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Effect of Plant Fixed Oil Extracts Incorporation to Heat Cured Denture Soft Lining Material on its Mechanical Properties

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ABSTRACT

Introduction: Denture liners have been used in dentistry for many years. They are used to enhance the fit of poor fitting dentures and prevent trauma to sensitive mucosa. Patients with complete dentures are satisfied with the masticatory ability provided by the soft lining materials. Requests for improvements to certain features of denture base materials have also been grown.

Aims: The aims of this study were to evaluate the effects of incorporation of either single oil (Sesame, Thyme) or mixture of two oils (Sesame and Thyme) addition on some denture soft lining material (Vertex) mechanical properties (Tensile strength, elongation, Shore A hardness, modulus of elasticity); cured according two different curing cycles (short and long) after two periods of immersion 2 and 30 days.

Materials and Methods: A total samples of (200) were prepared from acrylic based heat cured denture soft lining material (Vertex), which divided into two main groups (short curing cycle and long curing cycle according to ADA) respectively, each main group was subdivided into four groups according to oil addition [Sesame, Thyme, mixed (Sesame and Thyme), and control group].
Tensile strength and elongation percentage tests were done on main group one (short cycle), while Shore A, modulus of elasticity tests were done on each of two main groups (short and long cycle). The tests were done after two periods of immersion in distilled water (two and thirty days).

Results: The results of this study showed that plant oil extract of (Sesame and Thyme) at 5% per volume addition into monomer resulted in significant viscoelastic properties enhancement at $p \le 0.05$ (Tensile strength, elongation, Shore A and modulus of elasticity).

Conclusions: It is concluded that plant fixed oil extracts addition further enhanced viscoelastic properties of denture soft lining materials. Different curing cycle methods (short and long) had no effect on properties of denture soft lining material.

Introduction:

Denture liners used in prosthodontics to provide a cushioning layer on the fitting surface of a complete denture. The material absorbs some of the masticatory energy and reduces the energy transmitted to the underlying tissues (1, 2).

Soft-liners that are polymerized in the dental laboratory under controlled conditions similar to conventional laboratory-processed dentures exhibit greater physical and mechanical properties (3). The acrylic-based soft lining materials strongly adhere to the acrylic resin denture base, but the plasticizer can be leached out by the saliva, resulting in the gradual hardening of the materials (4).

The distribution of large plasticizer molecules minimizes entanglement of polymer chains, thereby permitting individual chains to "slip" past one another. This slipping motion permits rapid changes in the shape of the soft liner and provides a cushioning effect for the underlying tissues (6).

Hardening of the material occurs if the liner's plasticizing agent is not covalently bound to the polymerized matrix, it can leach into saliva, resulting in a hardening of the liner over time (3). Acrylic soft resins absorb water, swell and eventually deteriorate (6). Phthalates have solubility in human saliva 20 times higher than in water (7). It considered as one of the major reasons for failure of some soft liners (8). It can results in the delivery of greater occlusal forces to the underlying mucosa and increased clinical complaints (9).

Tensile strength provides information on the ultimate strength of a soft denture liner when subjected to tension, whereas elongation provides data on the ability of a material to deform prior to failure and thereby gives an indication of the flexibility of the material (10).

Acrylic based soft lining material was the most resilient to deformation after thermocycling in the laboratory, followed by silicon based materials (11).

Acrylic resin lining materials demonstrated the greatest changes in viscoelasticity over time. Silicone and polyolephin materials demonstrated smaller changes with time (12).
Tensile properties are regarded as a general guide to the quality of rubbers (13). Tensile strength of silicon based soft lining materials increased after thermocycling (14). Acrylic resin liner is softer than the silicone liner, but is less resilient and can be affected by aging (15).

Shore-A hardness test of permanent soft liners is used to evaluate viscoelastic properties of the materials as it should distribute and absorb the functional forces during mastication by means of viscoelastic behavior (16). The Shore hardness test employs a condensed cylinder. The ASTM specification for Shore hardness specifies a test specimen "shall be at least 6mm thick the lateral dimensions of the specimen shall be sufficient to permit measurements at least 12mm from any edge" (17).

However, some researchers have carried out measurements on much thinner samples, presumably to mimic clinical use, such as soft lining materials for dentures. One example is a study by Canay on three soft lining materials using 2mm thick specimens (6). A comprehensive experimental study made by Morgan of the effect of sample thickness on the measured Shore hardness, and other types of hardness. Shore hardness increased with decreasing thickness, the dependence increasing with decreasing hardness (18).

Hardness of plasticized acrylic resin soft lining materials over time, when curing procedures were modified. Polyzois concluded that processing method and time after processing have an effect on surface hardness of the tested materials (1).

The effects of aging by thermal cycling and mechanical brushing on resilient denture liners was investigated by Hermann, found that thermal cycling promoted increased hardness for plasticized acrylic lining materials (19).

There is a reasonably well-defined relationship between Shore A hardness and Young's modulus in the hardness (20).

Aims of the Study:

The aims of this study were to evaluate the effects of incorporation of either single oil (Sesame, Thyme) or mixture of two oils (Sesame and Thyme) addition on some denture soft lining material (Vertex) mechanical properties (Tensile strength, elongation, Shore A hardness, modulus of elasticity); cured according two different curing cycles (short and long) after two periods of immersion 2 and 30 days.

Materials and Methods:

Sesame seeds oil and Thyme oils have been extracted according to American Oil Chemists' Society. This method determined the oil content of oil seeds by solvent extraction. Soxhlet extractor as shown in Figure (1) was used for extraction. Petroleum Ether 70-80°C used as a solvent to dissolve raw material of plants (21).

For Sesame oil extraction 200 g of Indian Sesame seeds was grinded by electric coffee grinder at speed of 800-1000 rpm for one minute to produce final grinded particle size of 250 µm. Then about 100 g of grinded seeds enclosed with filter paper inside the distillation chamber for extraction, the round flask filled with 500 ml of solvent (Petroleum ether). The Soxhlet extractor heated by mantis at 45°C for about 6 hours and the solvent and extracts collected. This procedure was repeated for Thyme oil extraction.

To purify crude Sesame and Thyme oil extracts, the solvent should be evaporated using rotary evaporator to evaporate solvent under reduced pressure. The resultant crude oils extracts then collected.

For sample preparation, hard plastic foils (Imprelon, Scheu Dental) of different thicknesses were used. The sample models were prepared by using a CNC machine to cut precisely the plastic foils according to each sample shape and measurements. Tensile strength tests: A dumbbell's shaped model according to (ASTM D-412) (22), with dimensions of 100 mm length (33 mm of it as testing area), 16 mm width at grasping, and 3 mm width at testing area, with a 3 mm as thickness was used to prepare soft denture lining material samples moulds (23).

Figure 1 Soxhlet device used for extraction.

Shore A hardness test: A model with dimensions of 30 mm length, 15 mm width and 3mm thickness was used to prepare soft denture lining material samples moulds (24, 25). See Figure (2).

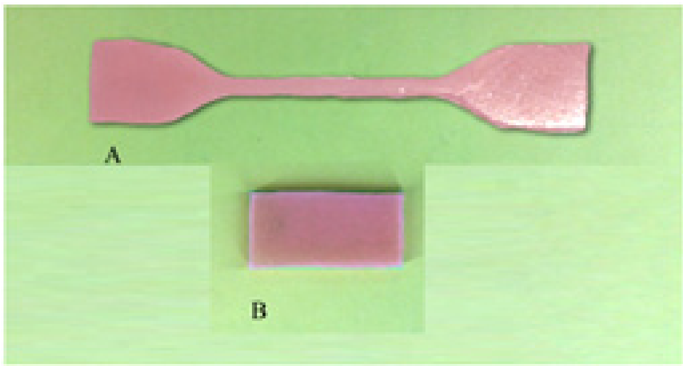

Figure 2 Soft liner samples. A: Tensile strength test. B: Shore A.

The plant oil extracts (Sesame and Thyme) were added into the monomer (26), at concentration of 5% per volume by an adjustable micropipette (DragonLab, China) with a ratio of 125:l for each 2.5ml monomer, while for mixed group a mixture of two oils (Sesame and Thyme 2.5% for each) were added to the monomer. The monomer was mixed with additives by a cement spatula until a homogenous mixture was produced, after that the powder was added as mentioned above.

Tensile strength evaluation has been performed only for all samples of short cycle group, at two time intervals two and thirty days after curing. These tests were performed using a universal testing machine (Tinius Olsen, USA) shown in Figure (3). Tensile strength evaluation was done at rate of 10mm/min according to ISO standard (23). The samples were tested at room temperature 24°C. Five tests were performed for each sub-group.

The universal testing machine was connected to a computer through Qmat (ver. 5.37) software (Tinius Olsen, USA), ultimate tensile strength, elongation, and stress-strain curve were plotted by this program and then collected for analysis.

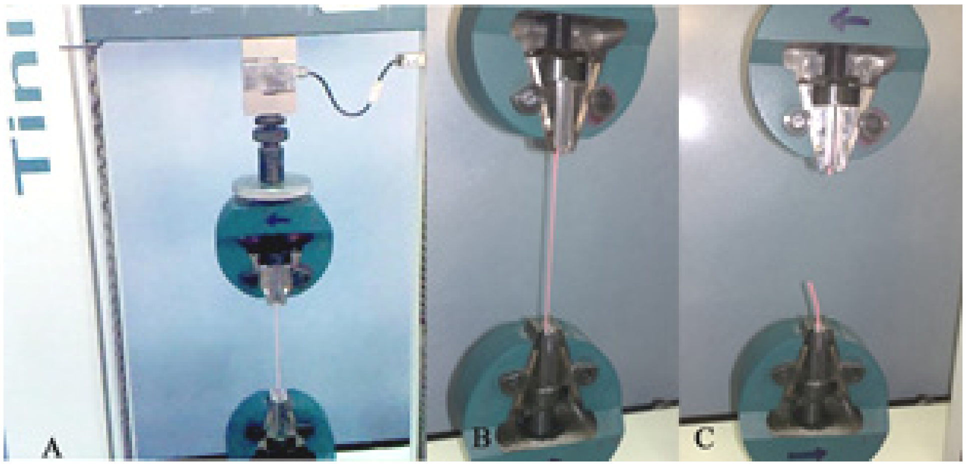

Figure 3 A: Universal testing Machine for tensile strength.

Both short and long cycle group samples were assessed for its surface hardness using Shore A scale, at two periods, two days and thirty days after curing. A Shore A hardness tester, (Zwick, Germany) shown in Figure (4) was used in this study. The test was performed according ISO standard (23) on the mentioned samples dimension. To reduce the error, the tests were repeated on three regions (top, middle, and bottom) of each sample, and then the average value was calculated. Five samples were tested for every subgroup. The samples were tested at room temperature 24°C.

Figure 4 Zwick, Shore A, hardness tester.

The relationship between Shore A hardness and Young's modulus was investigated in detail by Gent who derived the following semi-empirical equation which was used in the study (20):

$$E(MPa) = \frac{0.0981(56+7.66s)}{0.137505(254-2.54s)} \quad \ldots\ldots \text{(27)}.$$

Where s = the Shore hardness, hardness scale should of 0–100

Results and Discussion:

Tensile strength and Elongation:

Tensile strength means (MPa) and standard deviation for the tested groups at two and thirty days are shown in Figure (5).

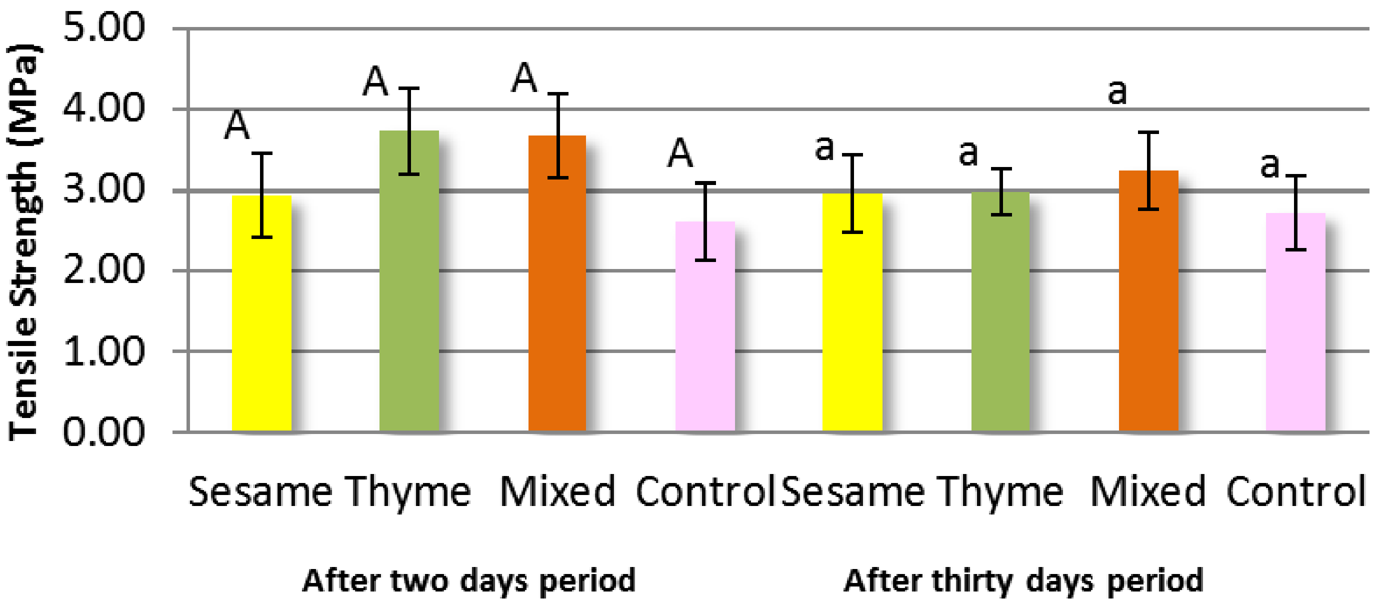

Figure 5 Means, standard deviation, and Duncan's multiple range test of tensile strength (MPa) for short cycle group at each two and thirty days periods. Different letters means significant differences.

One way ANOVA multiple comparisons to compare tensile strength means of short cycle sub-groups at two days and thirty days periods are shown in Table (1). The statistical analyses showed no significant difference between groups at two mentioned periods.

Duncan's multiple range tests for short cycle sub-groups at two days period and for thirty days periods are shown in Figure (5) along the two mentioned periods the tests indicated that there were no significant differences between tensile strength means of all tested groups. Tensile strength mean for mixed sub-group (Sesame + Thyme) was higher than other tested sub-groups and control.

Table 1 One way ANOVA, test for tensile strength for short cycle group at two days and thirty days.

Short cycle at two days					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.569	3	1.523	2.326	0.114
Within Groups	10.478	16	0.655		
Total	15.047	19			
Short cycle at thirty days					
Between Groups	0.664	3	0.221	0.799	0.512
Within Groups	4.436	16	0.277		
Total	5.100	19			

df: degree of freedom, *Sig.: significance at $p \leq 0.05$

Paired samples T-test was performed on short cycle group comparing means of tensile strength at periods of two days and thirty days is shown in Table (2), there was no significant difference between tensile strength means at two mentioned periods.

Table 2 Paired sample T-test for tensile strength for short cycle group at two days versus thirty days.

	Paired Differences		t	df	Sig. (2-tailed)
Tensile strength	Mean	Std. Deviation			
	0.2631	0.882	1.334	19	0.198

df: degree of freedom, *Sig.: significance at $p \leq 0.05$

Elongation percentage means (%) and standard deviation for the tested groups at two and thirty days are shown in Figure (6).

One way ANOVA multiple comparisons test to compare elongation percentage means between short cycle groups at two days and at thirty days periods are shown in Table (3). The tests showed no significant differences between groups that have been tested for elongation.

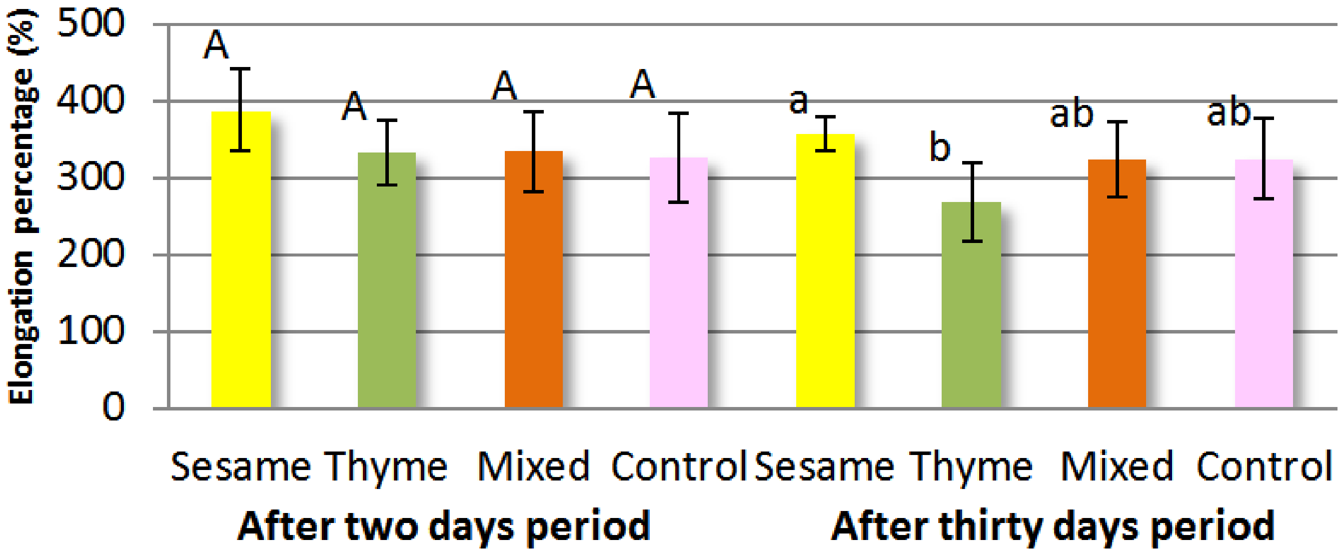

Figure 5 Means, standard deviation, and Duncan's multiple range test of elongation (%) for short cycle group at each two and thirty days periods. Different letters means significant differences.

Duncan's multiple range tests for short cycle groups to compare elongation percentage means at two and thirty days periods are shown in Figure (5). The highest elongation percentage mean was for Sesame group among other groups also there was a significant difference between groups at thirty days period.

Table 3 One way ANOVA, elongation percentage for short cycle group at two and thirty day's periods.

Short cycle at two days					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	11976.546	3	3992.182	0.996	0.420
Within Groups	64145.632	16	4009.102		
Total	76122.178	19			
Short cycle at thirty days					
Between Groups	20671.154	3	6890.385	2.643	0.085
Within Groups	41711.044	16	2606.940		
Total	62382.198	19			

df: degree of freedom, *Sig.: significance at $p \leq 0.05$

Paired samples T-test was performed on short cycle group comparing means of elongation percentage at periods of two days and thirty days is shown in Table (6), there was no significant difference between two periods.

Table 6 Paired sample T-test for elongation for short cycle group at two days versus thirty days.

	Paired Differences		t	df	Sig. (2-tailed)
Elongation	Mean	Std. Deviation			
	26.9	85.672934	1.404	19	0.176

df: degree of freedom, *Sig.: significance at $p \leq 0.05$

Thyme oil group showed the best tensile strength enhancement with mean of (3.72 MPa), while for mixed group was (3.67 MPa), and for Sesame (2.9 MPa) as compared with control group of (2.61 MPa).

Sesame oil group showed an increased elongation percentage, followed by Thyme oil then mixed group; all of these groups have an elongation higher than control group at two days period.

There was a significant difference between Sesame and Thyme oils groups after thirty days of immersion indicated that Thyme oil may be leached out more rapidly than Sesame oil, but both groups (Sesame and Thyme) did not differ significantly from control group at thirty days period.

Tensile strength and elongation enhancements was due to oil addition to the monomer of denture soft lining materials at (5%) as all the tested groups showed increased tensile strength mean, but not to a significant level.

Organic oily additive entered between polymer lattice leading to change in its physical configuration from irregular form into more regular and straight form this will lead to sliding of polymer chains onto each other producing a more flexible materials (28). Small plasticizer molecules when added to a stiff uncross-linked polymer, reduce its rigidity. As small molecules surround large ones, the large molecules are able to move more easily. A plasticizer therefore lowers the glass-transition temperature (Tg) of the polymer, so a material that is normally rigid at a particular temperature may become more flexible. The glass-transition temperature has a strong effect on polymer strength properties (29).

In contrast, tensile strength and elongation means have been decreased for all groups of after a period of thirty days of immersion this was probably due to the leaching out of the low molecular weight plasticizer (like soft liner own plasticizer and oil additives) and absorption of water, which resulted in the deterioration in the viscoelasticity of the tested samples (12, 15).

Shore A hardness:

Shore A means and standard deviation for short cycle groups at two days and at thirty days periods were shown in Figure (6).

One way ANOVA multiple comparison test to compare Shore A means for short cycle groups at two days and thirty days periods are shown in Table (7). There were significant differences between groups.

Duncan's multiple range tests of Shore A means for short cycle groups at two days and at thirty days are shown in Figure (6) it showed a significant decrease in Shore A mean for Thyme oil group then Sesame oil group followed by mixed group (Sesame + Thyme) at two mentioned periods. There were significant differences between all the tested groups.

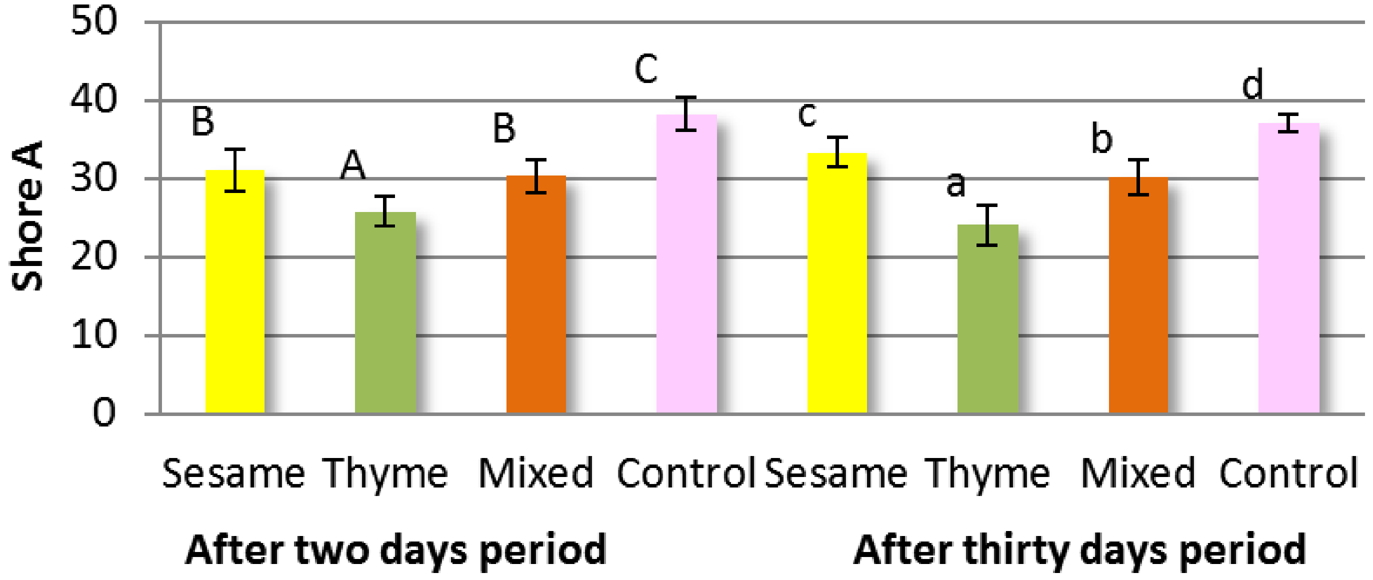

Figure 6 Means, standard deviation, and Duncan's multiple range test of Shore A for short cycle group at each two and thirty days periods.
*Different letters means significant differences (upper case for two days, lower case for thirty days).

Table 7 One way ANOVA, test for Shore A means for short cycle group at two and thirty days periods.

Short cycle at two days					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	394.889	3	131.630	27.711	0.000*
Within Groups	76	16	4.750		
Total	470.889	19			
Short cycle at two days					
Between Groups	454.906	3	151.635	37.211	0.000*
Within Groups	65.2	16	4.075		
Total	520.106	19			

df: degree of freedom, *Sig.: significance at $p \leq 0.05$

Paired samples T-test was performed on short cycle group comparing means of Shore A at periods of two days and thirty days is shown in Table (8), there was no significant difference between two periods.

Table 8 Paired sample T-test for Shore A for short cycle group at two days versus thirty days.

	Paired Differences		t	df	Sig. (2-tailed)
Shore A	Mean	Std. Deviation			
	0.1833	2.585327	0.317	19	0.755

df: degree of freedom, *Sig.: significance at $p \leq 0.05$

Shore A means and standard deviation for long cycle groups at two days and at thirty days are shown in Figure (7).

One way ANOVA multiple comparison test to compare Shore A means for long cycle groups at two days and thirty days periods are shown in Table (9). There were significant differences between groups.

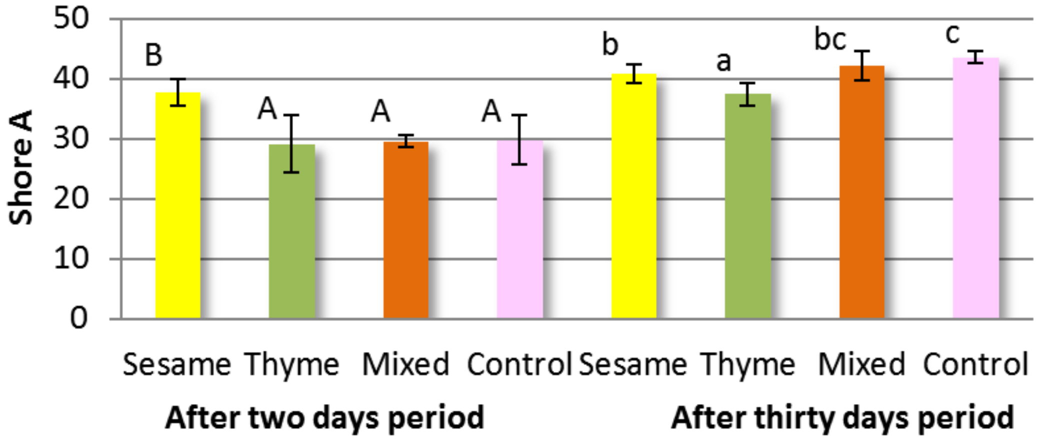

Figure 7 Means, standard deviation, and Duncan's multiple range test of Shore A for long cycle group at each two and thirty days periods. Different letters means significant differences.

Table 9 One way ANOVA, test for Shore A for long cycle group at two and thirty day's periods.

Long cycle at two days					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	257.200	3	85.733	7.574	0.002*
Within Groups	181.111	16	11.319		
Total	438.311	19			
Long cycle at thirty days					
Between Groups	104.283	3	34.761	10.463	0.000*
Within Groups	53.156	16	3.322		
Total	157.439	19			

df: degree of freedom, *Sig.: significance at $p \leq 0.05$

Duncan's multiple range tests of Shore A means for long cycle groups at two days and at thirty days are shown in Figure (7) it showed a significant decrease in Shore A mean for Thyme oil group compared with other groups at two mentioned periods.

There were significant differences between all the tested groups.

Paired samples T-test was performed on long cycle group comparing means of Shore A at periods of two days and thirty days is shown in Table (10), there was a significant difference between two periods.

Table 10 Paired sample T-test for Shore A for long cycle group at two days versus thirty days.

	Paired Differences		t	df	Sig. (2-tailed)
Shore A	Mean	Std. Deviation			
	-9.45	5.662305	-7.464	19	0.000*

df: degree of freedom, *Sig.: significance at $p \leq 0.05$

Independent sample T-test was done between Shore A mean values for two groups (short cycle versus long cycle) for all sub-groups, to find the differences between short and long curing methods for two and thirty days periods the results are shown in Table (11). It showed that there was no significant difference between groups at two days period while it showed a significant difference at thirty days period.

Table 11 Independent sample T-test comparing means of Shore A for short cycle versus long cycle groups at two and thirty day's periods.

Short cycle vs long cycle at two days						
	Levene's Test		t-test for Equality of Means			
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Equal variances assumed	0.12	0.731	-0.129	38	0.898	-0.2
Equal variances not assumed			-0.129	37.951	0.898	-0.2
Short cycle vs long cycle at thirty days						
Equal variances assumed	8.715	0.005*	-7.364	38	0.000*	-9.833
Equal variances not assumed			-7.364	29.537	0.000*	-9.833

df: degree of freedom, *Sig.: significance at $p \leq 0.05$

Shore A means were decreased significantly for all groups compared with control group, Thyme oil group was the softest group between other groups, high value of Shore A was for control group.

The addition of oil act as plasticizer changing the viscoelastic properties of the materials leading to decreased Shore A mean. Shore A mean was reduced to a level which is accepted by ISO 10139-2 as ISO standard for long term denture soft lining materials requires Shore A value ranging from 25 to 50 (23).

As the distribution of large molecules plasticizer minimized entanglement of polymer chains, thereby permitting individual chains to "slip" past one another. This slipping motion permits rapid changes in the shape of the soft liner and provides a cushioning effect for the underlying tissues (5).

After immersion in distilled water for thirty days Shore A means increased for all groups but not to a significant level, in the other hand all modified denture soft lining materials (with additive Sesame, Thyme and mixed oil groups) still had Shore A means significantly lower than that of control group which accepted by ISO range (25-50). This can be explained by the fact that oil additives have leaser rate of leaching out from denture soft lining materials than the original plasticizer of the same material.

Hardening of the material occurs if the liner's plasticizing agent is not covalently bound to the polymerized matrix; it can leach into saliva, resulting in a hardening of the liner over time (3, 19).

The results agreed with many authors who have suggested an increase in the Shore A means after water immersion. Shore A hardness increased and reached the maximum value after a month (1).

It also agreed with Mutluay who studied the hardness changes in a variety of commercial soft liner products during long-term water storage, a gradual hardening of all other acrylic based soft liner products was found over the immersion period (30).

The effect of curing cycle was studied in Table (11) it showed that the method of curing did not affect significantly Shore A values of the tested samples at two days period. While, there was a significant difference between short and long curing cycle at thirty days in which Shore A mean for short cycle group was significantly lower than that for long cycle, the samples cured according to short cycle were softer than other. This can be due to curing method as soft lining material cured with a high temperatures and pressure would likely exhibit lower levels of leachable components such as plasticizers (1).

The results agreed with Parr and Rueggeberg who discussed the effect of polymerization method on Shore A values they found when specimens were stored in water, a little difference was noted in physical properties based on method of polymerization could be that little difference exists in degree of polymerization, resin solubility (3).

Modulus of Elasticity:

Modulus of elasticity (MPa) means and standard deviation for short cycle groups at two days and at thirty days are shown in Figure (8).

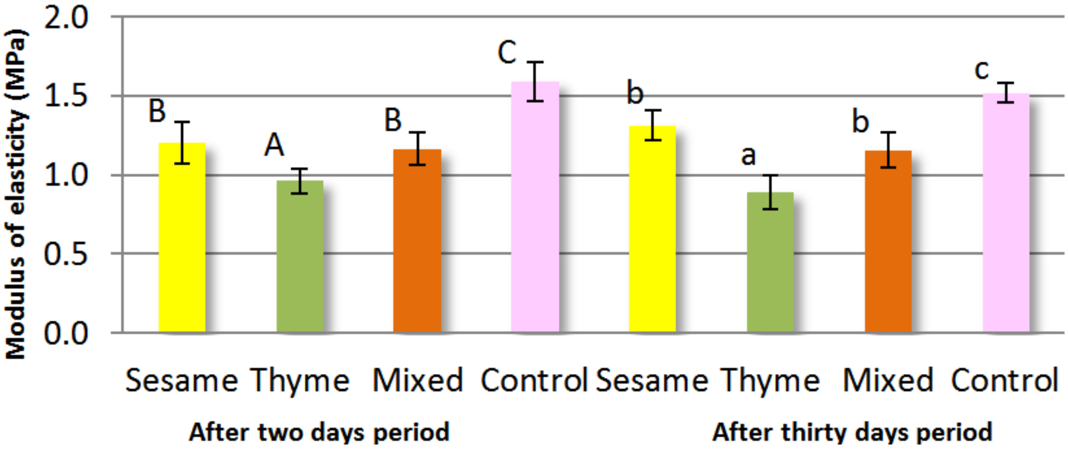

Figure 8 Means, standard deviation, and Duncan's multiple range test of modulus of elasticity for short cycle group at each two and thirty days periods.Different letters means significant differences.

One way ANOVA multiple comparison test to compare modulus of elasticity means for short cycle groups at two days and thirty days periods are shown in Table (12). There were significant differences between groups.

Duncan's multiple range tests of modulus of elasticity means for short cycle groups at two days are shown in Figure (8) it showed a significant decrease in modulus of elasticity mean for Thyme oil group then Sesame oil group followed by mixed group (Sesame + Thyme) at two mentioned periods. There were significant differences between all the tested groups.

Paired samples T-test was performed on short cycle group comparing means of modulus of elasticity at periods of two days and thirty days as shown in Table (13), there was no significant difference between two periods.

Table 12 One way ANOVA, test for Modulus of elasticity for short cycle group at two and thirty days.

Short cycle at two days					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.027	3	0.342	27.935	0.000*
Within Groups	0.196	16	0.012		
Total	1.223	19			
Short cycle at thirty days					
Between Groups	1.047	3	0.349	38.603	0.000*
Within Groups	0.145	16	0.009		
Total	1.192	19			

df: degree of freedom, *Sig.: significance at $p \leq 0.05$

Table 13 Paired sample T-test for modulus of elasticity for short cycle group at two days versus thirty days.

	Paired Differences		t	df	Sig. (2-tailed)
Modulus of elasticity	Mean	Std. Deviation			
	0.0084	0.128421	0.291	19	0.774

df: degree of freedom, *Sig.: significance at $p \leq 0.05$

Modulus of elasticity (MPa) means and standard deviation for long cycle groups at two and at thirty days periods were shown in Figure (9).

One way ANOVA multiple comparison test to compare Modulus of elasticity means for long cycle groups at two days and thirty days periods are shown in Table (14). There were significant differences between tested groups.

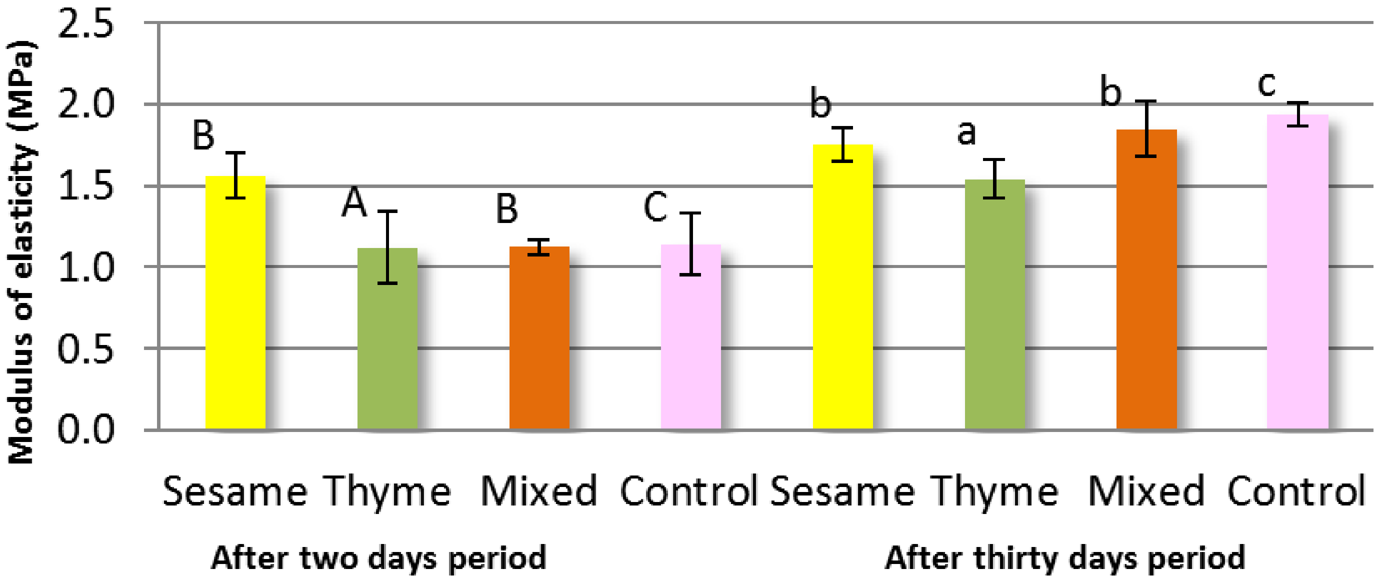

Figure 9 Means, standard deviation, and Duncan's multiple range test of modulus of elasticity for long cycle group at each two and thirty days periods.Different letters means significant differences.

Duncan's multiple range tests of modulus of elasticity means for long cycle groups at two days are shown in Figure (9) it showed a significant decrease in modulus of elasticity of Thyme oil group then control group followed by mixed group (Sesame+Thyme) at two mentioned periods. There was significant difference between the tested groups.

Table 14 One way ANOVA, test for modulus of elasticity for long cycle group at two and thirty days.

Long cycle at two days					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.699	3	0.233	8.887	0.001*
Within Groups	0.420	16	0.026		
Total	1.119	19			
Long cycle at thirty days					
Between Groups	0.440	3	0.147	9.734	0.001*
Within Groups	0.241	16	0.015		
Total	0.681	19			

df: degree of freedom, *Sig.: significance at $p \leq 0.05$

Paired samples T-test was performed on long cycle group comparing means of modulus of elasticity at periods of two and thirty days as shown in Table (15), there was a significant difference between two periods.

Table 15 Paired sample T-test for modulus of elasticity for long cycle group at two versus thirty days.

	Paired Differences		t	df	Sig. (2-tailed)
Modulus of elasticity	Mean	Std. Deviation			
	-0.5326	0.312073	-7.633	19	0.000*

df: degree of freedom, *Sig.: significance at $p \leq 0.05$

Independent sample T-test was done between modulus of elasticity mean values for two groups (short cycle versus long cycle) for all sub-groups, to find the differences between short and long curing cycle methods. For two and thirty days periods the results are shown in Table (16) it showed that there was no significant difference between groups at two days period, but there was a significant difference at thirty days period.

Table 16 Independent sample T-test for modulus of elasticity comparing short cycle versus long cycle groups at two and thirty day's periods.

Short cycle vs long cycle at two days						
	Levene's Test		t-test for Equality of Means			
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Equal variances assumed	0.108	0.745	-0.108	38	0.914	-0.008504
Equal variances not assumed			-0.108	37.925	0.914	-0.008504
Short cycle vs long cycle at thirty days						
Equal variances assumed	2.774	0.104	-7.827	38	0.000*	-0.549466
Equal variances not assumed			-7.827	35.371	0.000*	-0.549466

df: degree of freedom, *Sig.: significance at $p \leq 0.05$

Modulus of elasticity showed a significantly decrease in modulus for all groups compared with control group, Thyme oil group was the least significant modulus among other groups which were a significantly decreased modulus as compared with control group.

Low modulus of elasticity indicates softer materials compared with high modulus, as the area under the curve increased by decreasing the value of modulus of elasticity which represents the Tan value of the angle formed by stress-strain curve, for less Tan value. This means larger area under the curve for elastic region. So that, permanent deformation for the materials with low modulus will not occur rapidly as compared with materials of high modulus, this will enhance the cushioning action of the material which is one of the requirements of the ideal denture soft lining materials (31-33, 15).

This difference was corresponds Shore A values, since there was a reasonably well-defined relationship between Shore A hardness and Young's modulus in the hardness as they are proportionate directly (20).

These results agreed with Deb and Murata who found that acrylic resin materials showed a greater increase in the elasticity with time. This is probably due to the leaching out of the low molecular weight plasticizer and absorption of water, which resulted in the deterioration in the viscoelasticity (12, 32).

The results also agreed with Murata who proposed the desired Young's moduli of denture soft lining materials to be at the same range of the oral mucosa moduli from approximately (0.4-4.4 MPa), since all the tested groups moduli were ranged at the same values (16).

It also agreed with Lacoste-Ferre who measured denture soft lining material (Vertex) modulus of elasticity and found it within the range of modulus of elasticity measured for the oral mucosa at 37°C (34).

Conclusions and Suggestions

Conclusions:

From this study the following conclusions could be drawn:

1. Plant fixed oil addition at (5% per volume) resulted in viscoelastic properties enhancement (Tensile strength, elongation, Shore A and modulus of elasticity); Thyme oil addition resulted in best enhancement for denture soft lining material (Vertex).

2. Different curing cycle methods (short and long) had no effect on of denture soft lining material properties.
3. As a recommendation denture soft lining material (Vetex) with Thyme oil addition cured by using long curing cycle could be recommended.

Suggestions:

Further studies are needed on modified denture soft lining material to discuss: Porosity, water sorption, surface roughness for denture soft lining material after addition at two curing cycles.

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