Journal of Research in Medical and Dental Science
2020, Volume 8, Issue 1, Page No: 96-106

Available Online at: www.jrmds.in
eISSN No. 2347-2367: pISSN No. 2347-2545

The Effect of Virgin Coconut Oil Addition on the Hardness and Wettability of Acrylic Based Denture Soft Lining Material

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ABSTRACT

Maintaining an ideal hardness value during the long term use of soft liner is very difficult, because soft liner material will lose some of its components and gain others, this will adversely affect its properties. The aim of the current study was to evaluate the effect of virgin coconut oil addition on the hardness of heat-cured acrylic based soft denture liner material. In addition, to investigate the wettability of the material after this incorporation. Both investigations were conducted at different periods of time.

Material and method: one hundred eighty samples were prepared by the addition of 1.5% and 2.5% (by volume) of virgin coconut oil into acrylic-based heat cured soft denture lining material. The study samples were divided into two groups (90 samples for each group) according to the conducted test; hardness and wettability tests. Then each group was further subdivided into three subgroups (control 0%, 1.5% and 2.5%) according to the concentration of the incorporated coconut oil (n=10 samples for each subgroup). Each group was assessed at different time intervals (1 day in distilled water, 14 and 30 days in artificial saliva), ten samples were used for each time interval. Fourier transform infrared analysis was used to detect if there is any chemical reaction between soft lining material and coconut oil.

Results: Shore A hardness test demonstrated a reduction in the mean value of hardness after adding 1.5% and 2.5% coconut oil in comparison to the control group, this reduction was highly significant after 24 hours incubation in distilled water. The results revealed a fluctuating behavior at different time intervals in which the values showed an increase followed by a decrease in the hardness after incubation in artificial saliva for both 2 and 4 weeks. Regarding the wettability test, the results revealed a reduction in the contact angle values after 24 hours and 2 weeks of incubation intervals, this reduction was highly significant for the 1.5% group ($p<0.01$). While after 4 weeks of incubation, the mean values of contact angle of the experimental groups were increased. Conclusion: Virgin coconut oil was successfully incorporated into the soft denture liner and revealed an improvement in the material softness and wettability.

Key words: Soft denture liner, Virgin coconut oil, Hardness, Wettability

HOW TO CITE THIS ARTICLE: Bushra M Alamen, Ghassan Abdul-Hamid Naji, Mohammed A Alsmael, The Effect of Virgin Coconut Oil Addition on the Hardness and Wettability of Acrylic Based Denture Soft Lining Material, J Res Med Dent Sci, 2020, 8(1):96-106.

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Received: 11/07/2019

Accepted: 20/01/2020

INTRODUCTION

Natural soft rubbers have been early used in 1869 to fabricate the first soft lining material in dentistry field [1]. From that point forward, a marked evolution has influenced dental materials result in the development of different types of soft lining materials each has its own advantages and drawbacks [2].

In general, soft denture liners are resilient materials applied over the denture bearing surface to act as a cushion which absorbs the loads generated by the masticatory process and reduces its traumatic effects over the denture bearing area makes the denture wearer more comfortable [3]. At present, two common types of soft liners are available; acrylic based and silicone based materials. Acrylic based soft liners contains plasticizers which is released over time and increase the hardness of the material, while silicone base soft liners have no plasticizers and stay soft for longer period of time [4].

To be ideal, soft denture liners should exhibit certain properties to insure a maximum benefits for denture wearers; among these properties are the biocompatibility, dimensional stability, good resiliency, softness, proper wettability, color stability, low water solubility, sufficient bond strength with the underlying denture base and the ability to inhibit or reduce the microbial growth [5]. Acrylic-based soft lining material has a chemical structure that considered hydrophilic in nature, although this property may cause a greater affinity to water and saliva to the surface of the lining material, but at the same time it will aid in providing an even layer of saliva to lubricate the oral mucosa and hence enhances the denture retention and patient wellbeing. Heat cured acrylic based soft liner material is considered the best choice for denture relining material since it shows a greater wettability value than other materials [6].

Water solubility and sorption is major problems regarding soft lining materials, as time passed, some essential ingredients such as plasticizers of soft liner materials will leach out leaving a space with in the material structure that may be occupied by other strange particles and water, and this will change the chemical structure and physical properties of the soft liner [7]. As the plasticizer drain out, the modulus of elasticity of soft liner material will increase; subsequently it will lose one of its most important properties which are the resiliency. Moreover, some plasticizers such as phthalate ester will release and may initiate an adverse reaction in the epithelial tissue [8].

Hardness is considered as a simple method to evaluate the modulus of elasticity of a material [9], also, it provides a clue for material quality because as known the rigid material can't be used as a denture soft liner. Material with low hardness value is the best to be used as soft denture lining material [9,10]. Nevertheless, maintaining an ideal hardness value during the long term use of soft liner is very difficult, because soft liner material will lose some of its components and gain others, this will adversely affect its properties [9,10]. In addition, the need to clean the denture base daily by submerging it in different kinds of denture cleansers and disinfectant solutions will affect the fundamental properties of soft lining materials [11].

Virgin coconut oil (VCO) is a natural plant extracts derived from fresh coconut meat. VCO gained extra attention because of its bioactive components which is well known by its antipyretic, anti-inflammatory, antimicrobial and antioxidant properties [12]. It is mainly composed of medium chain fatty acids such as lauric acid, capric and caprylic acids which are approved to act against fungi particularly *Candida albicans* [13].

Moreover, coconut oil is considered as a potential alternative choice of plasticizers in polymer industry, since this oil is mainly composed from fatty acids which can work as a potent plasticizer, even in low concentrations, *via* increasing polymer chain mobility and decreasing material viscosity, this in turn will improve the material hardness as explained in the previous studies by Bhasney, et al. [14].

MATERIALS AND METHODS

Heat cured acrylic based soft denture lining material (Vertex, Netherlands) was used. Virgin coconut oil (VIVA naturals, Philippine) was added to the liquid part of the soft liner in two different concentrations. A total of 180 samples were prepared and divided into two groups (90 samples for each group) based on the conducted test; hardness and wettability tests. Then each group was subdivided into three subgroups (control 0%, 1.5% and 2.5%) based on the concentration of the added virgin coconut oil (n=30 samples for each subgroup). These concentrations were selected to discover the difference of the effect of a small and large amount of VCO without a potential adverse effect on the material properties [15]. And each subgroup was tested in different time intervals; 1 day in distilled water, 14 and 30 days in artificial saliva (n=10 samples for each time interval).

Shore a hardness test

Soft liner samples were prepared using disk-shape plastic molds measuring 30 mm in diameter and 3 mm thickness [16]. The hardness value was measured using Shore A durometer, reading were obtained from different five points that were pointed on each sample (one point on the center of the sample and the other 4 points were marked 6 mm away from the center [17] and the average of these readings was taken automatically from the durometer Figure 1.

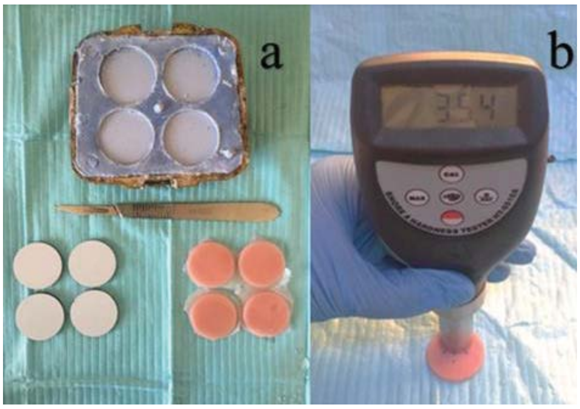

Figure 1: Bar chart showing mean values and standard deviation of shore A hardness for control and experimental groups at different periods of incubation.

Wettability test

The static sessile drop method was used in this study for measuring the wettability; a side view of a liquid drop on a solid substrate placed on horizontal flat base was captured and analyzed using optical subsystem [18]. The contact angle which is the angle developed between the liquid (distilled water), solid (sample surface) and air was captured using Dino-lite digital microscope that take a magnified picture (45x magnification) of the sample profile with a drop of distilled water over its surface. In order to standardize the drop size, a micropipette was used to give 40 µl distilled water drop and held vertically over the surface of a horizontally placed soft liner sample. Dino-lite digital microscope was placed parallel to the sample surface and a magnified picture of the contact angle was captured and analyzed using the special software of the microscope (Dino-Capture) Figure 2. As the contact angle increased the wettability decreased and vies versa [19,20].

Statistical analysis

The results of this study were analyzed using SPSS (statistical package for social science–version 24) computer software. Descriptive statistics which include Means Standard deviation and Graphical presentation by bar-chart. Inferential statistics includes: Two ways ANOVA (analysis of variance) was used to compare means among all groups and Tukey's multiple comparisons test was used to show the significance among different groups. A “P” value of >0.05 was considered as statically non-significant, ≤ 0.05 was considered as significant and <0.01 was considered as highly significant.

RESULTS

Shore a hardness test

Results of shore A hardness test after 24 hours of incubation in distilled water showed that both experimental groups (1.5% and 2.5% coconut oil) had a lower mean values compared to the control group, the experimental group with 1.5% of coconut oil revealed the lowest value of 39.63 in this period, as shown in Figure 3 . At the second and third periods of evaluation (2 and 4 weeks incubation in artificial saliva), mean values of hardness for experimental groups (1.5% and 2.5% coconut oil) were less than mean value of control group, also the lowest values were noticed in 1.5% coconut oil group (45.41 and 42.99) respectively, while mean values of control group were 56.01 and 53.57, respectively as shown in (Figure 3).

The descriptive statistics of shore A hardness test for control and experimental groups at different periods of incubation are listed in Table 1.

Two way ANOVA (Table 2) indicated a highly significant difference among various concentrations of coconut oil incorporation (p<0.01), and among incubation periods (p<0.01). A highly significant interaction was seen between concentrations and incubation periods (p<0.01).

Tukey's multiple comparisons test was used to compare mean values of hardness for different groups. In first incubation period control group showed a highly significant difference compared to both experimental groups in the same incubation period, while it was non-significantly different compared to both control groups in different incubation periods, 1.5% samples

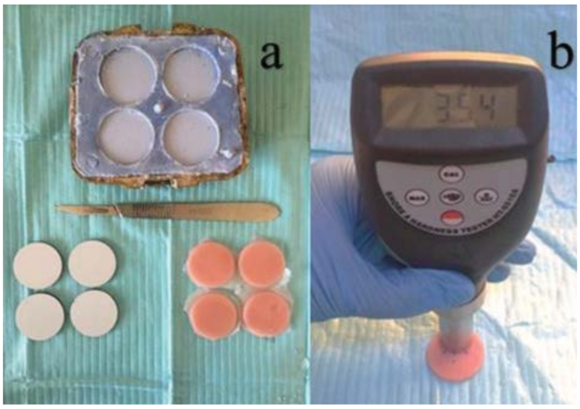

Figure 2: Bar chart showing mean values and standard deviation of static contact angles for control and experimental groups at different periods of incubation.

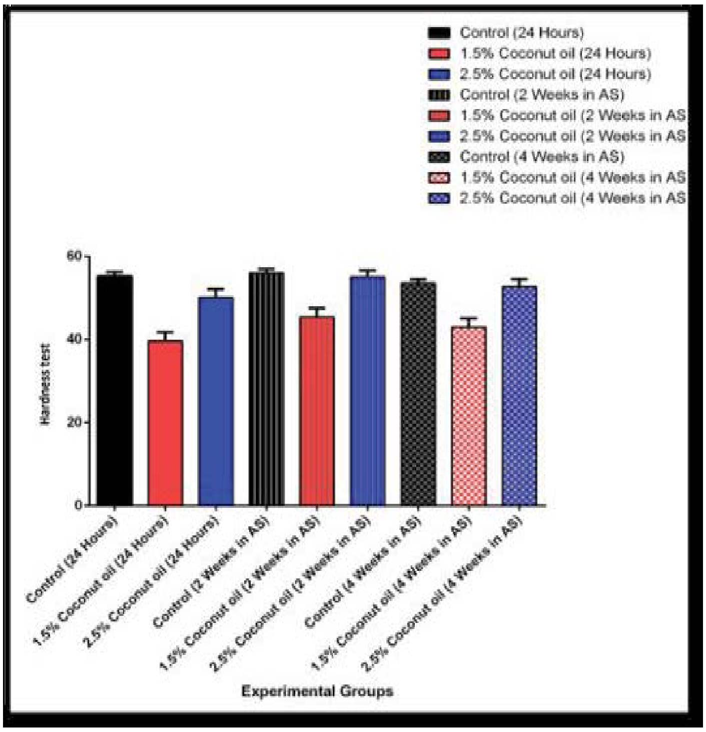

Figure 3: a) Plastic molds and soft liner samples for hardness test; b) Shore A durometer and sample testing.

showed a highly significant difference with 2.5% samples in the same incubation period, and it was highly significant difference also when compared to 1.5% samples in 2 and 4 weeks incubation period. Regarding 2.5% samples, the difference was highly significant with 2.5% samples after 2 weeks incubation period while it was significant when compared to 2.5% samples after the third incubation period (4 weeks). Control group of the second incubation period (2 weeks) showed a highly significant difference in comparison to 1.5% for the same period. 1.5% samples showed a highly significant difference when compared to 2.5% in the same period.

The third control group in the 4 weeks incubation period showed a highly significant difference when compared to 1.5% (4 weeks). 1.5% samples in the third incubation period showed a highly significant difference when compared to 2.5% in the same periodic group, as shown in Table 3.

Wettability test

Results of wettability test (by measuring static contact angle) after 24 hours of incubation in distilled water revealed that both experimental groups (1.5% and 2.5% coconut oil) had a lower mean values of contact angle than control group, the experimental group with 1.5% of coconut oil showed the lowest value in this period (71.74°), followed by 2.5% samples (74.44°), as shown in Figures 4 and 5. At the second period of evaluation

Table 1: Descriptive statistics of shore a hardness test.

Incubation period	Group	N	Mean (shore A unit)	S.D.
After 24 hours of incubation	Control	10	55.24	1.01
	1.5% of coconut	10	39.63	2.167
	2.5% of coconut	10	50.13	2.034
After 2 weeks of incubation	Control	10	56.01	0.9814
	1.5% of coconut	10	45.41	2.168
	2.5% of coconut	10	55.11	1.501
After 4 weeks of incubation	Control	10	53.57	0.9068
	1.5% of coconut	10	42.99	2.079
	2.5% of coconut	10	52.74	1.776

Table 2: Comparison of average values of hardness test using two ways ANOVA.

	Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Concentration	2552.547	2	1276.273	440.606	0	0.916
Incubation period	226.338	2	113.169	39.069	0	0.491
Concentration * Incubation period	97.393	4	24.348	8.406	0	0.293

Table 3: Tukey's multiple comparisons test of different groups for shore A hardness test results.

Period	Groups		Mean difference	P value	Sig.
After 24 Hours of incubation	Control	1.5% (24 hours)	15.61	<0.0001	HS
		2.5% (24 hours)	5.11	<0.0001	HS
		Control (2 weeks)	-0.77	0.985	NS
		Control (4 weeks)	1.67	0.4402	NS
	1.50%	2.5 % (24 hours)	-10.5	<0.0001	HS
		1.5% (2 weeks)	-5.78	<0.0001	HS
		1.5% (4 weeks)	-3.36	0.0014	HS
	2.50%	2.5% (2 weeks)	-4.98	<0.0001	HS
		2.5% (4 weeks)	-2.61	0.0303	S
After 2 weeks of incubation	Control	1.5% (2 weeks)	10.6	<0.0001	HS
		2.5% (2 weeks)	0.9	0.961	NS
		Control (4 weeks)	2.44	0.0552	NS
	1.50%	2.5% (2 weeks)	-9.7	<0.0001	HS
		1.5% (4 weeks)	2.42	0.0591	NS
	2.50%	2.5% (4 weeks)	2.37	0.0698	NS
After 4 weeks of incubation	Control	1.5% (4 weeks)	10.58	<0.0001	HS
		2.5% (4 weeks)	0.83	0.976	NS
	1.50%	2.5% (4 weeks)	-9.75	<0.0001	HS

N.S: No statistically significant difference between groups at p>0.05; HS: Highly significant difference between groups at p<0.01

(2 weeks of incubation in artificial saliva), the mean values of experimental groups (1.5% and 2.5% coconut oil) were less than mean value of control group, also the lowest mean value was noticed in 1.5% coconut oil group (65.31°), as shown in Figure 4. At the third evaluation period (4 weeks of incubation), the mean value of contact angle of 1.5 % samples (74.44°) were higher than that of control group (71.74°), while the mean value of 2.5 % samples (71.36°) were lower than that of control group (71.74°) (Figure 4). The descriptive statistics of static contact angle test for control and experimental groups in different periods of incubation are listed in Table 4. In Table 5, Two way ANOVA test indicated a highly significant difference among various concentrations of coconut addition ($p<0.01$), and among incubation periods ($p<0.01$). A highly significant interaction also was seen between concentrations and incubation periods ($p<0.01$).

Tukey's multiple comparisons test was utilized to compare mean values of different groups. In first incubation period, the control group showed a high significant difference compared to 1.5% samples and it was highly significant difference compared to both control groups in different incubation periods, 1.5% samples showed a significant difference with 2.5% samples in the same incubation period, and it was highly significant difference also when compared to

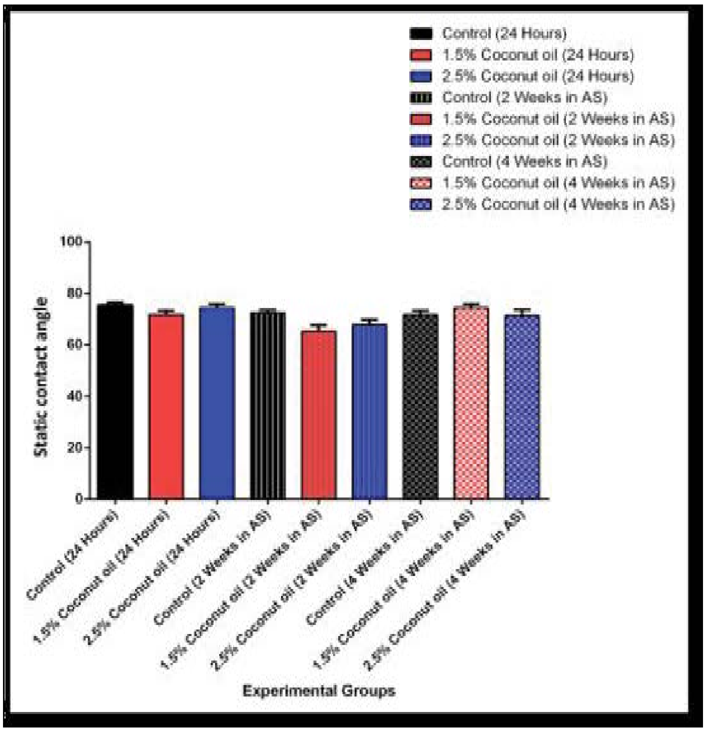

Figure 4: a) Dino-lite digital microscope and micropipette; b) Microscope placed parallel to the sample; c) Magnified picture of distilled water drop.

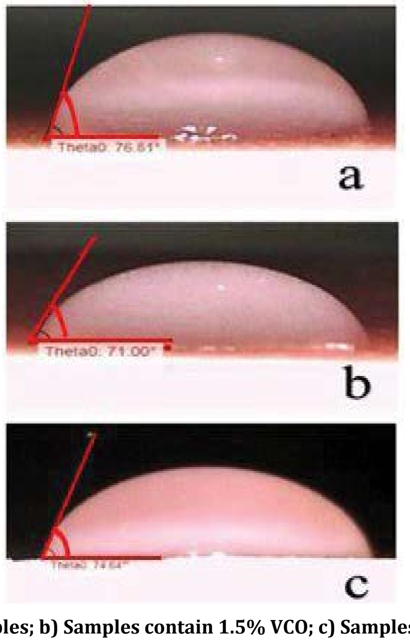

Figure 5: Static contact angle of: a) Control samples; b) Samples contain 1.5% VCO; c) Samples contain 2.5% VCO.

1.5% samples in 2 weeks and significant when compared to 1.5% samples in 4 weeks incubation period, regarding 2.5% samples the difference was highly significant with 2.5% samples after 2 weeks incubation period.

Control group of the second incubation period showed a highly significant difference when compared to 1.5% samples from the same period, while showed a significant difference with 2.5% samples (2 weeks). 1.5% samples showed a highly significant difference with 1.5% samples (4 weeks). In the 4 weeks incubation period, the control group showed a significant difference when compared to 1.5% samples, as presented in Table 6.

DISCUSSION

Hardness is a physical property measured by an instrument called Shore A durometer, this

Table 4: Descriptive statistics of static contact angle test.

Incubation period	Group	N	Mean (°)	S.D.
After 24 hours of incubation	Control	10	75.38	1.257
	1.5% of coconut	10	71.74	1.623
	2.5% of coconut	10	74.44	1.425
After 2 weeks of incubation	Control	10	72.44	1.126
	1.5% of coconut	10	65.31	2.327
	2.5% of coconut	10	67.92	1.928
After 4 weeks of incubation	Control	10	71.74	1.623
	1.5% of coconut	10	74.44	1.425
	2.5% of coconut	10	71.36	2.312

Table 5: Comparison of average values of static contact test using two ways ANOVA.

	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Concentration	200.934	2	100.467	33.516	0	0.453
Incubation period	539.496	2	269.748	89.99	0	0.69
Concentration * Incubation period	235.93	4	58.983	19.677	0	0.493

Table 6: Turkey's multiple comparisons test of different groups for static contact angle.

Period	Groups		Mean difference	P value	Sig.
After 24 Hours of incubation	Control	1.5% (24 hours)	3.64	0.0076	HS
		2.5% (24 hours)	0.94	0.7726	NS
		Control (2 weeks)	2.94	0.0068	HS
		Control (4 weeks)	3.64	0.0076	HS
	1.50%	2.5 % (24 hours)	-2.7	0.0191	S
		1.5% (2 weeks)	6.43	0.0075	HS
		1.5% (4 weeks)	-2.7	0.0191	S
	2.50%	2.5% (2 weeks)	6.52	0.0007	HS
		2.5% (4 weeks)	3.08	0.0554	NS
After 2 weeks of incubation	Control	1.5% (2 weeks)	7.13	< 0.0001	HS
		2.5% (2 weeks)	4.52	0.0102	S
		Control (4 weeks)	0.7	0.9857	NS
	1.50%	2.5% (2 weeks)	-2.61	0.3408	NS
		1.5% (4 weeks)	-9.13	< 0.0001	HS
	2.50%	2.5% (4 weeks)	-3.44	0.0793	NS
After 4 weeks of incubation	Control	1.5% (4 weeks)	-2.7	0.0191	S
		2.5% (4 weeks)	0.38	0.9999	NS
	1.50%	2.5% (4 weeks)	3.08	0.0554	NS

instrument usually used in rubber dentistry to evaluate the hardness of elastomeric materials [11]. Hardness also represents the surface resistance to permanent indentation [21], and it is a simple way to measure the modulus of elasticity of a material [9]. One of the most important advantages of soft lining material is impact absorption during masticatory cycles, this require a soft non-rigid viscoelastic material to act as a cushion between denture base and residual ridge. So lower hardness values is considered a desirable feature for soft lining materials. Nevertheless, no limitation was found for the Shore A hardness values to be considered as clinically acceptable. However, a scale ranging from 13 to 49 Shore A hardness units during 24 hours was considered as acceptable range for the material to be used clinically [22].

After 24 hours, the incorporating of different concentrations of VCO (1.5% and 2.5%) to the heat cured acrylic-based soft liner caused a highly significant reduction in the mean values of the material hardness ($p<0.01$) when compared to the control group (0% VCO). While after two and four week's incubation periods, this reduction in the mean values in comparison with the control group was also highly significant for 1.5% VCO group but non-significant for 2.5% group. This could be related to the fact that coconut oil is considered as a potential alternative choice of plasticizers in polymer industry, since this oil is mainly composed from fatty acids which can work as a potent plasticizer, even in low concentrations, by increasing polymer chain mobility and decreasing material viscosity as explained in the previous studies by Bhasney, Patwa [14]. Moreover, as approved by the FTIR test in this study; no chemical reaction was shown between VCO and lining material (Figure 6), this mean that the bond presents between lining material and VCO is physical rather than a chemical. This physical bond explains the low hardness values and high material resiliency [11].

The present study showed a highly significant decrease in the hardness values for 1.5% VCO when compared to the 2.5% group for all time intervals. This could be attributed to the higher amount of VCO which make a state of instability inside the sample as more VCO will migrate to the sample surface result in more rapid loss of VCO this in turn decrease the amount of plasticizer presents inside the 2.5% samples in a faster rate than 1.5% sample. This phenomenon also may be responsible for the reduction in the mean value of 2.5% VCO samples after 2

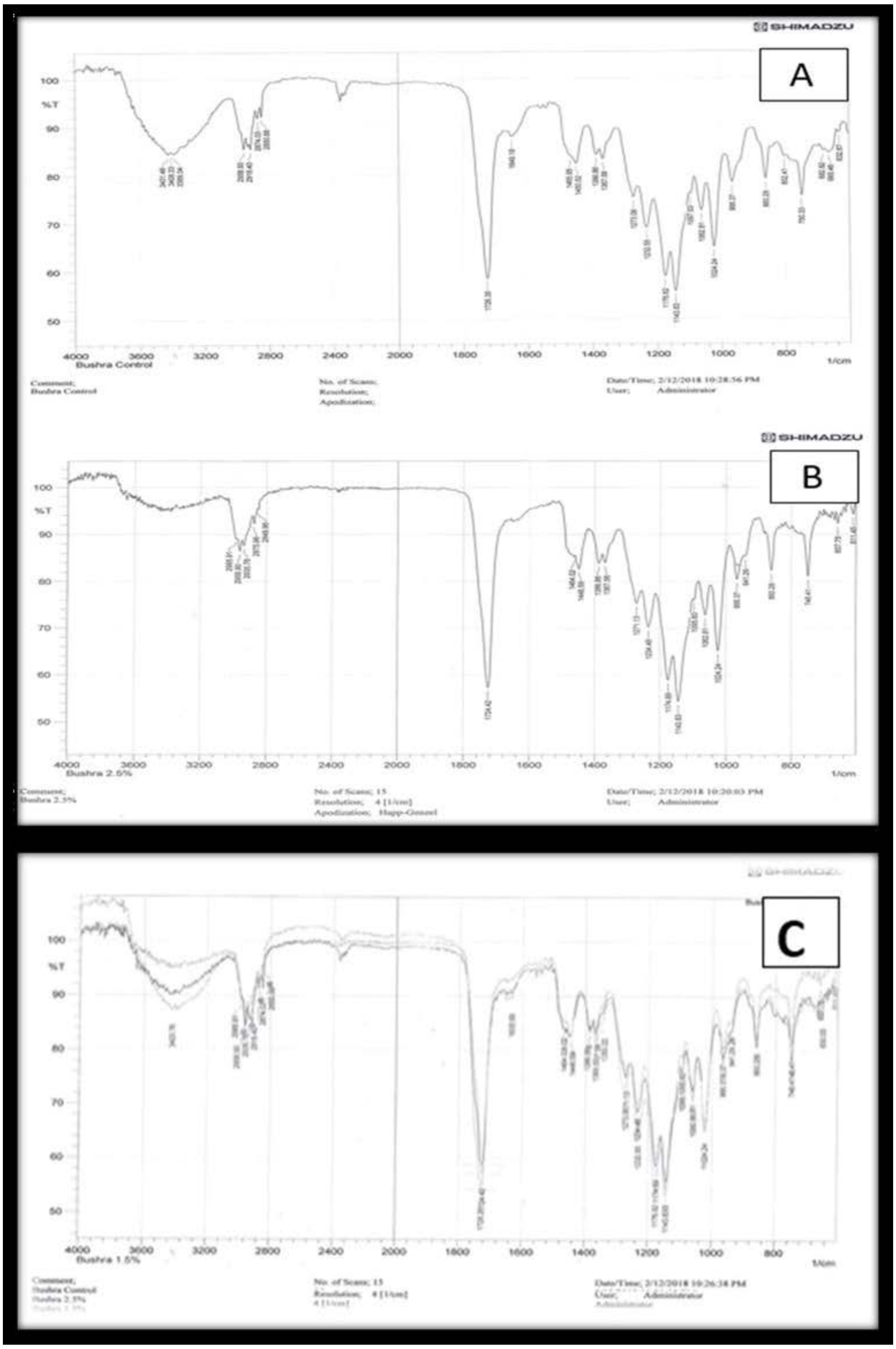

Figure 6: FTIR test.

and 4 weeks incubation period in artificial saliva in comparison to control groups of the same incubation period; since as time interval increased more VCO will be lost from the sample surface making the hardness values closer to that of the control groups.

For each concentration, the results also demonstrated an increase in the hardness values after 2 weeks incubation period in artificial saliva in comparison to that of 24 hours storage in distilled water, then the values start to decrease again after 4 weeks incubation in artificial saliva. A non-significant difference was obtained for control group, whilst a highly significant for 1.5% group ($p<0.01$) and significant for 2.5% group ($p<0.05$). This finding may be attributed to the dynamic process which take place during long term storage of soft liner samples in water or any aqueous media in which the reported increase of hardness values after 2 weeks could be explained by leaching out of the plastizcer molecules along with VCO, this in turn can reduce the polymer chains movements and decrease the resiliency of the material [11].

From another standpoint, the leaching out-uptake is a time dependent procedure and diffusion monitored; so as the time interval of sample storage is increased, more soluble contents will be released and the smaller size of water molecules will start to diffuse and fill the micro pockets created inside the samples acting as alternative plasticizer and facilitating the polymer chains mobility as explained by Rajaee, Vojdani [21], mostly leading to reduction in the hardness values after 4 weeks of storage. The statistical difference was significant for each concentration, could be related to the amount of water absorbed *via* each sample group.

Wettability is a fundamental requirement for a denture base, it has a great effect on the denture retention because it allows the saliva to spread smoothly and easily over the denture surface, this in turn increases the denture retention. Moreover, wettability plays a role in minimizing accumulation of candida on the denture surface by a cleansing action, the more the wettability the more the clean ability [23]. Also, by creating a lubricating layer over the denture surface; wettability enhances the patient comfort [6].

Contact angle is an essential parameter in the measurement of wettability of denture lining materials. Contact angle is the angle formed by a tangent to the drop of liquid and the solid surface [24]. This angle is a unique feature for each substance because it is related to the surface energy of the solid substances and surface tension of liquid substances. The highest is the contact angle the lowest is the wettability value [6].

After 24 hours and 2 weeks incubation periods, the results revealed that the incorporation of 1.5% and 2.5% VCO caused a decrease in the mean values of static contact angle (increase wettability), when compared to 0% VCO group (control). This difference was highly significant for 1.5% group in both incubation periods ($p<0.01$), while it was non-significant for 2.5% in the first period and significant in the second one ($p>0.05$(. This may be attributed to the higher surface energy acquired by the soft liner samples after VCO addition, since VCO known by its high surface activity, high flow rate, high saturation and less viscosity compared with other oils [25], it is possible that adding VCO to soft lining materials could result in higher surface energy of the samples, this consequently reduce the contact angle of the water droplet with the sample surface result in overall increase in the material wettability [26]. This was in agreement with Muttagi, et al. [23] who reported that seed oil incorporated soft liner samples demonstrated a better wettability than control group in which a significant reduction of the mean values of the contact angle was noticed after oil addition in comparison to the control group. Moreover, a previous study was conducted by Dankovich, et al. [27] trying to fabricate a hydrophobic material, by coating it with different plants oils states that all utilized oils was able to produce a hydrophobic material with less water sorption except coconut oil and relates this to the fact that coconut oil contains mostly saturated fatty acids with very low percent of unsaturated fatty acids, on the contrary to other oils used in the previous study which contain mostly unsaturated fatty acids that have the ability to form a cross-linked network to increase the hydrophobicity of the material.

For the third incubation period (After 4 weeks), the results demonstrated a significant increase in the mean values of static contact angles for 1.5% VCO group in comparison to the control group. This unexpected increase need to undergo further investigation and may be related to the long period of incubation in which some components of artificial saliva was adsorbed or accumulated over the sample surfaces reducing its surface energy and adversely affecting its wettability by increasing the contact angle with water droplet. In addition this adsorption of salivary components is not constant for all groups and varies with the difference in chemical composition of the outmost layer of the sample surface at the time of measurement as stated by Sipahi, et al. [28] who declared that one cannot make a clear conclusion about the interaction between the solid and liquid materials since the wettability of a solid surface covered by organic layer mainly depend on the surface chemical properties of the most external atoms presents on the solid surface which require a very complicated and extensive investigations to be determined. This explanation can also be applied for the release and accumulation of free VCO over the sample surface decreasing its surface energy and impairing its wettability by creating a large contact angle with water droplet. Although incorporation of VCO into soft denture lining materials can improve its wettability as mentioned previously, but knowing that the behavior of liquid differs in accordance to its state whether it is pure liquid or it is mixed with other components because the composition present in the surface of a mixture is not necessarily similar to that presents in the bulk [29].

Comparing 1.5% VCO group to 2.5% VCO group, the results showed that the mean value of 1.5% was lower than that of 2.5% and this is also support the previously mentioned explanation in which the more VCO incorporated in the sample leads to more instability in the sample and faster release rate of the oil from the sample. This result explain the lesser beneficial effect of VCO in the wettability of 2.5% group than 1.5% group. This is why 1.5% group demonstrated a lower contact angles with improved wettability. For each concentration of experimental samples, statistical results also demonstrate a highly significant decrease in mean values of the static contact angle after 2 weeks incubation period in artificial saliva in comparison to that of 24 hours storage in distilled water, and this reduction had continued for the control group only. Researchers studying the effect of water storage on the wettability of soft lining material for a very long period of time was not conducted yet, but Jin, et al. [6] stated that the wettability of heat cured acrylic based soft denture lining material was increased after 24 hour of water storage due to leaching out of plasticizer and water imbibition. While after 4 weeks of incubation, the mean values of contact angle of the experimental groups were increased, this might be related to the accumulation of free VCO or saliva components over the samples surfaces impairing its wettability.

CONCLUSION

Within the limitations of the present study; the following conclusions can be obtained:

1. The addition of VCO into soft lining material resulted in increased the softness of the material for both experimental groups compared to the control group; The 1.5% group showed the lowest hardness values for all incubation periods.
2. Adding VCO into soft denture lining material result in a more hydrophilic material with no adverse effect on the material wettability.
3. The effect of the incubation period in artificial saliva for the soft lining material shows fluctuating results for both hardness and wettability tests which were reflected by the dynamic (uptake-release) process of the material.

ACKNOWLEDGEMENT

The authors would like to thank the University of Baghdad and Faculty of Dentistry for their support. The authors wish to gratefully acknowledge the National Center for Educational Laboratories in the Medical City, Baghdad.

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