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Determination the flow of experimental modeling waxes by using vicat apparatus

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Abstract
Aim of the study: Evaluation the flow of a new experimental modeling waxes. Materials and methods: synthesis of one hundred twenty (120) samples of different modeling waxes by mixing different percentages of local natural waxes (hard paraffin, soft paraffin and beeswax) and additives (starch, gum Arabic, rosin and Na-CMC (Na-carboxymethylcellulose)) using mold made from brass according to ADA specification No.24, then measure the flow of them by using vicat apparatus after making modification. Results: The experimental modeling wax (80% hard paraffin+20% soft paraffin) and (80% beeswax+20% soft paraffin) had the most nearest properties to control (Poly wax) at 40°and 45°C and experimental modeling wax (90% beeswax +10% Starch) to control (Major) at 40°C 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 45°C. Conclusions: Flow of waxes showed increased with the increasing heating the temperature from 40°C to 45°C.

Keywords: Flow, Wax, Vicat apparatus.

Introduction
Follow 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]

Previous studies showed the flow is highly dependent on the temperature degree, composition of wax,[6] the force that causing the deformation and length of time that the force is applied. Flow was greatly increased as the melting point 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 temperature or mouth temperature, because the results in permanent distortion of wax pattern.[2] The amount of flow required from a wax depends on its uses.[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 was applied vertically to the specimen, in order to obtained the amount and direction of force, the standard vicat apparatus has been modified according to ADA No.24 specification,[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 10mm., 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 (Fig. 1 and 2).

Fig 1: Standard Vicat apparatus

Fig 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 (Fig. 3).

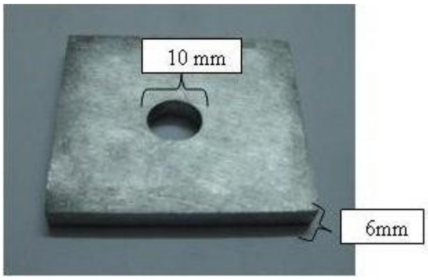

Fig 3: Mold used in flow, hardness and accuracy test

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 the water bath, the wax became to melt and starting to fluid, the wax reaches (75 ± 5) °C and maintained at this temperature degree until pouring into mold. A thermometer (REG T. M. France) was used to measured the temperature degree. The melted points of wax then poured into a mold that has been lubricated with separating medium oil (Dentaire, S.A., vevey, Suisse). The mold was preheated to (55 ± 5) °C and then placed on a smooth glass slab distance (150 mm. x 75 mm.) preheated to the same temperature. As the wax freezes and shrinkage voids appear, liquid wax was added to the sample. When the wax lost its mirror – like surface, Aluminum foil covered with a heated glass plate to (55 ± 5) °C was placed on the top of the mold. A load of (2kg) force was applied on the top of the glass plate for 30 min. The weight and the glass plate then together were removed and the excess wax trimmed away. The specimen of wax was removed from the mold by chilling in water at 10°C, then they stored at room temperature (20 ± 2)ºC for 24 hours before testing Fig. 4.

Fig. 4: Samples of different waxes used in flow, hardness and accuracy test

D-Procedure of Flow Determination: The initial height of the specimen was determined at room temperature (20 ± 2) ºC by Electronic digital caliper machine. Four measurements were made around the circumference and one measurement was made in the center of specimen. The flow testing instrument machine and wax specimen were immersed in water bath and held at testing temperature for 20 min. Constant axial load 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 (Fig. 5-8).

Fig. 5: Controlled water bath

Fig. 6: Sample placed under the axial load of vicat apparatus

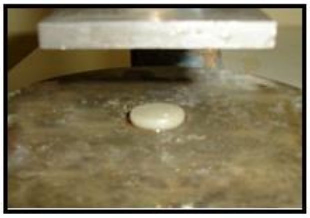

Fig. 7: Sample after applying axial load 40 °C and 45° C from right to left side

Fig. 8: Different wax flow at (20 ± 2)ºC

The experimental materials are divided into three groups and represented by codes as follow:
Group 1: This group includes Iraqi natural waxes (hard paraffin, soft paraffin and bees wax).

Group 2: This group contains experimental modeling waxes that consist of different mixtures of the 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 different samples of wax flow at (20 ± 2)ºC,40 'C and 45' C from right to left side 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. (Table1).

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

Results

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

Table 2: Descriptive statitics for flow at 40°C of control, groups 1, 2 & 3

		Flow at 40 °C (%)			Flow at 45 °C (%)		
Group							
		N	**Mean**	**SD**	**N**	**Mean**	**SD**
Control	Polywax	3	72.58	0.32	3	83.81	.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	.0365	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

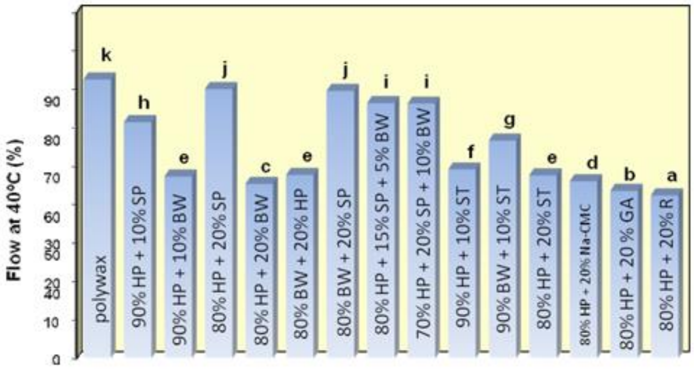

Fig. 9: Duncan's multiple range test of flow at 40°C of the control (1) and experimental the modeling waxes in groups 2 & 3

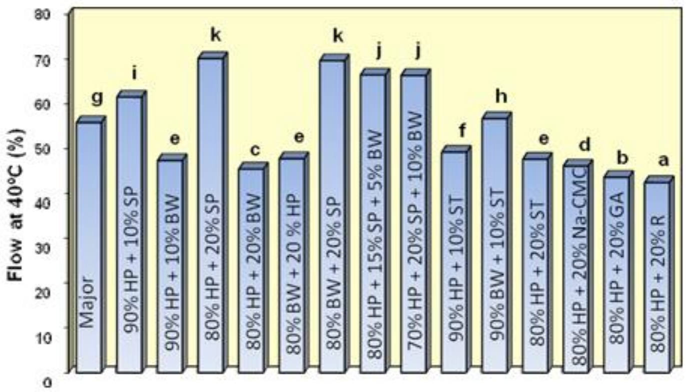

Fig. 10: Duncan's multiple range test of flow at 40°C of control (2) and experimental modeling waxes in groups 2 & 3

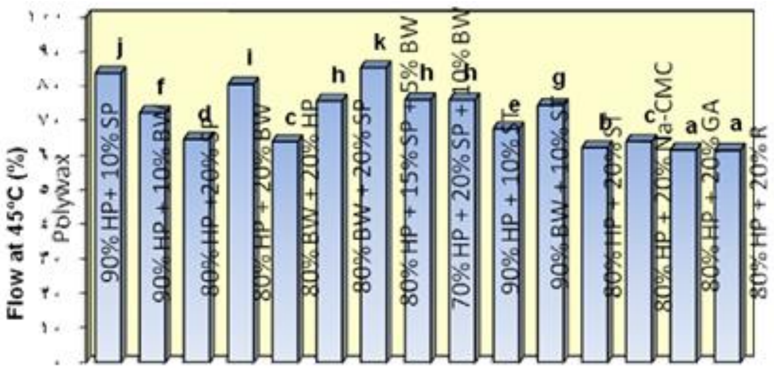

Fig. 11: Duncan's multiple range test of flow at 45ºC of control (1) and experimental modeling waxes in groups 2 & 3

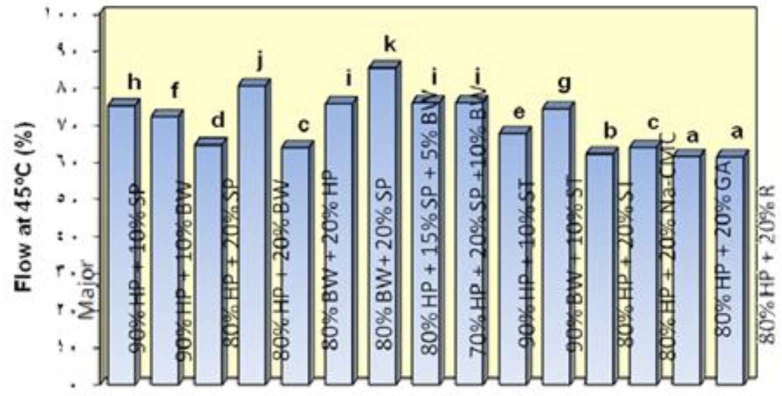

Fig. 12: Duncan's multiple range test of flow at 45ºC of the control (2) and experimental modeling waxes in groups 2 & 3

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 the 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 were considered as Type II dental modeling waxes.[8]

From the above results that obtained of flow at 40ºC and 45ºC, it has been seen that when the temperature of waxes increases, the percentage flow would also increase Table 2. These results were in agreement with previous researches, 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 showed that the soft paraffin gives the highest flow percentage than other experimental waxes and this can be due to the related to its low melting point, and when the temperature raise to 40ºC and 45ºC, this temperature is nearest to its melting point of wax, so it will flow extensively Table 2. This evidence in agreement with Craig and Powers results[5] who stated that the flow greatly increased as the melting point of the wax in approached. The soft paraffin had higher flow value than hard paraffin and this is in agreement with McCrorie study.[11]

The results data also showed that the degree flow of beeswax was less of soft paraffin, and this may be due to the presence of the 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 (Fig. 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 compound to paraffin wax produces the highest flow reduction than other additives; this refer to the fact that resins are commonly added to paraffin to produce harder material.[17]

Conclusions

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

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