Determination The Flow of Experimental Modeling Waxes by Using Vicat Apparatus

ABSTRACT

Aim of the study: measuring the flow of new experimental modeling waxes. **Materials and methods**: preparation of one hundred twenty (120) samples of different experimental modeling waxes by mixing of different percentages of Iraqi natural waxes (hard paraffin, soft paraffin and beeswax) and additives (starch, gum Arabic, rosin and Na-carboxymethylcellulose) using mold made from brass according to ADA specification and measure the flow of them by using vicat apparatus after making modification on it. **Results**: The experimental modeling wax (80% hard paraffin + 20% soft paraffin) and (80% beeswax + 20% soft paraffin) had the most nearest properties to control (Polywax) at 40c°and 45c° and experimental modeling wax (90% beeswax + 10% starch) to control (Major) at 40c° and experimental modeling waxes (80% beeswax + 20% hard paraffin), (80% hard paraffin + 15% soft paraffin + 5% beeswax), (70% hard paraffin + 20% soft paraffin + 10% beeswax) and (90% beeswax + 10% starch) to control (Major) at 45c°. **Conclusions**: The flow of waxes increased with increasing heating temperature from 40°C to 45°C.

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Key Words: flow, wax, vicat apparatus

Flow is the change in shape under an applied force[1,2] it also means the viscous response to an applied stress [3].

Wax has a tendency to flow. It results from the slippage of wax molecules over each other [4,5].

Flow is highly dependent on the temperature, composition of wax[6], force causing the deformation and length of time that the force is applied. Flow greatly increases as the melting range of the wax is approached or as the load and its length of application are increased[7]. For pattern waxes, flow is generally not desirable at room or mouth temperature, because it results in permanent distortion of wax pattern[2]. The amount of flow required from a wax depends on its use [6,7].

MATERIALS AND METHODS

Flow Test at 40°C and 45°C[1]:

A-Preparation of Flow Testing Instruments:

In flow test, the amount of force applied to the specimen is 2 kg. (19.6 N) force, this load is applied vertically to the specimen, to obtain this amount and direction of force, the standard vicat apparatus has been modified according to ADA specification No.24[8], the weight of standard vicat apparatus arm is 300 gm., after the removal of the needle (1 mm.) diameter and weighed (12.179±0.1) gm., the weight of standard vicat apparatus arm becomes (287.821±0.1) gm.

The other needle (10) mm. diameter of vicat apparatus arm was used and aluminum plate rectangular in shape,{ (50) mm. length, (45) mm. width and (6) mm. thick}, containing hole with diameter 10 mm., was attached to this needle, this aluminum plate weighed (31.360±0.1) gm., the total weight of standard vicat apparatus arm becomes (319.181±0.1) gm. and in order to make the weight 2 kg. (19.6 N) force, a weight of about (1.680.819) kg. ± 2 gm has been added to the vicat apparatus arm and this weight is prepared with hole of about (1.5± 0.1) cm. diameter and (3±0.1) cm. depth in order to be placed vertically on the top of vicat apparatus arm Figures(1 and 2).

Figure: (1) Standard Vicat apparatus.

Figure: (2) Vicat apparatus After modification.

B-Preparation of Mold:

The mold consists of aluminum plate (6±0.1) mm thick, having flat parallel top, and bottom surfaces, and containing hole (10±0.1) mm in diameter (Figure 3).

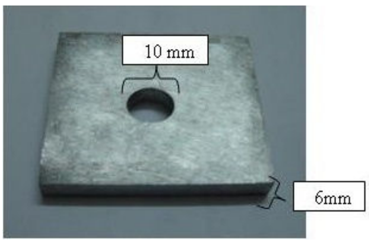

Figure: (3) Mold used in flow, hardness and accuracy test.

C-Procedure of Samples Preparation:

A quantity of Iraqi natural waxes with specific percentages are broken into small pieces and placed in a metal pouring pan. The pan was then placed in water bath and the wax starts to melt and becomes fluid, the wax reaches (75 ± 5) °C and maintained at this temperature until pouring into mold. A thermometer (REG T. M. France) is used to measure the temperature. The melted wax then poured into a mold that has been lubricated with separating medium (Dentaire, S.A., vevey, Suisse)

The mold was preheated to (55 ± 5) °C and placed on a smooth glass slab (150 mm. x 75 mm.) preheated to the same temperature. As the wax freezes and shrinkage voids appear, liquid wax is added to it. When the wax lost its mirror –like surface, Aluminum foil covered glass plate preheated to (55 ± 5) °C is placed on the top of the mold. A load of (2kg) force is applied on the top of the glass plate for 30 min. The weight and the glass plate then are removed and excess wax trimmed away. The specimen of wax was removed from the mold by chilling in water at 10°C and then be stored at room temperature (20 ± 2)ºC for 24 hours before testing Figure(4).

Figure: (4) Samples of different waxes used in flow, hardness and accuracy test.

D-Procedure of Flow Determination:

The initial height of the specimen is determined at room temperature (20 ± 2) ºC using Electronic digital caliper. Four measurements are made around the circumference and one measurement is made in the center of specimen. The flow testing instrument and wax specimen were placed in water bath and held at testing temperature for 20 min. Constant axial load of 19.6 N (2kg) force was then applied to the specimen for 10 min after which the specimen then removed and cooled in air at room temperature and the final height is determined in the same manner as the original height, the flow evidenced by the change in height and reported as percentage of the total height Figures (5-8).

Figure: (5) Controlled water bath.

Figure: (6) Sample placed under the axial load of vicat apparatus.

Figure: (7) Sample after applying axial load

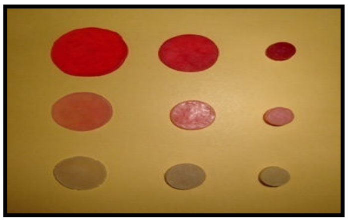

Figure: (8) Different wax flow at (20 ± 2)ºC, 40 °C and 45° C from right to left side.

The experimental materials are divided into three groups and represented by codes as follow:

Group (1): This group contains Iraqi natural waxes (hard paraffin, soft paraffin and bees wax).

Group (2): This group contains experimental modeling waxes that consist of different mixtures of natural waxes that are commonly used as dental wax ingredients with different percentages. This group consists of:

A-Hard paraffin and soft paraffin mixture.

B- Hard paraffin and beeswax mixture.

C- Soft paraffin and beeswax mixture.

D- Hard paraffin, soft paraffin and beeswax mixture.

Group (3): This group contains experimental modeling waxes consist of natural waxes and different additives, the percentage of mixing as follow:

1- Ninety (90 %) natural wax and 10% additives.
2- Eighty (80%) natural wax and 20% additives. Table(1).

Table (1): The control with experimental groups and their codes.

Materials		**Codes**
Control	Polywax Major	Polywax Major
(Pure waxes) Group 1		
	Hard paraffin	HP
	Soft paraffin	SP
	beeswax	BW
(Natural waxes mixtures) Group 2		
	90% HP + 10% SP	90% HP + 10% SP
	90% HP + 10% BW	90% HP + 10% BW
	80% HP + 20 % SP	80% HP + 20 % SP
	80% HP + 20 % BW	80% HP + 20 % BW
	80% BW + 20% HP	80% BW + 20% HP
	80% BW + 20% SP	80% BW + 20% SP
	80% HP + 15% SP + 5% BW	80% HP + 15% SP + 5% BW
	70 % HP + 20 % SP + 10 % BW	70 % HP + 20 % SP + 10 % BW
{ (Natural waxes + additives) mixtures } Group 3		
	90% HP+ 10 % Starch	90% HP+ 10 % ST
	90% BW+ 10% Starch	90% BW+ 10% ST
	80% HP + 20% starch	80% HP + 20% ST
	80% HP + 20% Na-CMC	80% HP + 20% Na-CMC
	80% HP + 20% gum Arabic	80% HP + 20% GA
	80% HP + 20 % rosin	80% HP + 20 % R

Na-CMC: Sodium carboxymethylcellulose.

RESULLTS

The number of samples, mean and standard deviation, of flow percentages at 40ºC and 45ºC of the tested samples of control, groups 1, 2 & 3 are listed in Table (2), Duncan's multiple range test of control, group 2&3 are shown in Figures (9,10,11, & 12).

Table (2): Descriptive statistics for flow at 40 ºC and 45ºC of control, groups 1, 2, & 3.

Group		Flow at 40 ºC (%)			Flow at 45ºC (%)		
		N	Mean	SD	N	Mean	SD
Control	Polywax	3	72.58	0.32	3	83.81	0.292
	Major	3	55.82	0.672	3	75.20	0.125
Group 1							
Hard paraffin		3	49.85	0.38	3	68.98	0.13
Soft paraffin		3	94.53	0.45	3	95.19	0.04
beeswax		3	67.51	0.43	3	80.12	0.1
Group 2							
90% HP + 10% SP		3	61.51	0.196	3	72.32	0.23
90% HP + 10% BW		3	47.36	0.099	3	64.67	0.07
80% HP + 20 % SP		3	70.10	0.175	3	80.61	0.423
80% HP + 20 % BW		3	45.45	0.199	3	63.98	0.225
80% BW + 20% HP		3	47.77	0.419	3	75.74	0.074
80% BW + 20% SP		3	69.62	0.365	3	85.43	0.21
80% HP + 15% SP + 5% BW		3	66.45	0.067	3	76.07	0.298
70 % HP + 20 % SP + 10 % BW		3	66.32	0.261	3	76.03	0.252
Group 3							
90% HP+ 10 % ST		3	49.21	0.635	3	67.76	0.047
90% BW+ 10% ST		3	56.70	0.456	3	74.48	0.025
80% HP + 20% ST		3	47.65	0.455	3	62.23	0.143
80% HP + 20% Na-CMC		3	46.12	0.177	3	64.04	0.030
80% HP + 20% GA		3	43.62	0.095	3	61.59	0.306
80% HP + 20 % R		3	42.44	0.120	3	61.45	0.089

SD: standard deviation. N: number of samples

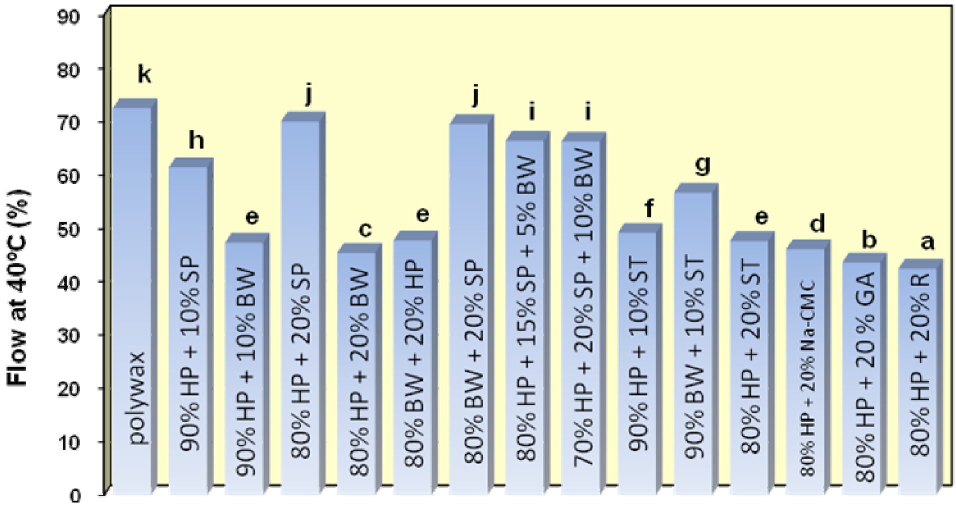

Figure (9) Duncan's multiple range test of flow at 40ºC of the control (1) and experimental modeling waxes in groups 2 & 3.

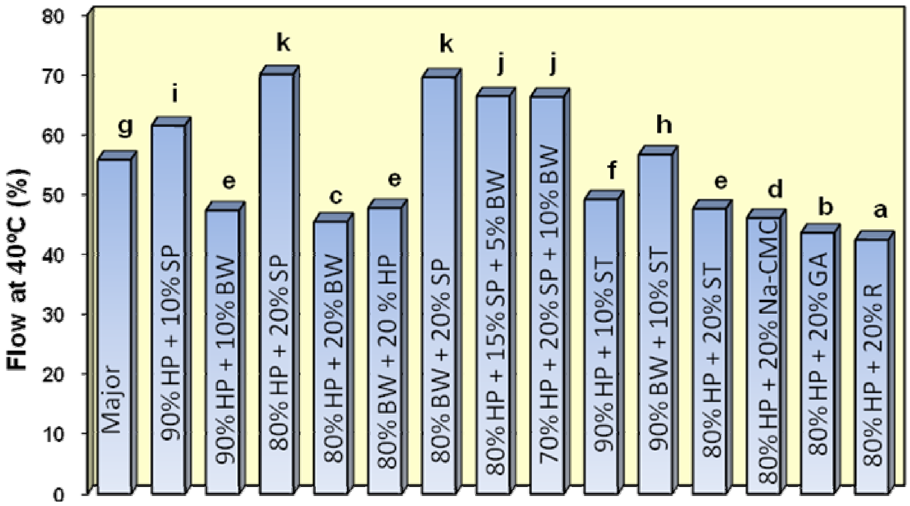

Figure (10) Duncan's multiple range test of flow at 40ºC of control (2) and experimental modeling waxes in groups 2 & 3.

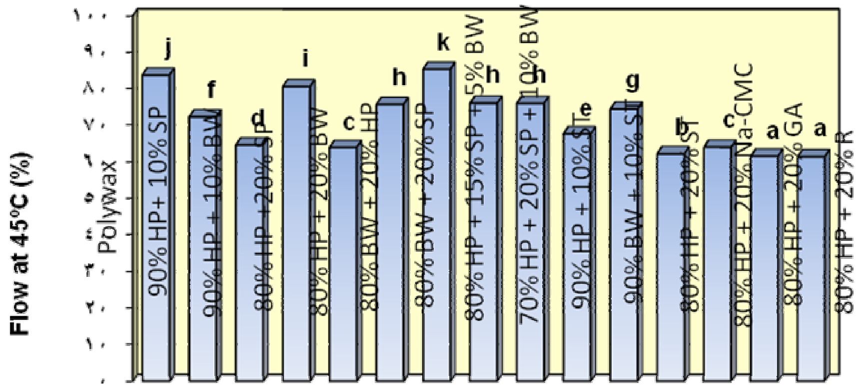

Figure (11)Duncan's multiple range test of flow at 45ºC of control (1) and experimental modeling waxes in groups 2 & 3.

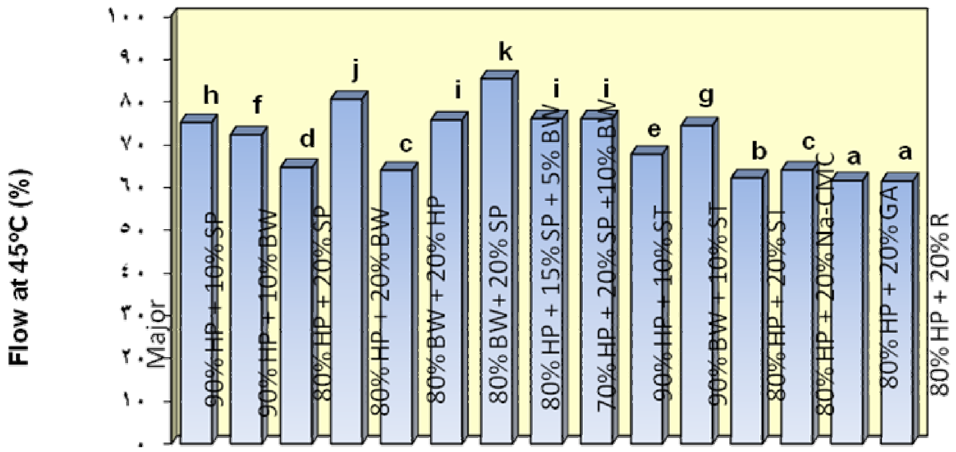

Figure (12) Duncan's multiple range test of flow at 45ºC of the control (2) and experimental modeling waxes in groups 2 & 3.

DISCUSSION

For laboratory use, a high degree of plastic deformation (flow) is necessary at temperature which will not cause injury to the operator in the manual manipulation of the material. Under these conditions, plastic deformation of 60%-70% at 45ºC is required to ensure that the material may be adapted or molded accurately to form a pattern [9].

Table (2) showed that all experimental modeling waxes had flow properties that coincide with ADA specification No.24; all flow values were located between 50% and 90% at 45°C which are considered as Type II dental modeling waxes [8].

From the results obtained of flow at 40ºC and 45ºC, it has been seen that when the temperature of waxes increase, the percentage flow would also increase Table (2). These results are in agreement with Craig *et al.*[10] and McCrorie[9] who stated that the increases in temperature resulted in decreases in the mechanical properties of all waxes, and lead to increase the flow under load.

The results revealed that the soft paraffin had the highest flow percentage than other experimental waxes and this may be related to its low melting point and when the temperature raise to 40ºC and 45ºC, this temperature is near its melting point, so it will flow extensively Table(2). This is in agreement with Craig and Powers[5] who stated that the flow greatly increases as the melting point of the wax is approached.

The soft paraffin had higher flow value than hard paraffin and this is in agreement with McCrorie[11].

The results also showed that the flow of beeswax was less than that of soft paraffin, and this may be due to the presence of ester group in beeswax, the secondary valence forces are rather strong, and high temperature is necessary to overcome these forces, once the secondary forces are overcome, these waxes flow rapidly, below this point, however these often appear to fracture in a manner similar to brittle materials [12].

The addition of soft paraffin to hard paraffin led to increase in the flow of the latter and the flow increased with increasing percentage of addition from 10% to 20%. This may be due to the interference between the physical properties of two waxes.

The addition of soft paraffin to beeswax led to increase in the flow of the latter; a possible explanation of this observation is an increase in the mutual solubility of paraffin and beeswax, since beeswax consists of considerable quantities of hydrocarbons as well as ester molecules, while paraffin wax consists essentially of hydrocarbons. The effect of this increased solubility would be to interfere with the matrix of higher melting point beeswax and reduce the intermolecular attraction between ester groups, thus reducing the transition temperature and increasing the flow [6].

The results revealed that there was a significant reduction in the flow of hard paraffin at 40ºC and 45ºC by the addition of 10% and 20% beeswax as in experimental modeling waxes (90% HP + 10% BW) and 10 (80% HP + 20% BW). The flow reduced more with increasing the percentage of addition from 10% to 20% and this is in agreement with Craig *et al*.[6] who stated that the addition of beeswax to paraffin leads to raise the transition temperature slightly and thus reducing the flow.

McCrorie[9] reported that the addition of 25% beeswax to the paraffin wax (low melting point) reduced the plastic deformation of the paraffin wax by almost 50%. Further additions of beeswax to the paraffin wax produced a gradual increase in the plastic deformation of the mixtures, but this was still less than that of the original paraffin wax, while the addition of beeswax to the higher melting point paraffin wax did not follow a similar pattern. At 37ºC the percentage flow of paraffin was reduced from 20% to 5% and 4% by the addition of 25% beeswax and 50% beeswax respectively. This can be explained as that the paraffin wax: beeswax mixtures might form a matrix where the beeswax helped to support the paraffin wax as at 37ºC the solid-solid phase changes had not yet occurred in the beeswax.

Kotsiomiti and McCabe[13] stated that the flow of paraffin was significantly reduced by the addition of beeswax.

Table (2) showed that the addition of 10% starch did not affect the flow of hard paraffin significantly as in experimental modeling wax (90% HP + 10% ST) but when the percentage of addition increased to 20% as in experimental modeling wax (80% HP + 20% ST) led to reduce the flow of hard paraffin at 40ºC and 45ºC. Also, the addition of 20% Na-CMC, 20 % Gum Arabic, and 20 % rosin to hard paraffin as in experimental modelling waxes (80% HP + 20% Na-CMC), (80% HP + 20% GA) & (80% HP + 20 % R) led to significant reduction in the flow of hard paraffin (Figures 9-12). This may be explained on the basis that these materials act as a thickening and binding agents and lead to increase the hardness of paraffin wax thus reducing the flow [14-16].

The addition of rosin to paraffin produces the highest flow reduction than other additives; this is due to the fact that resins are commonly added to paraffin to produce harder material [17].

CONCLUSIONS

The flow of waxes increased with increasing heating temperature from 40ºC to 45°C, The addition of beeswax to hard paraffin leads to decrease the flow, the additions of hard or soft paraffin to beeswax lead to increase the flow, The addition of soft paraffin to beeswax or hard paraffin leads to increase flow, The addition of starch to beeswax leads to decrease the flow, The addition of 20% Na-CMC, 20% gum Arabic, and 20% rosin to hard paraffin led to decrease the flow.

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