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Research Report

Mechanical properties of carving wax with various Ca-bentolite filter composition

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ABSTRACT

Background*: The carving wax is used as a medium in dental anatomy study. This wax composes of many waxes and sometimes a filler is added. Carving wax is not sold in Indonesian market. Whereas the gradients of carving wax such as beeswax, paraffin and bentonite are abundant in Indonesia. Based on that fact, to make high quality and standard,the exact composition if this carving wax should be known.* ***Purpose****: The aim of this study was to investigate the effect of carving wax composition with Ca-bentonite filler on the melting point, hardness, and thermal expansion.* ***Methods****: Five carving wax compositions were made with paraffin, Ca-bentonite, carnauba wax, and beeswax in ratio (% weight): 50:20:25:5 (KI), 55:15:25:5 (KII), 60:10:25:5 (KIII), 65:5:25:5 (KIV), 70:0:25:5(KV). All components were melted, then poured into the melting point, hardness, and thermal expansion moulds (n = 5). Three carving wax properties were tested: melting point by melting point apparatus; hardness by penetrometer; thermal expansion by digital sliding caliper. The data were analyzed statistically using One-Way ANOVA and* $LSD_{0.05}$. ***Result****: The Ca-bentonite addition influenced the melting point and thermal expansion of carving wax with significant differences between KI and other groups (p < 0.05). Ca-bentonite addition influenced the carving wax hardness and the mean differences among the groups were significant (p < 0.05).* ***Conclusion****: Ca-bentonite filler addition on the composition of carving wax influenced the physical and mechanical properties. The carving wax with high Ca-bentonite concentration had high melting point and hardness, but low thermal expansion.*

Key words*: carving wax, Ca-bentonite, melting point, hardness, thermal expansion*

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INTRODUCTION

A thorough knowledge of the surface anatomy of each tooth is essential in restorative dentistry. Three approaches to study tooth form are tooth drawing, wax block carving and tooth wax-up. Carving wax is used by dental students for dental anatomy study. Carving wax is not sold in Indonesian market. Whereas the gradients of carving wax such as beeswax, paraffin and bentonite are abundant in Indonesia. The production of carving wax does not need complicated method and equipments. Based on that fact, to produce high quality and standard, the exact composition of this carving wax should be known.

Wax block carving is to produce a wax tooth by carving it from a rectangular piece of wax.[1] Carving wax consists of high quality waxes similar to inlay wax.[2] Generally, the main ingredient of inlay waxes is paraffin.[3] Inlay wax may contain of 60% paraffin, 25% carnauba, 10% ceresin, and 5% beeswax.[4,5] This mixture is carried out to produce a material with the required properties for a specific application.[6]

Paraffin is a mixture of solid hydrocarbon, obtained from petroleum.[7] Paraffin consists of straight-chained hydrocarbon with 26–30 carbon atoms and has melting range between 40 and 71° C and thermal expansion coefficient of 307×10^{-6}/° C between temperature of 20 and 27.8 degree Celcius.[5] The hardness of paraffin is about 9–16 mm of penetration depth measured by ASTM D-1321.[8] In Indonesia, paraffin is produced by Pertamina in Cepu, Cilacap, and Balikpapan unit productions.

Carnauba wax is an exudates from the pores of the leaves of Brazilian wax palm tree (*Copernicia prunifera*).[7] Carnauba wax is composed of straight-chain esters, alcohols, acids, and hydrocarbons. This wax has melting range between 84 and 91° C and thermal expansion coefficient of 156×10^{-6}/° C between temperatures of 22 and 52 degree Celcius.[5] The hardness of carnauba wax is relatively high, 2–8 mm penetration depth.[8] Carnauba wax is used for increasing melting point and hardness of paraffin.[5] Although Brazilian wax palm tree is not grown in Indonesia, carnauba wax product is imported by chemical distributors.

Beeswax is a substance obtained from bee honeycombs and consists of ester complex mixture, saturated and unsaturated hydrocarbons, and organic acid with high molecules weight.[7] Two kind of beeswaxes are used in dentistry, yellow and bleached beeswax.[10] Beeswax has melting range between 63 and 70° C and thermal expansion coefficient 344×10^{-6}/° C (between temperatures of 22–41.2° C) for yellow beeswax and 271×10^{-6}/° C (temperature 22–38.6° C) for bleached beeswax.[5] The hardness of beeswax is between 8–23 mm penetration depth.[8] Beeswax is produced from many honey bee centres in some region of Indonesia.[11]

The accuracy and ultimate utility of the casting resultant depend largely on the accuracy and fine detail of the wax pattern. Inlay wax must possess certain, very important, physical properties. The desirable properties of inlay wax are; a) when softened, the wax should be uniform; b) the color should be contrast compared with the die material or prepared tooth; c) the wax should be no flakiness or similar surface roughening when the wax is bent and molded after softening; d) The inlay wax should leave no solid residue in excess of 0.10% of the original weight when vaporized at 500° C; e) The wax should be carved to a very thin layer; and f) the wax should be completely rigid and dimensionally stable at all time until it is eliminated.[3] Inlay wax should have a low thermal contraction, correct flow properties, and easy to carve without chipping or flaking.[12] Inlay wax may be softened over a flame or water at 54–60° C.[3]

Manufacturer could control the melting point and softening temperature of dental waxes by blending many wax components from mineral, animals, and plants.[6] Natural resins may be added to paraffin waxes to improve their tough, film forming characteristics, and melting ranges.[5] Some inlay wax formulation contain a compatible filler to control expansion and shrinkage of the wax products.[3]

Inorganic filler can act as an effective hardener for natural wax blended for dental applications. The addition of in organic silica filler up to 10% in paraffin and beeswax blend could increase hardness and decrease melting point.[13] Filler addition in resins and waxes will reduce plasticity of matrix, increase hardness, and reduce thermal expansion.[14]

Bentonite is one of inorganic filler. Bentonite usually formed from weathering of volcanic ash, most often in the presence of water.[15] Bentonite is used as a bleaching material, additive material, filler, and drilling mud.[16] Bentonite can be used in cement, adhesives, ceramic bodies, and cat litter. Bentonite is also used as a binding agent in steel making industry and a therapeutic face pack for the treatment of acne/oily skin.[15] For industrial purposes, two main classes of bentonite exist: Wyoming type bentonite (Na-bentonite) and meta bentonite (sub bentonite, Ca- bentonite). Natural Ca-bentonite expand less but after activated by acid has good absorbent properties, dispersed in water, and ion-exchange properties (especially by calcium and magnesium ions).[16]

In general, filler materials are added to certain composition in purpose to increase the hardness of mixture, increase toughness quality, avoid bubbles, avoid flaking, smoother carving, improve accuracy, and free of tackiness to models and instruments.[17] The application of Ca-bentonite as a filler in carving wax would give chemical reaction between Calcium and Magnesium ions with hydrogen atoms from hydrocarbon chain of paraffin to form Calcium salt bond and consequently increase physical and mechanical properties of carving wax. The aim of this study was to investigate the effect of carving wax composition with Ca-bentonite filler toward the melting point, hardness, and linear thermal expansion properties.

MATERIALS AND METHODS

The materials used in this research were paraffin (Pertamina, Indonesia), yellow beeswax (SEA, Indonesia), carnauba wax (Bratachem, Indonesia), inlay wax (GC, Japan), Ca-bentonite (Bratachem, Indonesia). Five groups of carving wax with Ca-bentonite filler were composed (Table 1).

Two thousands grams of each composition of carving wax was prepared. The carving waxes were prepared by melting the ingredients together under continuous stirring

Table 1. Carving wax compositions

Composition	Ingredients concentration (% weight)			
	Paraffin	Carnauba	Ca-bentonite	Beeswax
K I	50	25	20	5
K II	55	25	15	5
K III	60	25	10	5
K IV	65	25	5	5
K V	70	25	0	5

at the temperature below 100° C on the hot plate. Then, the mixtures were poured into the moulds and stored at room temperature for 24 hours prior to testing. The mixtures were poured into cylindrical metal mould for hardness specimens (35 mm height and 55 mm diameter), bar metal mould (22.2 × 305 × 14.3 mm), and plate polycarbonate mould for melting point (50 × 10 × 2 mm). Five specimens were made from each composition for each tests. Commercial inlay wax product was melted and 5 specimens were prepared for linear thermal expansion testing.

The melting point was measured by melting point apparatus (Fischer John, UK). The carving wax plate was cut into 5 × 5 × 2 mm, then put on the specimen plate and the temperature when the wax was melted is observed in 0.1 degrees Celcius accuracy. Hardness was measured based on ASTM D 1321 standards using penetrometer (Setamatic, UK).[9] Specimens were immersed in waterbath at 25° C for 1.5 hours, then, moved into the waterbath under the penetrator needles. The penetration were measured by moving down the penetrator needle to the wax surface until the needle cannot penetrate the wax anymore. The penetration depth was measured in 0.1 mm accuracy.

Linear thermal expansion was measured based on ANSI/ADA Specification number 24.[18] After the specimens is prepared, it was stored at 37° C for 24 hours before testing. The specimens were immersed in bath water at 25° C for 20 minutes, then the specimens length were measured by digital calipers (0.01 mm accuracy). After that, the specimens were immersed again in bath water at 40° C for 20 minutes and the specimens length were measured again. The percentage of linear thermal expansion were calculated from the subtraction of two length measurements divided by the initial length of specimens at 25° C.[19] The data were analyzed statistically by ANOVA and $LSD_{0.05}$.

RESULT

Five composition of carving waxes with different concentration of Ca-bentonite filler were tested for melting point, hardness (penetration depth), and linear thermal expansion. The means and average of melting point, hardness, and linear thermal expansion showed in table 2. The linear thermal expansion of commercial inlay wax products was 0.57 ± 0.06%. The composition of carving wax influence the melting point, hardness, and linear thermal expansion significantly (Table 3). The $LSD_{0.05}$ results of carving wax melting point showed significant differences between KI group and KII, KIII, KIV, KV groups. The $LSD_{0.05}$ results of carving wax hardness (penetration depth) showed significant differences among all groups. The $LSD_{0.05}$ results of carving wax linear thermal expansion showed significant differences between KI group and other groups.

DISCUSSION

The results showed the variation in melting point average of carving waxes. The group without filler had the lowest melting point and the group with 20% filler had the highest melting point. Those value were lower than the commercial inlay wax product (GC, Japan) from the previous study (59.20° C).[20] But, the melting point of carving waxes were still in the range of desirable softening points (54–60° C).[3] The result of this research was in accordance with Kotsiomiti & McCabe[13] results that the filler addition up to 10% prohibit the melting properties of wax mixtures. Based on that research, the higher temperature was needed in the melting of wax mixtures with filler. The inorganic filler particles in wax mixtures had function as seeds to form gel structure. The energy that was accepted by the

Table 2. Mean and average of melting point, penetration depth and linear thermal expansion of carving wax

Carving wax compositions	Melting point (° C)	Penetration depth (mm)	Linear thermal expansion (%)
KI (50:20:25:5)	55.00 ± 1.36° C	912 ± 0.39	0.17 ± 0.01%
KII (55:15:25:5)	52.40 ± 1.16° C	10.60 ± 0.98	0.37 ± 0.04%
KIII (60:10:25:5)	53.06 ± 0.59° C	12.43 ± 0.95	0.38 ± 0.03%
KIV (65:5:25:5)	53.13 ± 1.12° C	14.06 ± 0.38	0.41 ± 0.06%
KV (70:0:25:5)	52.93 ± 0.75° C	20.13 ± 1.56	0.44 ± 0.04%

Table 3. ANOVA results

	F	Significancy
Melting point	4.554	0.009
Penetration depth	98.246	0.000
Linear thermal expansion	31.408	0.000

wax was absorbed by gel structure of filler particles, so the amount of heat absorbed by paraffin wax was decreased. This caused the increasing of wax melting point.

The average penetration depth of carving wax were in the range of 20.13 to 9.12 mm. The higher filler concentration showed the increasing of carving wax hardness, that expressed by lower penetration depth. The hardness value of the group without filler was lower than the commercial inlay wax (GC, Japan) from Irnawati's study (14.12 mm).[20] The results was similar with previous study on series of filler content of composite restorative materials that showed the filler influence with strong positive correlation on the elastic properties.[21] The carving wax with 5% filler showed higher hardness than the previous study. Some formulation of inlay wax contain a compatible filler to control expansion and shrinkage of the wax product.[3] Silica as in organic filler effectively played important role in the increasing of wax mixture hardness.[13] The linear thermal expansion of carving waxes were in variation but lower than the inlay wax product (GC, Japan). Those value were also lower than the typical inlay wax (0.45%).[3] The linear thermal expansion of carving waxes fulfilled the ANSI/ADA Specification. no. 4 standard (0.6%) and also the ISO specification (0.8%) from temperature 25 to 40° C.[18,22]

Paraffin wax structure consists of covalent bonds with the non polar coordination. The non polar bond with other molecules had weakness properties, making the other molecules moved easily. The smaller the amount of non polar bond in the compound caused the smaller the expansion when the material was heated.[22] In general, the filler was mixed in physicochemically with wax while decreasing the paraffin volume. This phenomenon caused the decreasing of expansion in heating and contraction in cooling of carving wax.

It was comcluded that serums was with high ca-bentolite filter composition had high melting point and hardness, but low linear thermal expansion.

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