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Original Research Article

Effect of Different Paraffin's and Microcrystalline Waxes on the Mechanical Properties of Base Plate Dental Waxes

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Abstract: Waxes, included beeswax, as one of the most versatile natural substances ever used by man, have already been used in people's life widely for a long time. Current dental waxes are mixture of paraffin's, microcrystalline waxes, natural and synthetic raw materials. However, waxes characterize same disadvantage as plasticity and law stability of volume after melting and cooling. Aim of this study was to investigate the influence of different paraffin's and microcrystalline waxes on the properties of base plate waxes. Fife new compositions (S1-S5) were compared to four commercial products like base plates from Modelling wax, Modelling wax, Modellierwachs rosa standard, Modelling wax Ceradent. The plasticity and the volumetric shrinkage of the waxes after melting and cooling were measured. Samples S1-S5 to reflect of the requirements of the ISO standard and have the proper plasticity. Changing the paraffin's and microcrystalline waxes have a big influence on the plasticity of the final composition. Microcrystalline waxes decrease the wax contraction. Shrinkage after heating up to 110°C and cooling to 68°C is changing from one wax to other Modelling wax (Interdent) 4.5%, Modeling Wax Ceradent (Spofa) 8.9%, Modelling wax (Bredent) 9.8%, Modellierwachs rosa (Bego) 11.9%. During the re-melting process (inside wax warmers) waxes can change their properties like flowing and volumetric shrinkage due the thermal degradation. Such process can be reducing by producer adding thermal stabilizer, but this material can be consumed after several cycles. From clinical point of view is not recommended to heat and re-melt the base plate waxes for long time in wax warmer especially at higher temperatures.

Keywords: dental wax, plasticity, volume shrinkage

INTRODUCTION

In dentistry waxes are using for different purposes, included some of the highest precision work in dentistry, as well as cruder tasks. Belong them there is a big family calls Pattern waxes which include inlay, casting wax and baseplate waxes [1]. They are used to form the general predetermined size and contour of an artificial dental restoration, which is to be constructed of a more durable material like acrylic resins, dental alloys and ceramics.

Dental waxes are blends of several ingredients: natural waxes, synthetics waxes, natural resins, oil, fats, gums, and colouring agents. It can be simply defined as a substance that is solid at ambient temperature and when subjected to moderate temperatures, becomes a low viscosity liquid [2, 3].

Waxes are complex mixtures of organic polymers consisting hydrocarbons and their derivatives (e.g. esters and alcohols). Most mineral waxes have as their chief constituent's hydrocarbons ranging from 17 to over 44 carbon atoms. This material is relatively soft with a low melting range (50°C to 70°C), and the melting temperatures generally increase with increasing molecular weights [1-3]. Plant and animal waxes contain considerable concentrations of esters, and carnauba (a plant wax) contains 85% alkyl esters of various kinds. The principal ester in beeswax is myricyl palmitate. Beeswax has an intermediate melting range (60°C to 70°C) [4]. It is used to modify the properties of paraffin waxes because of its desirable flow properties at oral temperature.

Carnauba waxes come from a fine powder on the leaves of certain tropical palms. Material is characterized by quite high hardness, toughness, brittleness, and high melting points from 65°C to 90°C. It possesses the outstanding quality of increasing the melting range and hardness of paraffin waxes.

Paraffin's are the main ingredients of dental waxes; they consist the long unbranched hydrocarbon chains. A main source is crude oil distillation process. Popularity of this raw material in casting technic is due to lower price, and low melting point, which can influence on the mechanical properties of waxes at room temperature.

Microcrystalline waxes are mixtures of solid, purified, mainly branched chain, saturated microcrystalline hydrocarbons, monocyclic and polycyclic compounds as well as normal alkanes. They have higher molecular weights, with the average molecule containing 41 to 50 carbon atoms. They differ from paraffin waxes in that they have poorly defined, extremely smaller crystalline structure. It is of interest that microcrystalline waxes have less volumetric change during solidification than paraffin waxes have. They are added to modify the softening and melting ranges of the wax and to make it behave in a harder and more brittle or softer and more pliable manner.

The use of synthetic waxes and resins, though on the increase, is still limited in dental formulations, and the natural waxes continue to be the primary components. Synthetic waxes are complex organic compounds of varied chemical compositions. They have specific melting points and are blended with natural waxes. The average molecular weight of a wax blend is about 400 to 4,000, which is low compared with structural acrylic polymers.

The ISO standard has established a specification that includes three type of base plate wax [5]. Type 1 is a soft and is for veneers and contours. Type 2 is a medium hardness, designed for temperature weather for patterns to be tried in the mouth. Type 3 is the hardest base plate wax and is for patterns to be tried in the mouth in hot regions. In literature, there are only few articles which describe the measurements of physical properties of dental waxes. In scientific and patent papers, it is very difficult to find information about composition of the dental waxes; they are trade secrets of producers.

The aim of this study was to try to prepare composition which can be potentially applicable like a dental base plate wax and compare their several mechanical properties with popular dental waxes.

MATERIALS AND METHODS

For this study fife new waxes composition, in quantity 100g, were prepared (Table 1). The composition of the commercial products used in these tests are shown in Table 2 (Table 2). For melting the waxes it was used ordinary electrical kitchen Sencor (producent). Power of the equipment was fixed to not excess 110°C (checked by lab calibrated thermometer) during the melting process to avoid overheating of the raw material and their decomposition. Before melting each ingredient was balance on the Balance KPZ 2-05-3 (KP-Z WAAGEN). For one test 100g samples was made. Commercial products in the form of plates were melted in the same manner. During the heating material was mixed with laboratory paddles mixer MZ-1 (Dvoracek lab mixer), rotary seed 60 rpm. Mixing and dissolving process takes 1 hour after material was slowly cold to 60C and poured to the forms.

Table 1: Composition of different kinds of base plate waxes

	S-1	S-2	S-3	S-4	s-5
paraffin 50/52	37.3	44.3	39.4	37.3	25.7
Microwax DMW 6266	30	30		20	
bees wax yellow	3.6	3.6	3.6	3.6	3.6
Bees wax white	5	5	5	5	5
Sasolwax 7835			30	5	38.7
Ozocerite wax	23	16	20.9	18	25.9
paraffin 56/60				10	
Carnauba wax	1.1	1.1	1.1	1.1	1.1

Table 2: Commercial products used for tests.

Description	Composition	Batch Number
Modeling wax (Interdent)	Paraffin's, microcrystalline waxes	Ref 2312 lot 40001420 exp. date 02-2019
Modeling wax (Bego)	Paraffin's, microcrystalline waxes	Ref 4001 lot93553913113
Modellierwachs rosa standard (Bredent)	Paraffin's, microcrystalline waxes	Ref 43001645 lot D116861-2
Ceradent (Spofa Dental)	Paraffin's, microcrystalline waxes	Lot 2273363-5 Exp. 2017-11

Plasticity measurements

The plasticity of the all materials were tested according to ISO 15854:2005 – Dentistry - Casting and baseplate waxes, and contraction after melting and cooling. For plasticity measurements forms have diameter 10 mm and thickness 6mm (according to ISO requirements) [5]. Form was placed on the glass slabs and poured with liquid wax. After cooling the upper excess of the material was removed by the knife, to obtain 6 samples with flat surface. After 24 hours storage in laboratory condition samples were tested for the plasticity test at 23°C and 37°C. Thicknesses of the samples were measured using micrometer screw Tesa Jigit (Tesa) and write in lab notes like H1, before putting in to the ware and after. Samples were put for 10 minutes in water bath Tw10 (Julabo) in tested temperature for achieving the right temperature. After were load with the mass 2 kg using special equipment (make internally in workshop) describe in ISO standard for plasticity measurement. Wax due their viscoelastic properties can flow under load stress during 10 minutes. After such time samples were removed from water batch and the thickness was measured again with the same micrometer screw. The value was called H2. Plasticity of the wax in proper temperature was established from the equal: (H1- H2)/H1 *100%.

Measurement of the volumetric shrinkage of the waxes

This test was done according Archimedes law. Three samples 20 mm diameter and 40 mm of high were poured from each wax after melting and cooling to 60°C. Heating and cooling procedure was described at point 2.1 Plasticity measurement. After 24 hours at 23°C samples were measured.

The volumetric shrinkage is calculated as follows according Er. Charanjeet Singh Sandhu [6]. On beginning layer of coating of grease was put on two halves of die to make it leak-proof from water and align the two halves of die together. After die cavity was filled with water and measure its volume with the help of a measuring flask. This value was calling *Vd.* Water in a measuring flask was filled by the water and notes the initial reading (*Vi*). For the next step wax pattern was placed inside the measuring flask, which increase the volume and take the final volume was notice. (*Vf*). The difference between the two readings (*vf* - *vi*) gives the volume of pattern. The percentage of volumetric contraction of the pattern is given by the following expression.

$$\text{Shrinkage \%} = \frac{\{V_D - (V_f - V_i)\}}{V_D} \text{ x } 100$$

Flowing and volumetric shrinkage after several melting cycles

Sample S-4 was tested for plasticity at 23°C and 37°C and volumetric shrinkage after 6 times of re-melting to 150°C, heating 1 hours and cooling down to solidification at room temperature. This test was done to simulate the several heating and cooling cycles in dental lab when wax is storage at wax warmers.

RESULTS

Results from plasticity measurement were shown in Table 2 for commercial products and in table 3 for the preparing samples S1- S5

Table 3: Plasticity measurements at 23°C and 37°C for commercial products

	Interdent	Bredent	Bego	Spofa
Plasticity [%] at 23°C	0.46	0.38	0.22	0.12
	0.50	0.28	0.26	0.2
	0.53	0.29	0.27	0.15
Avg.	**0.50**	**0.32**	**0.25**	**0.16**
SD.	0.04	0.06	0.03	0.04
Plasticity [%]at 37°C	59	83.5	84.9	70.2
	62	83.8	83.2	73
	59.5	82.7	80.5	72.5
Avg.	**60.17**	**83.33**	**82.87**	**71.90**
SD.	1.61	0.57	2.22	1.49

Commercial products have different plasticity at 37°C from 60.17 to 83.33%.

Table 4: Plasticity measurement at 23°C and 37°C for samples made in point 2.1

	S-1	S-2	S-3	S-4	S-5
Plasticity [%] at 23°C	0.1	0.1	0.11	0.56	0.32
	0.12	0.1	0.12	0.68	0.34
	0.09	0.12	0.19	0.6	0.39
Avg.	**0.10**	**0.11**	**0.14**	**0.61**	**0.35**
SD	0.02	0.01	0.04	0.06	0.036
Plasticity [%]at 37°C	47.69	51.3	67.1	87.5	64.8
	49	50.6	65.9	90.4	67.5
	42.3	47.9	67.5	88.2	66.9
Avg.	**46.33**	**49.93**	**66.83**	**88.7**	**66.4**
SD	3.55	1.80	0.83	1.51	1.42

According ISO standard base plate waxes have the plasticity at 23°C not more 1% (to avoid distortion). Higher plasticity at 37°C avoids cracking of the wax during manipulation and improves the production process. Samples S 3 and S5 have good range of plasticity.

Plasticity of the waxes is changing due the composition from 46.33% to 88.7%

Fig-1: Visible shrinkage of waxes patterns (from left Bego, Interndent, Bredent)

Table 5: Shrinkages of the commercial waxes.

	Interdent	Bredent	Bego	Spofa
Shrinkages	4.5	9.6	11.8	8.7
	4.60	10	12	8.9
	4.60	9.8	11.8	9.2
Avg.	**4.57**	**9.80**	**11.87**	**8.93**
SD	0.06	0.20	0.12	0.25

Between comprisal products wax from Interdent has the lowest volumetric shrinkage (4.57%) and the highest value was obtained with Bego (11.87%)

Table 6: Shrinkage of samples made during this work

	S-1	S-2	S-3	S-4	S-5
Shrinkages	9.20	8.30	7.96	5.57	9.55
	10.50	8.90	8.12	6.21	9.23
	10.50	9.00	8.12	6.05	9.55
Avg.	**10.07**	**8.73**	**8.07**	**5.94**	**9.44**
SD	0.75	0.38	0.09	0.33	0.18

Samples S-4 has the lower volumetric contraction 5.94 % and sample S-1 the biggest one 10.07%. For the clinical point of view, wax should have as lower shrinkage as possible, to avoid any mistakes during working procedures. Sample S-4 with lower shrinkage can be used like base plate material.

Table 7: Sample S-4 was re -melted 5 times and cooling down for testing the changing in plasticity

	1	2	3	4	5
Plasticity 23C	0.5	0.4	0.4	0.35	0.32
	0.48	0.4	0.35	0.35	0.34
	0.40	0.43	0.34	0.3	0.39
Avg.	**0.46**	**0.41**	**0.36**	**0.33**	**0.35**
SD	0.05	0.02	0.03	0.03	0.036
Plasticity [%]at 37C	75.5	70	67.1	67.5	64.8
	73	74.3	65.9	65.5	63.9
	71	73.1	67.5	69.8	66.9
Avg.	**73.16667**	**72.46667**	**66.83**	**67.6**	**66.4**
SD	2.25	2.22	0.83	2.15	1.54

After several melting process, base plate wax is change and the plasticity is significantly reduced.

Table 8: Volumetric shrinkage after 5 times re- melting.

	1	2	3	4	5
Shrinkages	6.21	6.23	6.45	6.72	6.78
	5.94	6.34	6.51	6.81	6.90
	6.12	6.34	6.25	6.54	7.10
Avg.	**6.09**	**6.30**	**6.40**	**6.69**	**6.93**
SD	0.14	0.06	0.14	0.14	0.16

DISCUSSION

Flow results from the slippage of wax molecules over each other. It is a measure of a wax's ability to deform under light forces and is analogous to creep. Usually, maximum flow is required while the adaptation is being carried out, while minimum flow is desirable when the process is complete. The magnitude of flow will influence the degree of setting expansion of dental waxes [3].

Commercial waxes have the plasticity below 1% at 23^{o}C, and like a soft base plate waxes passed ISO standard requirements. It means that work made from such wax is stable at room temperature. All tested samples S-1, S-5 passed the same requirement. For Type 1 plasticity at 37^{o}C has to be between 5-90% and it is very bright range. Commercial products have the plasticity from 60-83%. Too low plasticity make the wax brittle during clinical procedure, it couldn't properly adapt to oral mucosa during placement in patient's mouth. In such case sample S-4 has the similar plasticity like other products existing on the market. For the plasticity, big influence has the percentage composition of raw materials. For example, increasing the concentration of paraffin with low melting point (50/52^{o}C) it is possible to increase the plasticity at 37^{o}C from 46.33% to 49.93% (samples S-1 and S-2). If the composition has the higher melting point paraffin S-4, material has even higher plasticity at 37C- 88.7%. On the flowing properties, big influence has the type of microcrystalline wax softer type increase the flowing of the wax at high temperature (Sassolwax 7835 compare to Microwax DMW 6266).

Craig observe the influence between raw materials flowing properties Most of the mineral waxes had about a 10° C. range between 1 and 70 per cent flow, which indicated that these waxes were softening gradually over a broad temperature range. Mineral waxes are straight- or branch-chained hydrocarbons, and the secondary valence forces in these waxes are rather weak and gradually dissipated as the temperature is increased [2].

Second important information form Craig article is that plant waxes also required temperatures close to their setting ranges to produce 50% flow. Due to the presence of esters groups in these waxes, the secondary valence forces are rather strong, and a high temperature is necessary to overcome these forces.

In general, waxes with lower melting temperatures have a greater ductility at any temperature than those with higher melting temperature [3].

Ito *et al* [9] investigated the relationship between flow characteristics, bending strength, and softening temperature of paraffin and dental inlay waxes to casting shrinkage. They found that the casting shrinkage decreased as the flow of the wax pattern increased.

Volumetric shrinkages of the waxes are a big problem in several applications. Grzeskowiak and others, describe the several re-melting and cooling process of the jewelry waxes (from 1-15). Authors of this article fond correlation between contraction and heating of the waxes. The linear shrinkage of waxes increased together with the increasing number of melting cycles from 1.5% to 3.66% [7].

The same trend was observed during current investigation. After each re-melting process plasticity and volumetric shrinkages were increasing. This process can be explained by thermal decomposition of the wax like all the polymeric materials. At higher temperature with contact with oxygen from air, some polymers can degrade. Paraffin’s are long chain hydrocarbons, which can be oxidized or breaking down in to small molecules. Natural raw materials like bees wax or carnauba wax have and ester acid and alcohols groups in their composition. At higher temperature, such acid can speed up this degradation process. Producers of paraffin’s and microcrystalline waxes adding to their products some antioxidants, for thermal stability, but during several re-melting process such material are consumed and the degradation process can start.

Some aspects about exposure of dental waxes at very high temperature was noticed by Kotsiomiti. For one product, the flow at 40 +/- 0.5 degrees C was reduced by 25.3% following heating above 200 degrees C. A decrease of the elastic modulus at 20 +/- 1 degree C by approximately 66% was observed in some cases after the heating temperature had been increased to 300 degrees C [8].

Shrinkages of commercial products are changed from one producer to other, from 4.57% to 11.87%. Changing the ration between microcrystalline waxes to paraffin is possible to reduce the volumetric shrinkage from 10.07% to 5.94%. But when the composition contains only paraffin’s volumetric shrinkage is very high. During solidification and cooling, there is a volumetric contraction that varies from 11% to 15% [9].

Microcrystalline wax can influence on the wax properties. Zhang in his work observe that addition of microcrystalline wax from 1-20% increase the tensile strength. When the concentration reaches 20%, the tensile strength was five times the value of that of the crude paraffin wax. Similar observation was done with volumetric shrinkage from more than 25% to 6% when the concentration of microcrystalline wax reached 30%.

Er. Charanjeet observed a significance effect of wax temperature, initial die temperature and ambient temperature on final wax pattern [6]. If melted wax has a higher temperature, than the contraction of the wax pattern is higher.

Waxes possess other phenome due to the residual stress; there will be a significant warpage happened to waxes. This is also called the “memory effect”. Therefore, they should not be heated more than necessary for achieving a sufficiently plastic quality for use. The longer the wax pattern is left before being invested, the greater the distortion that must be result [3].

Waxes in different temperature possess different physical properties. In lower temperature bellow their glass transition temperature they are brittle. At temperatures between the melting point and the transition temperature, the wax is partly fluid and partly solid, i.e. it is VISCOELASTIC. Attempting to shape the wax at temperature below the melting point will not result in full and permanent deformation [11].

The flow of waxes depends not only on the various forces, but also strongly on the temperature [12].

CONCLUSIONS

Commercial base plate waxes are mixture of several raw materials: paraffin’s, microcrystalline waxes, and natural products like bees’ wax, carnauba wax and other.

During the re-melting process (inside wax warmers) waxes can change their properties like flowing and volumetric shrinkage due the thermal degradation. Such process can be reduced by producer adding thermal stabilizer, but this material can be consumed after several cycles.

From clinical point of view is not recommended to heat and re-melt the base plate waxes for long time in wax warmer especially at higher temperatures.

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