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Article

The influence of lemongrass essential oil addition on some of the properties of the heat-cured acrylic resin material

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Abstract

Polymethylmethacrylate (PMMA) has been used as a model for many different dental materials. However, PMMA appliances and products do not have the best mechanical properties. Various fillers and oils, such as bergamot essential oil, thymol, eucalyptus, mer,maid and ginger, have been added to address this issue. So, this study looked at what happened when lemongrass essential oil (LGEO) was added to heat-cured PMMA denture base material and how it changed the properties of PMMA. Methods: 120 samples were prepared and split into four equal groups based on the tests that were done (the transverse strength, impact strength, surface roughness, and surface hardness), and each group their specimens were prepared and divided into three groups; control 0 vol.% without additive and two experimental groups (with 2.5 vol. % LGEO additive, with 5 vol. % LGEO additive) Results**:** The addition of 5 vol. % LGEO has the best effect on the acrylic's improved mechanical and physical properties (transverse strength, impact strength, and surface roughness) except for the surface hardness, which is less affected with the addition of 2.5 vol. % LGEO at $p < 0.05$. Conclusion**:** By adding LGEO to heat-curing acrylic material, it is possible to make a material with better mechanical and physical properties

Keywords: Essential oils, Lemongrass essential oil, Mechanical properties, Physical properties, polymethylmethacrylate material.

Introduction

Dentures made of PMMA were the best because they were easily molded and had excellent esthetics and mechanical properties. The best material for a denture base is biocompatible and has good mechanical properties, especially a high hardness, impact strength, flexural strength, and modulus of elasticity. It should also be easy to fix and have accurate dimensions [1 and 2]. PMMA has flaws, like shrinking when heated and having low mechanical and fatigue strength. [3]. Reinforcing different materials has been studied as a way to improve their physical and mechanical properties. Adding essential oils to the polymer matrix has been shown to change how the material works. These changes depend on the types and amounts of essential oils. [4, 5]. Lemongrass essential oil (LGEO) belongs to the section of *Andropogan* called *Cymbopogam* of the family *Germineae* [6]. **(**Atal and Kapur, 1982). LGEO was added by binding it with PMMA. After that, the specimens of LGEO/PMMA were examined for their mechanical characteristics.

Material and methods

Specimen's preparation:

Plastic patterns for the transverse strength, hardness, and roughness tests with dimensions of (65mm x 10mm x 2.5mm) [7], and the impact strength test recommended with a dimension of (80mm x 10mm x 2.5mm) [8, 9]. The plastic patterns were embedded in the lower portion of the dental flask, filled previously with type IV extra hard dental die stone (freshly mixed according to. manufacturer's instructions (W/P ratio: 25ml/100g) [10].

Measurement and blending of heat-curable acrylic (PMMA):

The quantities of polymer, monomer, and LGEO were determined with the assistance of an electronic balance having an accuracy of (0.001g) for powder weighing and a micropipette for liquid measuring; the mixing was carried out by the guidelines provided by the manufacturer (P/L ratio of 22g: 10ml). For the control heat-cured PMMA specimens, in a glass jar, the correct quantity of PMMA powder and liquid were combined and stirred until the mixture took on the consistency of dough. For the addition of lemongrass essential oil into the heat-cured acrylic resin, After deducting the required quantity of oil from the volume of monomer using a micropipette, the remaining monomer was added to a dry, clean glass beaker, and the mixture was blended using a mini electric hand mixer for approximately twenty seconds. This was done to combine the oil with the monomer thoroughly. This mixture was then added to the acrylic powder and mixed; then, it was put in the dental flask to prepare for packing.

Packing

When the polymer was like dough and kneaded by hand and put into a mold that had already been made, it was covered with a polyethylene sheet. After that, the top part was placed and covered with its lid. The hydraulic press then kept putting 100 kg/cm2 of pressure on it [11]. Then, clamping was done so that curing could happen.

Curing of acrylic resin

For curing acrylic specimens, the short curing cycle was used. Following the instructions from the manufacturer, the flask was put in cold water, and the temperature was raised to 70°C for 30 minutes. The temperature was kept for the next 30 minutes, and after that, the temperature was increased to 100°C within 30 minutes; then, the temperature was held for a further 30 minutes, so the total polymerization time is 2 hrs.

Finishing and polishing

All acrylic specimens used for mechanical and physical properties were finished and polished. Then, immersion of specimens in water can be used to reduce the amounts and duration of release of residual compounds and improve the mechanical properties of the PMMA [(12)]. Before the test, the acrylic samples were kept in distilled water at 37°C for 48 hours to reach a standard state [(6)].

Transverse strength test

After putting the samples in distilled water for 48 hours, the transverse strength test showed that both experimental groups were 2.5 vol. % LGEO and 5 vol. % LGEO had higher mean values than thecontrol group, 0 vol. % LGEO had a mean value of (74.457N/mm^2), and the experimental group with 5 vol. % LGEO showed the highest mean value of (81.930 N/mm^2) as shown in Figure (1).

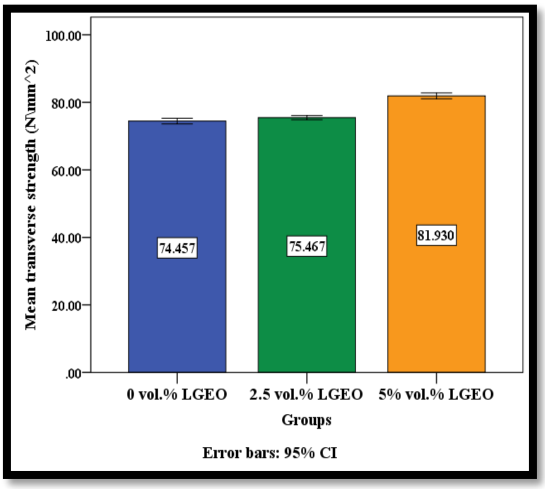

Figure 1. Bar chart for mean values of transverse strength test results among the studied groups.

One-way ANOVA showed that there was a significant difference between all of the groups that were tested for transverse strength at $p>0.05$ in Table 1.

	Sum of Squares	Df	Mean Square	F	Effect size	*P* value
Between Groups	328.829	2	164.415	137.636	0.911	0.000*
Within Groups	32.253	27	1.195			
Total	361.082	29				

Levene test=0.503**, *= significant at $p<0.05$, **= not significant at $p>0.05$.

Table 1. Statistical test of transverse strength (N/mm^2) using one–way analysis of variance ANOVA among groups.

Tukey's multiple comparisons test was used to compare mean values between two groups. The -ve control group, 0 vol. % LGEO, showed a non-significant difference compared to the experimental group, 2.5 vol. % LGEO at $p>0.05$, with a significant difference from the experimental group of 5% LGEO at $p<0.05$. As well as there was a significant difference between the two experimental groups at $p<0.05$ in Table 2.

Groups		Mean Difference (I-J)	*p*-value
0 vol. % LGEO (-ve Control)	2.5 vol.% LGEO	-1.01020	0.11590 **
	5 vol. % LGEO	-7.47353	0.000*
2.5 %	5 vol. % LGEO	-6.46333	0.000*

* =significant at $p<0.05$, **=not significant at $p>0.05$.

Table 2. Multiple comparisons of transverse strength between groups using Tukey's HSD test.

Results

Impact strength test

The results of the impact strength test after 48 hrs of the specimens' incubation in distilled water showed that the control group 0 vol. % LGEO had the lowest mean value (10.161 Kj/m2). In contrast, the highest mean value was (12.446 Kj/m2) for 5 vol.% addition of the LGEO group Figure 2.

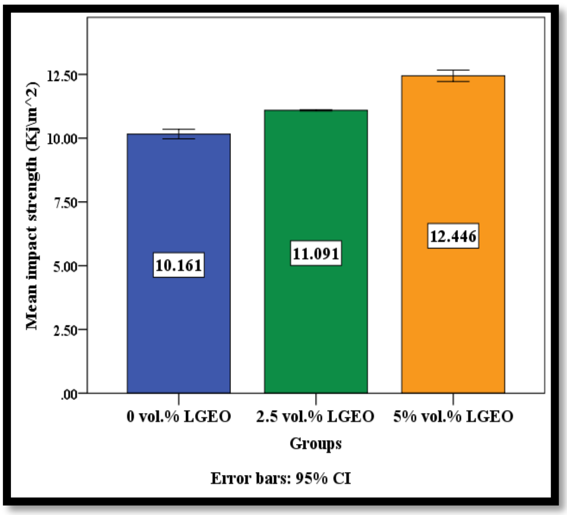

Figure 2. Bar chart of mean values of impact strength test among studied groups.

One-way ANOVA for impact strength test results showed a significant difference between all groups tested at p<0.05 in Table 3.

	Sum of Squares	Df	Mean Square	F	Effect size	*P* value
Between Groups	26.407	2	13.204	236.903	0.946	0.000*
Within Groups	1.505	27	0.056			
Total	27.912	29				

Levene p value=0.006*, *=significant at p<0.05

Table 3. Statistical impact strength (Kj/m2) test among groups using one-way variance analysis (ANOVA).

Dunnett T3 was conducted to compare the mean values between every two groups; there was a significant difference between the -ve control group 0 vol. % LGEO and 2.5 vol. % LGEO group and a significant difference between the -ve control group 0 vol. % LGEO and 5 vol.% LGEO group at p<0.05. As well as there was a significant difference between the two experimental groups at p<0.05 in Table 4.

Groups		Mean Difference (I-J)	*p*-value
0 vol. % LGEO (-ve Control)	2.5 vol. % LGEO	-0.93000	0.000*
	5 vol. % LGEO	-2.28500	0.000*
2.5 vol. % LGEO	5 vol. % LGEO	-1.35500	0.000*

*=significant at p<0.05.

Table 4. Multiple comparisons of impact strength between groups using Dunnett's T3 posthoc test.

Surface Roughness

After 48 hrs of incubation of the specimens in distilled water, the surface roughness test showed that both experimental groups (2.5 vol. % LGEO and 5% LGEO) had a lower mean value than the control group, the 0 vol. % LGEO control group had a mean value of (1.808µm) and the experimental group with 5 vol. % LGEO showed the lowest mean value of (1.089µm) as shown in Figure 3.

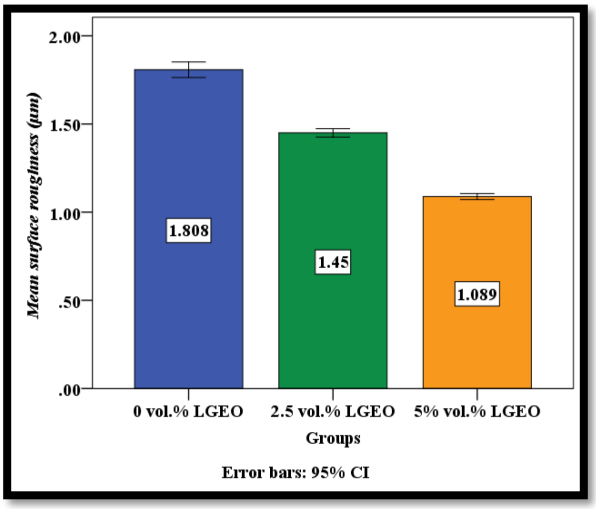

Figure 3: Bar chart of surface roughness test among studied groups.

One-way ANOVA test for surface roughness showed that the difference between groups was significant at p<0.05 Table (5).

	Sum of Squares	Df	Mean Square	F	Effect size	*P* value
Between Groups	2.583	2	1.292	711.245	0.981	0.000*
Within Groups	0.049	27	0.002			
Total	2.632	29				

Levene p value=0.000*, *=significant at $p<0.05$.

Table 5. Statistical surface roughness (µm) test using one-way analysis of variation (ANOVA) among groups.

Dunnett T3 was conducted to compare the means between the two groups. There was a significant difference between the control group 0 vol.% LGEO and 2.5 vol. % LGEO group and a significant difference between the control group 0 vol.% LGEO and 5% LGEO group, as well as a significant difference between 2.5 vol.% LGEO and 5 vol.% LGEO groups at p<0.05 Table (6).

Groups		Mean Difference (I-J)	p-value
0 vol. % LGEO (-ve Control)	2.5 vol.% LGEO	0.35780	0.000*
	5 vol.% LGEO	0.71880	0.000*
2.5 vol.% LGEO	5 vol. % LGEO	0.36100	0.000*

*=significant at $p<0.05$.

Table 6. Multiple comparisons of surface roughness between groups using Dunnett's T3 test.

Shore D hardness test

Results of the Shore D hardness test after 48 hrs of incubation of the specimens in distilled water showed that both experimental 2.5 vol. % LGEO and 5 vol. % LGEO had a lower mean value than the control group 0 vol. % LGEO, which has the mean value of (86.200 IU) and the experimental group with 5 vol. % LGEO showed the lowest mean value (83.010 IU) as shown in (4).

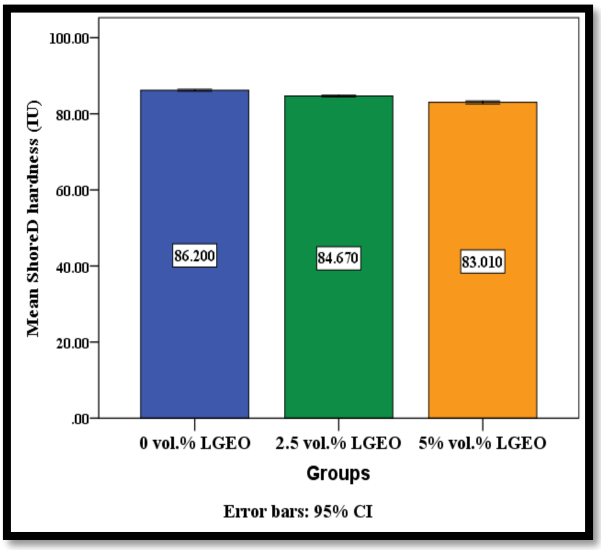

Figure 4. Bar chart of surface roughness test among studied groups.

One-way ANOVA test for Shore D hardness test results showed a significant difference among all the tested groups at *p*<0.05, Table (7).

	Sum of Squares	Df	Mean Square	F	Effect size	*P* value
Between Groups	50.909	2	25.454	145.917	0.957	0.000 *
Within Groups	4.710	27	.174			
Total	55.619	29				

Levene *p* value=0.103**, *= significant at *p*<0.05, **= not significant at *p*>0.05.
Table 7. Statistical test of Shore D hardness (IU) using one-way variation analysis (ANOVA) among groups.

Tukey's multiple comparisons test was used to compare mean values between each of two different groups. The control group, 0 vol. % LGEO, showed a significant difference compared to both experimental groups, 2.5 vol. % LGEO and 5% LGEO, and there was a significant difference between the two experimental groups at *p* <0.05 Table (8).

Groups		Mean Difference (I-J)	*p*-value
Control	2.5 vol.% LGEO	1.53000	0.000*
	5 vol.% LGEO	3.19000	0.000*
2.5 vol. % LGEO	5 vol.% LGEO	1.66000	0.000*

*=significant at *p*<0.05.
Table 8. Multiple comparisons of Shore D hardness between groups using Tukey's HSD.

Discussion

PMMA resin is the most common material because it is cheap and easy to work with. However, the weak mechanical properties that cause it to wear out or break are a big problem. PMMA could work better if essential oils were added to the acrylic matrix [13, 14]. This study added LGEO at concentrations of 2.5 vol. % and 5 vol. % to PMMA to improve its physical and mechanical properties (transverse strength, impact strength, surface roughness, and surface hardness).

Transverse strength is a mechanical property that is commonly measured in studies because its loading characteristics represent the clinical situation that the denture base faces intraorally [15]; so, you want the denture base acrylic to have high transverse strength because it lets the denture work better in the clinic [16]. In this study, the addition of 2.5 vol. % LGEO and 5 vol. % LGEO caused an increase in transverse strength values compared to the control (0 vol. % LGEO) group and this increase was statistically non-significant for the 2.5 vol. % LGEO experimental group, this is maybe because the concentration of the LGEO was very little, this result was in agreement with explanation by Fernanda *et al.* in 2009 [17], who said that adding elastomer in smaller amounts did not make PMMA stronger in the cross-section. While for the 5 vol. % LGEO experimental group, the increase was statistically significant, this result could be related to the water sorption phenomenon of PMMA denture base material[18] Also, this result could be attributed to LGEO, which may act as elastomeric to PMMA, or it could be attributed to maximum saturation of the matrix between PMMA and LGEO that occurred at this concentration and this in agreement with the study of Shukur, in 2018 [19], who showed that addition of tea tree oil in three different concentrations (10 vol. %, 15 vol. %, and 20 vol. %) to heat cure acrylic resin increase its transverse strength.
The result of the present study agrees with Mawlood [20], who conducted a study in 2019 that showed that adding bergamot oil in a concentration of (5 vol. % and 6 vol. %) to acrylic resin increases their transverse strength. These results disagree with the study of5Al-Nema in 2014, which showed that the addition of eucalyptus, mermaid and ginger oils in two concentrations (1.5 vol. % and 2.5 vol. %) to acrylic resin decreased its transverse strength, and this may be related to the difference in the type of the oil and its chemical composition or difference in concentrations of oils that added to the material.
Impact strength : The Charpy impact testing machine was used in this study, which is regarded as one of the most commonly used methods to evaluate a material's relative toughness in a fast and economical way [21]. Impact strength is an essential property of acrylic denture bases as it predicts the resistance of the denture to fracture if it is placed under high, short-term stress, such as during dropping [22]. In this study, adding 2.5 vol. % LGEO and 5 vol. % of LGEO revealed a statistically significant increase in impact strength values compared to (the control 0 vol. % LGEO) group. These results could be caused by the amount of oil added to the PMMA acrylic resin, which acts as an elastomer and a plastifying agent. When added to the resin matrix, the oil lowers the glass transition temperature and the module of elasticity, making the material less stiff at room temperature [23]. The low module of elasticity can also explain this, in turn, producing a larger resilience module, which results in a material with higher energy-absorbing capacity and higher deflexion force released on the material, Which means that adding elastomer makes the material better at absorbing energy and makes it less likely that the resin will break. This makes the prosthetic device less likely to break mechanically [17]. This result disagrees with the study of 20Mawlood in 2019, adding 5 vol. % and 6 vol. % Bergamot oil into the heat cure acrylic denture base material and revealed no adverse effect on the material's impact strength. The result of the present study disagree with the previous two studies and can be attributed to the use of different type of oil and the use of different concentrations.
Surface roughness: Increased surface roughness is bad for the look and cleanliness of dentures because it makes it easier for bacterial plaque and stains to form on the dentures. Also, making surfaces rougher encourages C. albicans to stick, which is bad for oral health [24]. In the present study, adding 2.5 vol. % LGEO and 5 vol. % LGEO caused a significant reduction in surface roughness values compared with the control group (0 vol. % LGEO), which was statistically significant for both experimental groups. This decrease may be attributed to the acceleration of

polymerization, which promotes further arrangement and supplement of polymer chains, resulting in fine, smooth surface or physical bonds of oil molecules and resin particles. The increased bonding of polymer chains leads to a decrease in the particles chipping away from the surface during deflating and grinding; this may contribute to reducing the roughness. The present study's result agrees with the study of [25]. They incorporated 60 vol. % origanum oil into the tissue conditioner and showed that the surface roughness was more minor with this incorporation. The present study's result agrees with the study of Mawlood in 2019 [20], who added 5vol. % and 6vol. % Bergamot oil into the heat-cured acrylic denture base material revealed a decreased effect on the surface roughness of the material. It is important to remember that it is hard to compare roughness values from different studies because the way the experiments were done, how the surface roughness was measured, and the type of PMMA used were all different.

Surface hardness: This is a crucial property related to the material wear that can happen when you brush your dentures daily, making them rough and making it easier for bacteria to stick to them [26]. The results of the present study revealed a significant reduction in the PMMA material's hardness, which can be explained as the concentration of LGEO increases and the hardness of acrylic resin decreases. The effect might happen because oil coats polymer particles and slows monomer conversion. This means there is much leftover monomer in the polymerized material, which has a "plasticizing" effect on the material's mechanical properties [27,28.29.30]. Also, another possible reason for the decrease in the hardness is that the flexibility of specimens increases as the concentration of LGEO addition increases, which leads to a reduction in the hardness. These results disagree with the study of [5], who stated that the addition of 1.5 vol. % mermaid and ginger oils would increase hardness; also agreed with [19], who added 20 vol. % tea tree oil to acrylic resin decreased its hardness; the possible reason for the decrease in the hardness is the flexibility of specimens increased significantly at a concentration of 20 vol. % which leads to a decrease in the hardness. It is worth mentioning that the difference in the result in the experimental studies may be due to the type of EO used in the study, the difference in oil concentrations applied, procedures of measuring the hardness test or discrepancies in the type of PMMA material used, all these make it challenging to compare hardness values with other studies [31],32.

Conclusions

The addition of 5 vol. % LGEO has the best effect on the acrylic's improved mechanical and physical properties (transverse strength, impact strength, and surface roughness) except for the surface hardness, which is less affected with the addition of 2.5 vol. % LGEO at $p < 0.05$. Conclusion: By adding LGEO to heat-curing acrylic material, it is possible to make a material with better mechanical and physical properties

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