with a fine grit silicon polishing bur and fine grit sandpaper and then kept in distilled water for 24 h removing residual monomer.^[7]

Specimen testing A total of 30 specimens were created, with 10 specimens for each subgroup. The specimens' Shore A hardness was measured using a durometer (Time group-TH200, China). The specimen was indented at a distance of 20 mm from the indenter, and the contact duration was set at 5 s after penetration. Five indentations were made for each specimen 5 mm from the edge of the specimen and 2 mm from each other, and the mean was considered.^[10]

Test for the strength of peel bond

Mold and specimen preparation Because the ASTM D903-93 specimen size is excessively big, length and width half measurements were used in the purpose of testing.^[11] The specimen was made by packing heat-cured acrylic resin (10 g/7.8 mL) (Spofa Dental, Czech Republic) onto acrylic-holed plates.^[12]

After that, the flask was sealed by putting it into a hydraulic press with gradual pressure to 100 MPa to ensure an even flow of the material. It was then left for 5 min. After packing, it was immersed in cold water, then heated to 70°C in 30 min, kept at that temperature for 30 min, then heated to 100°C on 30 min. The total polymerization duration was 2 h.

After polymerization, the flasks cooled for 30 min on the bench and 15 min under running tap water. After removing the acrylic strips, superfluous material was removed, the acrylic specimens smoothed, washed (using distill water), and dried, and then returned to the flask.^[12] Thirty mm of acrylic resin must be wrapped in tin foil before filling the soft liner. Only 70 mm of acrylic resin will adhere to the soft liner, leaving the rest undisturbed.^[11]

After mixing and measuring (the same steps in Shore A hardness specimens), the acrylic-based soft-liner polymer was added to the liquid. When the mixture became dough-like, it was placed in the plate's hollow sections intended for the soft lining. This plate was then covered with a 5-mm cover, the screws have been fastened,

and it was put in a hydraulic press to 100 MPa. After 5 min, surplus substances were removed from the flask.^[7]

After putting the flask in a room-temperature water bath, it was heated till reaching 100°C and then remained at that temperature for 20 min. After that time, the flask was removed and chilled on a bench. Extra material was then removed using a sharp blade.

Specimen testing A total of 30 specimens were created, with 10 specimens for each subgroup. Using the universal testing machine (Instron 1195, England) with an angle of 180 degrees and 152 mm/min speed, the specimen's analysis of the strength for peel bond test was done according to ASTM D903-93. The top clutch of the universal testing machine was clamped with the free portion of acrylic resin, and the lower clamp was secured with the free portion of the soft liner (25 mm of the soft liner).

After specimen testing, the kind of failure at the bonded region was assessed with the naked eye and classified as cohesive, adhesive, or mixed failures. Cohesive denotes that the soft lining itself experiences tearing. Adhesive failure denotes a complete separation of the soft liner and acrylic resin where they were bonded, whereas mixed failure denotes both forms of failure.^[11]

The equation used to determine the strength of the peel bond, in which the angle of peeling was taken to be 180°, is as following^[13]:

Strength of peel bond = average load/specimen's width.

Surface roughness

Specimen design CNC machine was used to prepare plastic specimen models, the test specimens of soft liner for surface roughness test prepared in a dimension of length of 65 mm, width of 10 mm, and thickness of 2.5 mm. Roughness of the surface measuring was done using the profilometer machine according to ANSI/ADA specification No. 12, 1999.

Mold preparation Mold preparation, the soft-liner proportion, blending, packing, and curing are as previously explained in the Shore A hardness test.

Specimen testing A total of 30 specimens were created, with 10 specimens for each subgroup, and the surface roughness test was performed with a digital roughness tester (Profilometer) (Time group—TR220, China). This device consists of a sharp sensible needle (stylus) made from diamond, which is the surface analyzer work to trace the profile of surface irregularities. The test was done according to the Profilometer instructions.

Statistical analysis

Statistical analyses were used as follows:

- 1 Descriptive analysis: mean, minimum, maximum, standard error (SE), and standard deviation (SD) for a quantitative variable, and frequency and percentage for a qualitative variable
- 2 Inferential analysis: (A) Shapiro–Wilk test; (B) Levene test; (C) analysis of variance (ANOVA) using Tukey's honestly significant difference (HSD) and Dunnett's T3; (D) Fisher exact.

Ethical approval

The study was conducted in accordance with the ethical principles that have their origin in the Declaration of Helsinki. It was carried out with patients verbal and analytical approval before sample was taken. The study protocol and the subject information and consent form were reviewed and approved by a local ethics committee according to the document number 645 (including the number and the date in 18/8/2022) to get this approval.

RESULTS

Test for Shore A hardness

The highest mean value was showed by the control group (70.110 IU), and the experimental subgroup 5% by volume of LGEO incorporation showed the lowest mean value (64.910 IU) [Table 2].

The findings of the Shore A hardness test revealed a difference that is statistically significant between the subgroups that were subjected to the one-way ANOVA ($P < 0.05$) [Table 3].

Tukey's HSD was used for the multiple comparisons of Shore A hardness between each two subgroups. The comparison of the two subgroups that were tested revealed a difference that is statistically significant in the findings at $P < 0.05$.

Test for the strength of peel bond

The test results for the strength of peel bond showed that both experimental subgroups have decreased peel bond strength values with the experimental subgroup 5vol.% of LGEO additive having the lowest value (1.830 Mpa) followed by the subgroup 2.5 vol.% of LGEO additive (2.040 Mpa) in comparison with the control subgroup, which has the mean value of 2.390 Mpa [Table 4].

The strength of peel bond test that was conducted using one-way ANOVA found that all of the subgroups that were tested differed significantly at $P < 0.05$.

Tukey's HSD test was used for making value comparisons between the two different study subgroups. At $P > 0.05$, there was a difference that was not statistically significant between the subgroups that contained 5vol.% of LGEO additive and the subgroups that contained 2.5 vol.% of LGEO additive. However, there was a difference that was significant statistically between the subgroups that contained the control and either 2.5 vol.% of LGEO additive or 5 vol.% of LGEO additive.

The naked eye was used to examine the failure mode for each specimen and categorize it as adhesive, cohesive, or mixed type of failure; it appeared that most specimens of

Table 2: Descriptive statistics of Shore A hardness among subgroups

Subgroups	N	Mean	±SD	±SE	Minimum	Maximum
0 vol.% LGEO	10	70.110	0.737	0.233	69.000	71.200
2.5 vol.% LGEO	10	66.250	0.564	0.178	65.200	67.100
5 vol.% LGEO	10	64.910	0.538	0.170	64.200	65.800

Table 3: Shore A hardness statistical test among subgroups by one-way ANOVA

	The sum of the squares	Df	The mean of the square	F	Value of P
Between subgroups	145.784	2	72.892	189.915	0.000*
Within subgroups	10.363	27	0.384		
Total	156.147	29			

Levene P value = 0.571

*Equal to not significant at $P > 0.05$

Table 4: Descriptive statistics of peel bond strength test (Mpa)

Subgroups	N	Mean	±SD	±SE	Minimum	Maximum
0 vol.% LGEO	10	2.390	0.331	0.105	2.000	2.900
2.5 vol.% LGEO	10	2.040	0.222	0.070	1.700	2.400
5 vol.% LGEO	10	1.830	0.164	0.052	1.600	2.100

the control group had an adhesive failure (6=60%; 6 of the 10 control specimens had an adhesive failure), except for four specimens that failed cohesively (1=40%; 1 of the 10 control specimens had cohesive failure), and a mixed failure (3=30%; 3 of the 10 control specimens had a mixed failure). And the specimens of group 2.5 vol.% of LGEO additive had a 2=20% mixed failure and 4=40% specimens failed cohesively and 4=40% adhesively, whereas specimens of group 5 vol.% of LGEO additive also had a 9=90% cohesive failure except for one specimen, which had mixed failure (1=10%).

For the distribution of failure mode among groups, the Fisher exact test and multiple pair-wise comparison tests were used.

The results for Fisher's exact test show that all the tested subgroups differed significantly at $P < 0.05$. Multiple pair-wise comparisons showed nonsignificant differences between the control and 2.5 vol.% additives of LGEO at $P > 0.05$, whereas the control subgroup and 5 vol.% additives of LGEO subgroup differed significantly at $P < 0.05$, as well as a difference that considered significant was found between 2.5 vol.% of LGEO additives and 5 vol.% LGEO additives at $P < 0.05$.

Surface roughness test

The experimental subgroup that contained 5% by volume of LGEO additive (2.352 m) was found to have the mean value that was the lowest, whereas the control subgroup was found to have the mean value that was the highest (3.354 m).

The descriptive statistics of surface roughness for each of the test subgroups are shown in Table 5.

Results from the one-way ANOVA test for surface roughness revealed that all the tested subgroups differ significantly at $P < 0.05$.

For surface roughness, multiple comparisons between each two subgroups, Dunnett's T3 *post hoc* test, was used [Table 6].

Each of the two test subgroups was found to have a difference that is statistically significant according to the findings ($P < 0.05$).

DISCUSSION

Shore A hardness

Hardness is a physical attribute that reflects the resistance to permanent indentation by the material and is a rapid method to assess its elastic modulus. Hardness can also be considered a measure of a material's durability.^[14] One of the soft-lining material's main advantages is its ability to absorb an impact force during mastication. This property necessitates that the material has adequate viscoelastic properties, which means it must be nonrigid to act as a cushion for the residual alveolar ridge when subjected to masticatory forces transmitted from the denture. As a result, it is assumed that lower hardness values are required for the soft-lining material to function correctly. Despite this, there is no limit to the range of Shore A hardness values that can be therapeutically appropriate.^[15]

According to Mese and Guzel^[16] in 2008, when compared with the other materials, the heat-cured acrylic soft liner had the maximum hardness after being stored in water for 24 h at a temperature of 37°C.

Mixing the soft-liner powder and liquid will lead to a swollen mixture because of the polymer particles' absorption of the ethanol in the monomer. This process will disarrange the polymeric chains, leading to more significant molecules of plasticizers penetrating between them, which is responsible for decreasing the hardness level.^[17]

This study result showed that the mean value of both experimental subgroups was significantly reduced in comparison with the control subgroup; LGEO was considered an alternative plasticizer in the polymer sector, even at low concentrations. This is because it increases the mobility of polymer chains and decreases the viscosity of the material, as was found in the study.^[18] Plasticizers are

Table 5: Surface roughness (μm) descriptive statistics of the test subgroups

Subgroups	N	Mean	$\pm\text{SD}$	$\pm\text{SE}$	Minimum	Maximum
0 vol.% LGEO	10	3.354	0.060	0.019	3.273	3.427
2.5 vol.% LGEO	10	2.503	0.096	0.030	2.412	2.692
5 vol.% LGEO	10	2.352	0.037	0.012	2.311	2.422

Table 6: Surface roughness (μm) multiple comparisons between each two subgroups using Dunnett's T3 *post hoc* test

L subgroups	N subgroups	Mean difference (L – N)	P value
0 vol.% LGEO	2.5 vol.% LGEO	0.851	0.000*
	5 vol.% LGEO	1.003	0.000*
2.5 vol.% LGEO	5 vol.% LGEO	0.151	0.001*

*Significant at $P < 0.05$

not permanently attached to the resin, which is why they leach away and produce significant changes in mechanical properties.^[19]

In agreement with the findings of the study,^[9] which found that coconut oil incorporation into soft liner resulted in a reduction in the material's hardness at all concentrations, the possible explanation for such an effect is that the polymer particles will be coated by oil. This coating will reduce monomer conversion to polymer, leading to a large amount of residual monomer.^[20]

The findings of this research were in contrast to the results of a study conducted by Godil,^[21] which concluded that the addition of *Ocimum sanctum* oil to soft denture liners had no impact on the level of hardness shown by the soft-lining material.

Strength of peel bond

The connection between the denture foundation acrylic resin and lining material is essential to the efficacy of denture lining. The liner must maintain this bonding to restore the damaged tissues completely. Sadly, one of the most frequent clinical failures that may occur with relined dentures is for the soft denture liner to tear away from the denture base. It is possible that the use of antifungal or antibacterial medications in soft denture liners, which have been demonstrated in the modification of the materials' physical characteristics, might make this condition worse. This is because these treatments alter the properties of the materials.^[22]

The detachment of the soft liner can be attributed to the interface's microleakage, enhances microbe adherence and proliferation, and frequently leads to prosthesis failure.^[23] It is typical for the soft liners and the denture base resin to lose their bond.^[24]

Compared with the control subgroup, this study's peel bond strength test results demonstrated a reduction that is significant in peel bond strength with the addition of LGEO in 2.5 vol.% and 5 vol.% of LGEO additive.

The reduced peel bond strength of the experimental subgroups (2.5 vol.%, 5 vol.%) also may be attributed to the slight accumulation of LGEO (attributed to the high level of surface energy), which may cause microfracture that weakens the polymer structure and affects soft liner/acrylic bond strength.^[25]

This test also studies each specimen's failure mode; adhesive failure was clear in the subgroup of control specimens indicating a relative deficiency of the interface strength, whereas cohesive failure was noticed in 4=40% specimens of the experimental subgroup (2.5% by volume) and 9=90% specimens of the experimental group (5% by volume); this is due to an increase in the amount of LGEO in the soft liner that inter the particles of the liner and open the chains leading to a decrease in the hardness rate; this

reduced hardness contributes to decreasing resistant of the liner to the force leading to the separation of the liner before the liner-acrylic interface.^[18] The mode of failure was changed from adhesive to a more cohesive type as the concentration of LGEO additive increased; this may be explained by that more reaction happened between the LGEO additive and soft-lining material, which was conducted from Fourier-transform infrared spectroscopy results, and affect this properties of the material and maybe also affect the interaction with the bonding acrylic with the material.

The mixed failures (both adhesive and cohesive) indicate that the soft liner was more strongly bonded to the acrylic material after the incorporation of LGEO and also imply that the two materials' interface strength in some areas was higher than the intermolecular bond of the soft liner.^[26] As the concentration of LGEO additive increases, this type of failure seems to reduce and be affected by additive material.

The comparison of the peel bond strength results between this study and other studies is difficult; this is due to the difference in the type of additive materials, the method of their extraction, and their composition.

Surface roughness

The roughness of the material surface is an important property that has a significant role in the determination of the object's interaction with its environment.^[27]

Because the roughness of material is primarily influenced by its inherent properties, operator skills, and polishing technique, the value of roughness in other studies differs due to differences in the methods used, including experimental procedures and surface roughness measurement procedures.^[28]

In this investigation, an addition of 2.5 vol.% and 5 vol.% LGEO reduced surface roughness values when compared with the control subgroup (0 vol.% LGEO additive), and this reduction was significant statistically for both experimental subgroups. This decrease could be attributed to polymerization acceleration, which promoted further arrangement and supplementation of polymer chains, resulting in a fine smooth surface^[28] due to chemical bonds of oil molecules and resin particles. Increased bonding of polymer chains leads to fewer particles chipping away from the surface during deflasking and grinding, which may contribute to a reduction in roughness. This explanation is consistent with a study done by Muttagi and Subramanya,^[29] which found that adding seed oils to the soft liner significantly reduced the surface roughness of that soft-lining material.

This is disagreed with a study by Godil,^[21] which found that the incorporation of *Ocimum sanctum* oil in soft denture liners does not affect the surface roughness of soft-lining material.

It is vital to remember that changes in experimental protocols, surface roughness measurement procedures, and the type of soft lining material employed make comparing roughness values from different investigations challenging.

CONCLUSIONS

There was a significant decrease in the Shore A hardness values of both experimental groups when compared with the control group: the experimental group 5 vol.% additive of LGEO showed the lowest values that are the best for the soft-lining material as it produces a more cushioning effect.

In comparison to the control group, both experimental groups' peel bond strength values significantly decreased when LGEO was added to the heat-cured acrylic-based soft-lining material. However, the 2.5 vol.% LGEO additions had the least effect. The mode of failure was changed from adhesive to a more cohesive type of failure as the concentration of LGEO was increased.

There was a significant decrease in the value of the surface roughness when LGEO was added to the heat-cured acrylic-based soft-lining material with the 5 vol.% additives of LGEO showing a greater decrease compared with the control group.

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Conflicts of interest

There are no conflicts of interest.

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