

Evaluation of some physical properties of prepared molding wax in comparison to commercial available wax

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الخلاصة

الأهداف: تحدد الدراسة إلى تقييم الخواص الفيزيائية (مدى الانصهار والصلابة والتمدد الحراري) لخلطتين معدتين من الشمع الذي يحتوي على زيت البارافين بالمقارنة مع النوع التجاري. **المواد وطرائق العمل:** تم تحضير خلطتين أتمودجيتين من الشمع، الخلطة الأولى (M1) NO.1 والخلطة الثانية (M2) NO.2 وخضعت هاتان الخلطتين إلى ثلاثة اختبارات فيزيائية إلى جانب الشمع التجاري وهي مجموعة مقارنة، وهذه الاختبارات هي: 1 - اختبار مدى الانصهار، إذ تم غلق وملئ 5 أنابيب شعيرية من كل نوع من أنواع الشمع ووضعت داخل جهاز نقطة الانصهار الكهروحراري، وتم اعتبار بدء انصهار الشمع هي نقطة بداية الانصهار واعتبار تحول الشمع بالكامل إلى سائل هي نقطة انتهاء الانصهار. 2 اختبار اختراق الإبرة (اختبار الصلابة)، تم تحضير 5 عينات اسطوانية الشكل لكل نوع من الشمع واختبار الصلابة من قبل جهاز Vicate القياسي. 3- التمدد الحراري والخطي، لكل نوع من الشمع، تم تحضير (5) عينات ثم سخنت العينات إلى درجة 25 °C و 40 °C ويتم حساب المسافة بين علامات المرجع عند درجة حرارة الواطئة والتغير في الطول عند التسخين لدرجة حرارة أعلى قد تم تحديدها عن طريق الفرجار الإلكتروني الرقمي وتم حساب التمدد الحراري كنسبة مئوية من إجمالي طول العينة. **النتائج:** وأوضح التحليل الإحصائي لاختبار مدى الانصهار فرقاً معنوياً بين المجموعات المختبرة اختباراً في كل من الحد الأدنى والحد الأقصى لدرجة الانصهار. كان أعلى متوسط في نقطة انصهار الحد الأدنى والحد الأقصى لخلطة الشمع الأولى M1. وأظهر اختبار تحليل الصلابة فرق معنوي بين المجموعات المختبرة، ولوحظ أعلى متوسط ارتفاع الصلابة في الخلطة الثانية M2 والخلطة الأولى M1 ومجموعة المقارنة على التوالي. وأظهر تحليلاً لتمدد الحراري الخطي فرق معنوي بين المجموعات في درجة حرارة 25 °C و 40 °C وقد أظهرت مجموعة المقارنة من الشمع متوسط أعلى للتمدد الحراري عند درجة 25 °C و 40 °C من النوعين الآخرين من الشمع. **الاستنتاجات:** إن تحويل شمع الأسنان أعطى أفضل من جانب الخصائص الفيزيائية أكثر من الشمع التجاري.

ABSTRACT

Aims: to evaluate the some physical properties (melting range, hardness and thermal expansion) of two prepared mixtures wax contain paraffin oil in comparison with commercial type wax. **Materials and Methods:** Two mixtures of experimental modeling wax were prepared, mixture No.1 (M1) and mixture No.2 (M2). These two mixtures underwent three physical tests in compare to commercial modeling wax which is a control group, these tests are: 1- Melting range test, 5 capillary tubes were sealed and filled with all type of wax and placed inside electro thermal melting point apparatus. The start of melting wax considered the beginning melting point and when the wax completely became fluid, it is considered the ending melting point. 2 Needle penetration test (hardness test), 5 cylindrical shape samples for each type of wax were prepared and tested for hardness by standard vicate apparatus. 3- Linear thermal expansion, for each type of wax, 5 samples were prepared in a mold, the samples were heated to 25 °C and 40 °C and the distance between reference marks at the lower temperature and the change in length on heating to higher temperature is determined by electronic digital caliper and thermal expansion is calculated as percentage of the total length of sample. **Results:** Statistical analysis of melting range test showed a significant difference between tested groups in both minimum and maximum melting point. M1 had the higher mean in minimum and maximum melting point. Hardness test analysis showed a significant difference between tested groups, higher mean of hardness was observed in M2, M1 and control group respectively. ANOVA of linear thermal expansion showed a significant difference between groups at 25 °C and at 40 °C. The control group of wax observed the highest mean of thermal expansion at 25 °C and 40 °C than the other two types of wax. **Conclusion:** The modification of dental wax improved some of the physical properties than commercial one.

Keywords: mineral oil, wax, beeswax, paraffin oil.

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INTRODUCTION

Wax is widely used in dental practice in many forms, forming an inlay pattern, boxing, and making an impression for the registration of occlusal bite relationships each requires a specially formulated wax.

Dental waxes composed of natural and synthetic waxes, gums, fats, fatty acids, oils, natural and synthetic resins, and pigments of various types. The particular working characteristics of each wax are achieved by blending the appropriate natural and synthetic waxes and resins and other additives⁽¹⁾.

Waxes are generally characterized by their thermal properties such as melting point and softening temperature. The coefficient of thermal expansion is a major factor affecting accuracy. Dimensional stability is primarily a function of the magnitude of the stresses which become incorporated during thermal contraction after moulding. Important mechanical properties are hardness and the degree of flow which a material will undergo in its working temperature range.⁽²⁾

The ultimate goal of the combination of waxes and additives is to produce dental waxes that possess a set of given physical properties over specified range of temperature⁽³⁾.

Paraffin waxes are saturated hydrocarbon mixtures, normally consisting of a mixture of numerous alkanes. their desirable characteristics, high latent heat of fusion, negligible super-cooling, low vapor pressure in the melt, chemically inert and stable, self-nucleating, no phase segregation and commercially available at relatively low cost. The carbon atom chain lengths for paraffin waxes with a melting temperature between 30 and 90 °C. Increased length of the carbon atom chains increases molecular weight and results in a higher melting temperature of the material.⁽⁴⁾

Modelling waxes composed of complicated mixture of many constituents. It is also certain that the major component is paraffin wax with the addition of varying amounts of higher melting point waxes such as beeswax, carnauba wax and microcrystalline waxes.⁽⁵⁾ The softening temperature of waxes varies widely by wax type.⁽⁶⁾

With complicated component, waxes have a melting range rather than a single, sharp melting temperature⁽⁷⁾, because these waxes contain several types of molecules, each having a range of molecular weights⁽⁸⁾

Addition of carnauba to paraffin wax resulted in a reduction of the flow and an increase in the transition temperature when a definite increase in flow was observed. Addition of beeswax to paraffin wax decreased the flow only slightly.⁽⁸⁾

The expansion of dental waxes can be quantified as a percentage of the original dimension of the specimen. It is usually reported as a part per million of expansion per Celsius degree of the rise in temperature of the specimen. This number is called the coefficient of the thermal expansion of the wax.⁽⁹⁾

The wax may be expanded as much as 0.7% with an increase in temperature of 20°C (68°F) or contract as much as 0.35% when it is cooled from 37°C to 25°C (99°F to 77°F). The average linear coefficient of thermal expansion over such a temperature range is 350×10^{-6} per degree centigrade⁽¹⁰⁾

The linear thermal expansion properties of the waxes may be explained on the basis of strength of secondary valence forces and the transition points⁽³⁾

Standard penetrometer needle is used to determine the hardness of petroleum wax. The penetration force is determined by the total mass (100 g) of the needle, plunger, and 50 g weight⁽¹¹⁾.

Aim of the study: evaluate the melting range, hardness and thermal expansion of two prepared wax with different bees wax and paraffin oil ratio in comparison with commercial wax.

MATERIALS AND METHODS

Two types of experimental modelling waxes were prepared, the first type was prepared by a mixture of (65 gm paraffin wax, 30 gm bees wax and 5 gm paraffin oil as an additive), the second type was prepared by a mixture of (45 gm paraffin wax, 50 gm bees wax and 5 gm paraffin oil as an additive) and the commercial modeling wax (Major Prodotti, Italy) was used as a control group. The mixing is carried out at 40°C at the semi-

solid stage, because at this stage, wax particles interconnect with each other and form a wax mesh that cannot separate after that by subsequent heating and re-solidification.

Physical Tests:

1. Melting Range

The melting point was measured according to method reported by Vogel⁽¹²⁾ using Electrothermal melting point apparatus (CE, VWR, INTERNATIONAL). One end of each of the capillary tube had been sealed by inserting it horizontally into flame for a few seconds.

The capillary tube filled by tabbing of 0.1gm of prepared wax through opened end until the material reaches the closed end of the capillary tube and the material reach 3-5 mm length. The filled capillary tube is placed inside the Electrothermal melting point apparatus, then starts by turn-on the apparatus and watching the wax inside the capillary tube through the magnifier of the apparatus, at the same time the temperature in the thermometer is watched also until wax starts to melt, this point considers the beginning point of the melting range, and continue viewing the wax through the magnifier until become completely fluid, and this consider the ending point of the melting range.

2. Hardness Test:

A sample was prepared by fill cylindrical shape mold with (6 mm) thick and (10 mm) diameter by prepared and commercial wax. In this test, the standard vicat apparatus is used. Needle of specified dimension (1mm) and mass (300gm) was to be held vertically against the surface of the wax specimen and released, after (5 ± 0.1) second the needle is stopped; the vertical travel defining the penetrative (flow). The depth of penetration is measured by Electronic digital caliper at room temperature $(20 \pm 2)^{\circ}\text{C}$. Four measurements are made around the circumference and one measurement is made in the center of specimen. Then, the mean of five measurements was calculated for each sample.

3. Linear Thermal Expansion

A-Preparation of Mold

The mold was made from glass then

duplicated to Aluminum, the mold consists of three parts (mold, cover and holder), the dimensions of mold are $\{(305 \pm 0.1) \text{ mm length}, (22.2 \pm 0.1) \text{ mm width}, \text{ and } (14.3 \pm 0.1) \text{ mm height}\}$. A small plate on each side of the mold was prepared with dimensions, $\{(19 \pm 0.1) \text{ mm length}, (6.35 \pm 0.1) \text{ mm width}, \text{ and } (6.35 \pm 0.1) \text{ mm height}\}$. The dimensions of cover are $\{(305 \pm 0.1) \text{ mm length}, (22.2 \pm 0.1) \text{ mm width}, \text{ and } (10 \pm 0.1) \text{ mm height}\}$. The dimensions of holder are $\{(280 \pm 0.1) \text{ mm length}, (19 \pm 0.1) \text{ mm width}, \text{ and } (13 \pm 0.1) \text{ mm height}\}$, the holder having two opening from each sides, which is $\{(9.52 \pm 0.1) \text{ mm in width and } (12.7 \pm 0.1) \text{ mm in length}\}$ and located $(6.35 \pm 0.1) \text{ mm}$ from each end of the holder.^(13,14)

B-Preparation of Samples:

The prepared and commercial wax was placed in a metal pan. The pan was then placed in water bath and the wax starts to melt and becomes fluid, the wax reaches $(75 \pm 5)^{\circ}\text{C}$ and maintained at this temperature until pouring into mold. The melted wax is then poured into a mold that has been lubricated with separating medium (coldmoldseal, spofadent, Czech republic) (separating film for acrylic resin). The mold was preheated to $(55 \pm 5)^{\circ}\text{C}$. The Aluminum cover preheated to $(55 \pm 5)^{\circ}\text{C}$ was placed on the top of the mold, then a weight of 90N (9kg) is placed on the top of the mold for 30 min, after that the weight and cover were removed and excess wax trimmed away and the specimen was stored at room temperature $(20 \pm 2)^{\circ}\text{C}$ for 24 hours before testing.⁽¹³⁾

C-Procedure of Testing

The specimen is heated to 25°C and 40°C and the distance between the reference marks at the lower temperature and change in length on heating to higher temperature is determined. The wax specimen is placed under the holder and the reference marks pass through the openings of the holder. The distance between the reference marks is determined to the nearest 0.01 mm. The electronic digital caliper is used to make the measurement. An initial measurement is made in water after 20 min at $(25 \pm 0.1)^{\circ}\text{C}$. The 25°C temperature was used as zero point. The temperature is then raised

in water bath to $(40 \pm 0.1) ^\circ\text{C}$. The specimen remains 20 min at that temperature before the distance between reference marks is determined.⁽¹³⁾

Three measurements for each sample were obtained and the mean of these measurements was calculated. The change in length was measured and the thermal expansion is calculated as percentage of the total length of specimen.

RESULT

Melting Range:

ANOVA of tested samples (Table 1) for minimum melting point revealed that there was a significant difference between control and two groups of modified wax ($p < 0.01$).

Table (1): ANOVA of minimum melting rang for control and two prepared mixture

Source	Sum of squares	DF	Mean of square	F- value	Significant
Between groups	1195.6	2	597.8	815.1	0.00
Within groups	8.8	12	0.733		
Total	1204.4	14			

Duncan's multiple range tests (Figure 1) showed that M (1) has higher melting point mean ($59.6 \pm 0.89^\circ\text{C}$) than

that for control and M(2) (39.8 ± 0.44 and $41.2 \pm 1.09^\circ\text{C}$ respectively) and both mixture was higher melting point than control.

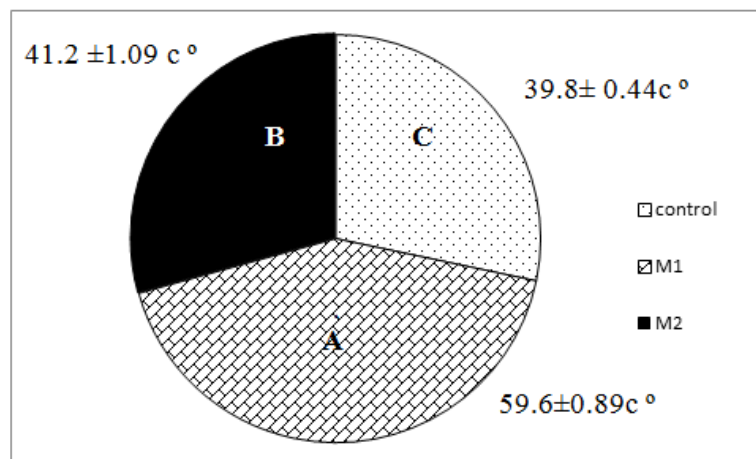


Figure (1): Duncan's multiples range test of minimum melting rang for control and two prepared mixture

While for maximum melting point ANOVA described (Table 2) that there

was significant difference between different tested groups ($p < 0.01$).

Table (2): ANOVA of maximum melting rang for control and two prepared mixture

Source	Sum of squares	DF	Mean of square	F- value	Significant
Between groups	29.7	2	14.8	13.1	0.01
Within groups	13.6	12	1.13		
total	43.3	14			

Duncan's multiple range tests (Figure 2) stated that M1 has higher mean for maximum melting point ($63.2 \pm 0.83^\circ\text{C}$)

in comparison to control and M2 and there was no significance difference between them.

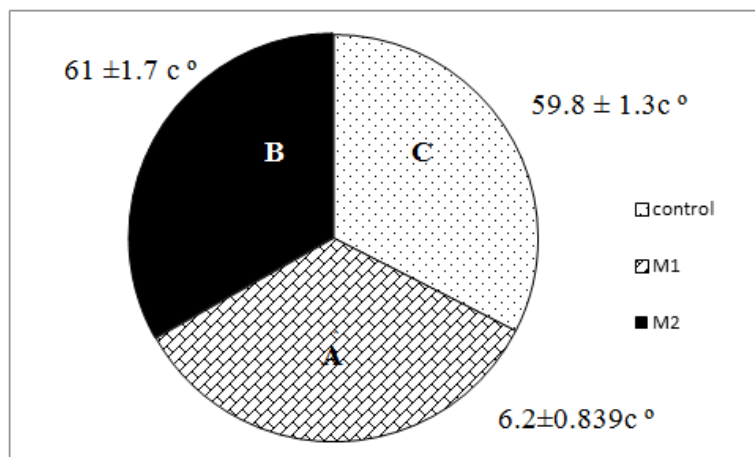


Figure (2): Duncan's multiples range test of maximum melting rang for control and two prepared mixture.

This result may be due to high percentage of paraffin wax (65%) in M1 in contrast to control and M2 samples which has high melting point due to high molecular weight of paraffin wax. These results are in agreement with McMillan and Darvell⁽⁷⁾, Craig and Powers⁽¹⁵⁾ who reported that the melting temperature generally increases with increasing molecular weight.

While in case of M2 the addition of soft paraffin to beeswax led to significant reduction in the minimum and maximum

melting point of beeswax. This is due to the difference in chemical composition of beeswax, hard and soft paraffin⁽¹⁴⁾

Hardness test:

Table (3) labeled that ANOVA of hardness test for tested sample showed that there was a significant difference between control and prepared wax ($p < 0.01$). While Duncan's multiple rang test (Figure 3) demonstrated that higher mean of hardness was for M2, M1 than control (0.94, 0.56, 0.18 respectively).

Table (3): ANOVA of hardness for control and two prepared mixture.

Source	Sum of squares	DF	Mean of square	F- value	Significant
Between groups	1.16	2	0.58	96.72	0.00
Within groups	.054	9	.006		
Total	1.21	11			

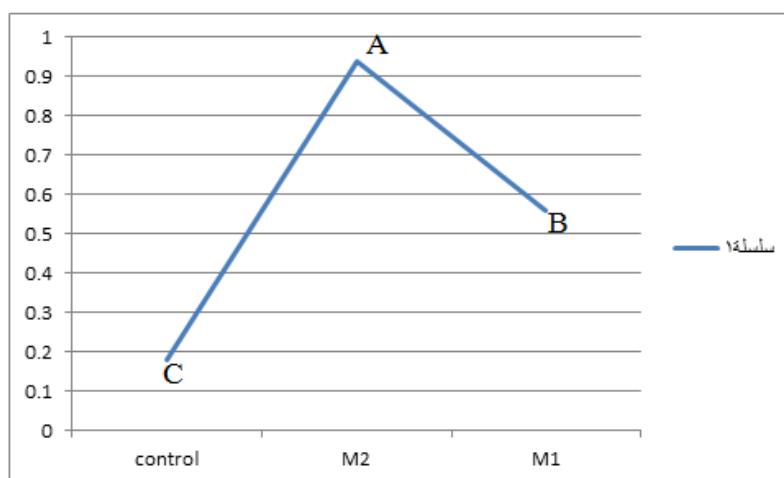


Figure (3): Duncan's multiples range test of hardness for control and two prepared mixture.

The results revealed that the control group was less hardness than M2 and M1. This may be related to the presence of hydrocarbon oils in paraffin waxes which lead to reduce their hardness (in M1 represent 65%). This is in agreement with Craig and Powers⁽¹⁵⁾ who reported that the paraffin waxes used in dentistry are refined waxes and have less than 0.5% oil. He also stated that hydrocarbon oils may be used to soften mixtures of waxes. while in case of M2 (beeswax represent 55%) the hardness increase which can be attributed to the effect of beeswax that

leads to increase the melting temperature of the mixture and increasing hardness and reduce the flow at room temperature. This is in disagreement with Powers and Craig⁽¹⁷⁾ and in agreement with Smith et al.,⁽¹⁹⁾

Linear Thermal Expansion:

Analysis of variance (ANOVA) (Table 4) explained that thermal expansion for tested groups at 25 c° was significantly different at $p < 0.01$. Duncan's multiple range tests (Figure 4) clarified that control group has higher mean value (0.78 %) for thermal expansion than two prepared mixture.

Table (4): ANOVA of thermal expansion at 25c ° for control and two prepared mixture.

Source	Sum of squares	DF	Mean of square	F- value	Significant
Between groups	1.6	2	0.8	20.8	0.00
Within groups	0.46	12	0.039		
Total	2.07	14			

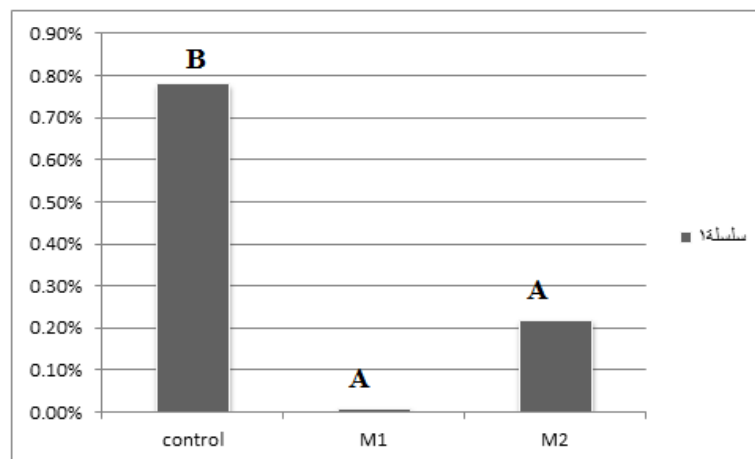


Figure (4): Duncan's multiples range test of thermal expansion at 25c° for control and two prepared mixture.

ANOVA (Table 5) clear up that there was significant difference between tested groups for thermal expansion at 40 c° at $p < 0.01$. And Duncan's multiple range test (Figure 5) showed that both prepared mix-

ture (M1, M2) has lower thermal expansion (0.87 ± 0.54 % and 0.77 ± 0.007 % respectively) than that for control group (1.56 ± 0.004 %).

Table (5): ANOVA of thermal expansion at 40c ° for control and two prepared mixture.

Source	Sum of squares	DF	Mean of square	F- value	Significant
Between groups	187	2	0.93	9.62	0.003
Within groups	1.16	12	0.097		
Total	3.04	14			

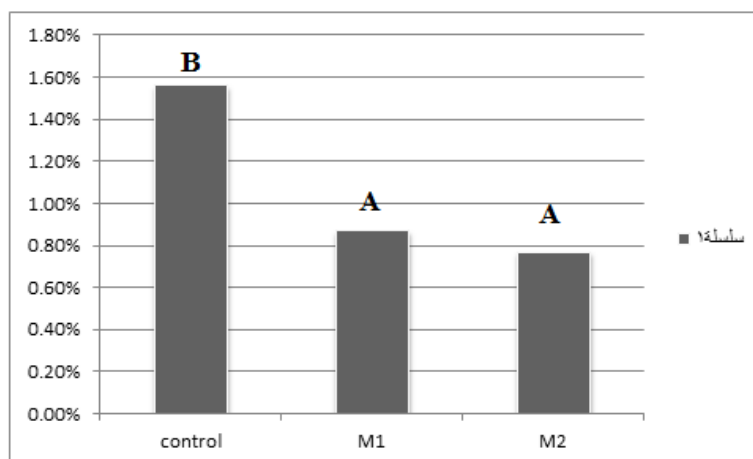


Figure (5): Duncan's multiples range test of thermal expansion at 40°C for control and two prepared mixture.

Dental waxes and their components have the largest coefficient of thermal expansion of any material used in restorative dentistry.⁽¹⁹⁾

The result revealed that M2 waxes had thermal expansion coincides with ADA specification No. 24, because their expansion not exceeding 0.8% on heating from 25°C to 40°C as shown in table (4 and 5).

This result may be due to the mineral waxes generally possess higher coefficient of linear thermal expansion than beeswax has. The mineral waxes expand more because they have weak secondary valence forces, which overcome easily by energy absorbed during a rise in temperature. This permits more movement of the wax components, thus allowing a greater amount of thermal expansion. Beeswax on the other hand, has high secondary valence forces because of the presence of high concentration of esters. Since the secondary valence forces restrict the movement of wax component, small coefficient of thermal expansion are observed until the melting range of the wax is approached.^(1,14,20)

CONCLUSION

The modification of dental wax was improving the physical properties than the commercial one. The high percentage of beeswax improves the hardness and thermal coefficient in compare to commercial wax. The presence of paraffin wax improve the melting rang of wax.

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