Thermal Properties of Dental Wax: A Relation between Thermal Change of Waxes and Setting of Cast Investments

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ABSTRACT

Thermal properies of dental waxes and cast pattern resin were examined by thermal expansion measurement in test temperature range 20 to 60°C. Thermal expansion curves showed a softening of dental waxes before the melting temperatures, showing that transition temperature ranged from 34 to 52.5°C depending on such treatment of dental waxes as melting, carving and thermal tratment. Thermal coefficient values calculated were 219 to 600×10^{-6} (1/deg) or 217 to 512×10^{-6} (1/deg) in a range of 25–30 or 25–37°C which had 0.09 to 0.48%, whereas chemically-cured resin (so-called cast pattern resin) had very small thermal expansion (0.08, 0.14%) with 122 and 160×10^{-6} (1/deg) as a thermal coefficient. Using differential scanning calorimetry (DSC) analysis at isothermal temperature (25°C) of dental cast investments, the heat for setting was calculated on DSC curves. The temperature increase in ethyl silicate-bonded investment (about 1°C) was very low than that in gypsum (about 38°C), whereas the phosohate-bonded and gypsum-bonded investments had intermediate values (about 5 to 9°C) between the former two. This study showed clearly that the combination of dental waxes and dental cast investment was important to prevent a distortion or softening of dental waxes during setting of dental cast investments. As described in the previous report that dimensional accuracy of titanium or glass ceramic was obtained exactly between some fitness values when appropriate combination was applied, the effectiveness of this result was confirmed here.

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INTRODUCTION

A wax pattern is prepared to make an inlay or crown for the casting, because the cavity is prepared in the tooth and the pattern is carved directly or on a die. The procedure is called to be the direct technique or the indirect technique. According to the revision of the ADA specification No. 4 for Dental Inlay Casting Wax[1], the *hard* wax was deleted and Type I is for *medium* employed in direct technique and Type II for *soft* waxes in indirect techniques. Their waxes needed an accurate reproduction of the missing tooth structure, and the wax pattern formed the outline of the mould cavity into which the dental matal alloys were cast. The maximal flow property for Type I waxes at 37°C was 1%, whereas the minimal flow of 70% at 45°C and a maximum flow of 90% for Type I and Type II, respectively. As an additional property, thermal properties were thermal conductivity and thermal coefficient. The thermal conductivity was low and thermal coefficient was 350×10^{-6} (1/deg) over the temperature range 25 to 37°C[1]. The linear thermal expansion was 0.7% with an increase in temperature of 20°C. We considered that thermal properties of dental waxes were analyzed effectively by the application of thermogravimetry, differential calorimetry and differential thermal analysis which were usually used[2–8]. This study was to examine thermal properties of dental waxes using thermal analysis of thermal expansion during heating to higher test temperatures until the melting, and to estimate them by the analysis of heat for setting of cast investments.

MATERIALS AND METHODS

Dental waxes investigated were indicated in Table 1, with code P, K, S and CP, brand name and manufacturer.

Table 1 Dental waxes, with code, brand name and manufacturer. Type I and Type II were used according to the definition of ADA specification.

Code		Brand name	Manufacturer
P	P1	PREPON Red	Bayer Dental, Germany
	P2	PREPON Green	
K	K1	KERR Hard Type I	Kerr Mfg Co, USA
	K2	KERR Regular Type II	
S	S1	Mity wax Hard	Shofu Inc, Tokyo
	S2	Mity wax Soft	
CP		Cast pattern resin	Nisshin Co, Osaka

Type I and Type II waxes were the *medium* and *soft* employed for direct and indirect techniques, as indicated as P1 and P2 in code P.

Dental cast investments were used to calculate heat for setting and the related temperature increase of dental waxes and cast pattern resin. One ethyl silicate-bonded investment (code E), one phosphate-bonded investment (code PB), two gypsum-bonded investments (code GC, GQ) and gypsum (hemihydrate; code GA) were tested. Silica-sol liquids used were 100% hydrolyzed liquids, HAS-1 (pH=1.1) or HAS-6 (pH=1.2) (Colcoat Co, Tokyo) or experimental ethyl silicate (pH=3.5), to mix cast investment powders (code E) (α cristobalite/α quartz =55/45 (wt%)) with ethyl silicate. The mixtures, comprizing ammonium carbonate solution (1.1 mL) for code E1 and E2 or ammonium aqueous solution (1.1 mL) for code EE added to silica-sol liquid (16.0 mL), was used as the liquid for the powder at a ratio of liquid/powder (0.34). Code PB and G were commercial phosphate-bonded (Ceravest G, GC Co, Tokyo) and gypsum-bonded investments (Cristobalite P investment, Shofu Inc, Tokyo; Quarz investment, Shofu Inc, Tokyo). Code GA was hemihydrate gypsum (MARUISHI Co, Tokyo).

Thermal expansion was measured for dental waxes (code P, K, S) and cast pattern resin (code CP) using thermal analyzer (Thermoflex, RIGAKU Co, Tokyo). The heating rate used was 1°C/min under the atmosphere which was degassed by the vacuum pump. The specimen samples (dimension=5 mm diameter×12 mm long) were obtained as follows: molten waxes (M), carved waxes (C) and thermally-treated waxes (T) for dental waxes, or chemically-cured resin for code CP. Seven test samples were used for each code under thermal analysis.

Table 2 Cast investments, with code, powders and liquids.

Code		Powders	Liquids
E	E1	α cristobalite/α quartz	HAS-1
	E2	α cristobalite/α quartz	HAS-6
	EE	α cristobalite/α quartz	Ethyl silicate
PB		α cristobalite/α quartz	Colloidal silica
G	GC	α cristobalite	Distilled water
	GQ	α quartz	Distilled water
GA		hemihydrate	Distilled water

Setting behaviours of cast investments and gypsum were measured using DSC analysis (differential scanning calorimetry; DT-50, Shimadzu Co, Kyoto), and heat for setting was calculated using gallium (fusion=82.3 J/g). The increased temperature of dental waxes (five samples for DSC analysis) was calculated with heat for setting of cast investments. The mixed investment (30 mg) was weighed out into an aluminum sample pan (1.5 mm height ×6 mm diameter) which was hermetically sealed by mechanical crumpling. An another pan (6 mm height×6 mm diameter) was used for gypsum (code GA). All measurements were carried out at 25°C, beginning at 1 min after setting the sample in the pan. The difference in temperature between the pan containing the mixed sample and a reference (empty pan) was obtained, showing that DSC curve had heat for setting with the increased time after mixng.

RESULTS

Figures 1, 2 and 3 show thermal expansion change when measured by DSC analysis for code P, code K, and code S and CP, respectively. The change of thermal expansion, which increased until certain test temperatures when test temperatures changed to 60°C, had different trends among dental waxes and cast pattern resin tested.

Table 3 indicates dental waxes (code P, K, S) and cast pattern resin (code CP) which were obtained by the molten waxes and the cured resin. The values of thermal coefficient ranged from 219 to 568×10^{-6} (1/deg), whereas code CP had 160 and 122×10^{-6} (1/deg). Thermal expansion expansion values ranged from 0.09 to 0.48% for dental waxes, whereas code CP had 0.08 to 0.14%.

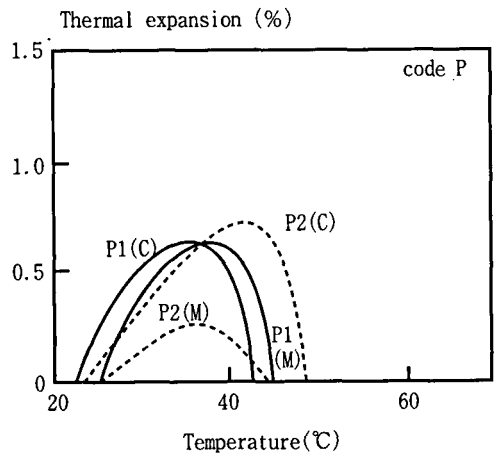

Figure 1 Thermal expansion curve (code P): M; molten state, C; carved state, T; thermally treated state.

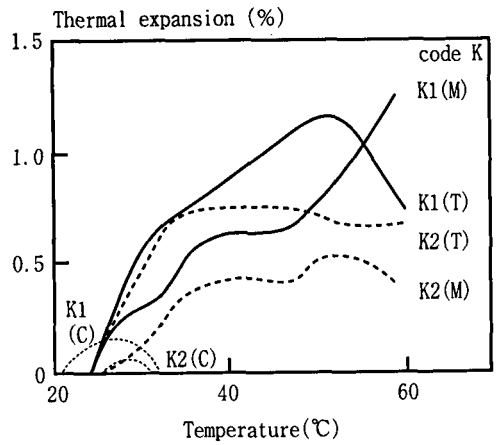

Figure 2 Thermal expansion curve (code K): M; molten state, C; carved state, T; thermally treated state.

Table 4 indicates thermal coefficient and thermal expansion of dental waxes (code P, K) which was obtained using a carving technique. Thermal coefficient values in code P (335, 490×10^{-6} (1/deg)) were greater than those of code K (40, 56×10^{-6} (1/deg)), whereas thermal expansion in code P (0.19 to 0.47%) was greater than those of code K (0.02, 0.03%).

Table 5 indicates thermal properties of dental wax (code K) which was obtained by thermal treatment to release the stress inside the wax. Thermal coefficient had greater values (595 to 720×10^{-6} (1/deg)), and thermal expansion was 0.34 to 0.66%.

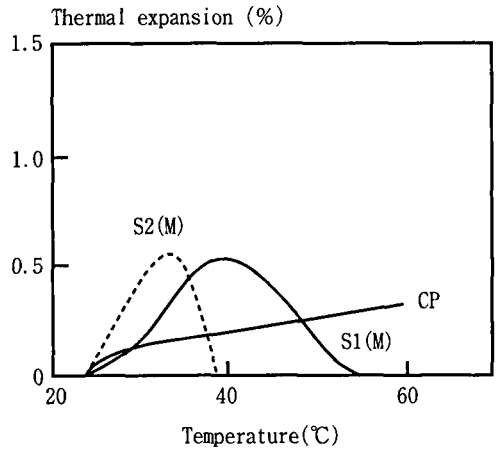

Figure 3 Thermal expansion curve (code S, CP): See Figs. 1, 2 for key.

Table 3 Thermal coefficient and thermal expansion in the temperature range of 25 to 30, and 25 to 37°C. A measurement of waxes was done using molten waxes.

Code		Thermal coefficient $\times10^{-6}$ (1/deg)		Thermal expansion (%)	
		25–30°C	25–37°C	25–30°C	25–37°C
P	P1	568 (16)	417 (41)	0.29 (0.01)	0.45 (0.05)
	P2	266 (13)	217 (5)	0.14 (0.01)	0.26 (0.01)
K	K1	384 (8)	401 (11)	0.19 (0.01)	0.48 (0.02)
	K2	271 (26)	427 (56)	0.09 (0.03)	0.33 (0.05)
S	S1	219 (46)	266 (49)	0.12 (0.02)	0.27 (0.06)
	S2	600 (16)	512 (19)	0.30 (0.01)	0.40 (0.02)
CP		160 (19)	122 (1)	0.08 (0.01)	0.14 (0.01)

Table 4 The values of thermal coefficient and thermal expansion. The wax samples were obtained for the carved waxes.

Code		Thermal coefficient $\times10^{-6}$ (1/deg)		Thermal expansion (%)	
		25–30°C	25–37°C	25–30°C	25–37°C
P	P1	490 (78)	335 (10)	0.18 (0.05)	0.37 (0.04)
	P2	373 (5)	423 (62)	0.19 (0.01)	0.47 (0.06)
K	K1	56 (25)	n.d.	0.03 (0.01)	n.d.
	K2	40 (9)	n.d.	0.02 (0.01)	n.d.

n.d. means that they are not detected.

Table 5 The values of thermal coefficient and thermal expansion. The wax samples were obtained for thermally treated waxes.

Code		Thermal coefficient $\times 10^{-6}$ (l/deg)		Thermal expansion (%)	
		25–30°C	25–37°C	25–30°C	25–37°C
K	K1	720 (43)	583 (33)	0.36 (0.02)	0.64 (0.04)
	K2	670 (80)	595 (3)	0.34 (0.04)	0.66 (0.01)

Table 6 Transition temperature at each sample (molten wax, carved wax and thermally treated wax, and cast pattern resin).

Code		Transition temperature (°C)		
		Melting	Carving	Thermal treatment
P	P1	37.7 (0.8)	38.0 (0.8)	——
	P2	36.7 (1.0)	42.0 (0.0)	——
K	K1	52.5 (1.0)	35.7 (2.8)	50 (0.8)
	K2	51.0 (0.1)	35.7 (0.3)	34 (0.8)
S	S1	38.7 (1.9)	——	——
	S2	37.6 (1.0)	——	——
CP		n.d.	——	——

n.d. means that it is not detected.
—— means that it is not obtained.

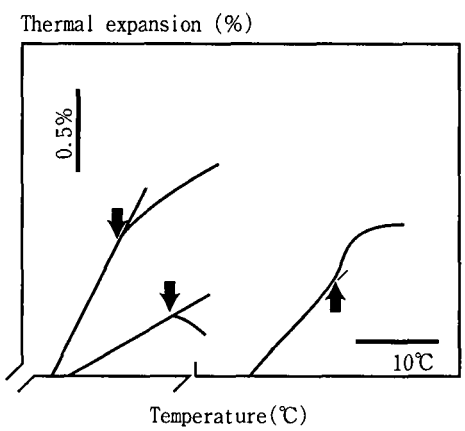

Figure 4 Schematic diagram of transition temperature.

Figure 4 shows schematic presentation of transition temperature of dental waxes from a change of thermal expansion due to temperature change, as decribed as an arrow. Table 6 indicates transition temperature of dental waxes and cast pattern resin, showing that transition temperature in code K (above 50°C) was higher than those of code P and S (about 37°C) when melted. Such treatments as carving and thermal treatment varied from 35 to 50°C, whereas transition temperature in code CP had not been detected in the temperature range.

DISCUSSION

The ingredients of inlay wax are paraffin wax, gum dammer and carnauba wax, with some colour material[1]. Paraffin wax is the main ingredient in a concentration of 40 to 60%, which is derived from the petroleum. The paraffin in Type I wax has a higher melting temperature than does the paraffin in Type II wax. Gum dammer as a natural resin is added to the paraffin, and a carnauba wax or a candellia wax (palms) is also added to it. Thus, dental wax is made to have the smoothness in the moulding of the shape.

Thermogravimetric analysis of dental waxes clarified the weight of a sample as a function of temperature or as a function of time at the fixed temperature[2]. The shape of the weight-to-temperature of molecular weights in the hydrocarbon waxes, showing that bees-wax in paraffin in binary mixture of paraffin wax and bees-wax or carnauba was satisfactory only at concentrations below 50%. As a detal wax, the following properties are needed. The wax is uniform when the wax softened after melting or before mekting. The wax pattern is needed for the dimensional accuracy on the die, showing the contrast in colour to the finishing of the margin. The wax pattern conforms to the die surface when the wax solidified. The wax pattern is eliminated from the mould when the mould is formed, and the heating eliminates the wax pattern within the investment mould. Thus, the handling of dental wax is very difficult, because the wax is subject to flow. In this study, thermoanalytical study of dental waxes is done using thermal expansion measurement and also the measurement of the heat for setting of dental cast investment with DSC analysis.

Thermal expansion was measured for dental waxes and cast pattern resin (Table 1, 3, 4, 5), and also transition temperature was measured (Table 6). Different change of thermal expansion with test temperature was found between Type I and Type II, and also the diffrent trends of dental waxes among them, showing different softening of dental waxes. Cast pattern resin had no softening and

small thermal expansion value. The handling treatments of dental wax as melting, carving thermal treatment affected the magnitudes of thermal expansion (Fig. 1, 2, 3). Especially, transition temperature appeared before the softening of dental waxes, so code K had greater thermal expansion associated with higher transition temperature (Fig. 2, Table 6).

Table 7 Calculated values (heat and highest temperature) of cast investments when analyzed by heat for setting of the investments.

Code		Heat (J/g)	Temperature (°C)
E	E1	2.4 (0.3)	26.0
	E2	2.9 (0.2)	26.0
	EE	3.1 (0.7)	26.5
PB		9.5 (0.4)	29.5
G	GC	18.5 (0.9)	33.8
	GQ	14.1 (3.1)	31.7
GA		79.3 (7.9)	62.8

Thermal behaviour of dental cast investment affected thermal behaviour of dental waxes (Table 7), and ethyl silicate-bonded investment (code E) had lower increased temperature than code PB and G, and also code GA gypsum with higher temperature increase might melt dental wax. These results suggest that the combination of dental waxes and dental cast investments are very important to select them for the casting of nonprecious or precious, and also castable glass ceramics. Code G investment with higher temperature increase than code E might affect a distortion of waxes when dental inlay gold alloys are cast into it. From this result, code K with smaller expansion of dental waxes is useful for the casting of gold alloys (Fig. 2). Titanium or titanium alloys is cast into the ethyl silicate-bonded investment mould, and also phosphate-bonded investment mould with a greater expansion value and lower heat with a very small distortion of waxes might be available for it. The dental waxes are stable to the heat for setting within the investment mould, and no softening during setting of investments is expected. Castable glass ceramic casting, which needs a very small distortion of wax during setting of cast investment, is effective for the same investment mould as titanium casting.

SUMMARY

This study summarized that thermal properties (thermal coefficient and thermal expansion) of dental waxes and cast pattern resin were analyzed by thermal expansion technique and the values should be calculated in the certain test temperature of 25–30 or 25–37°C. The heat for setting of cast investments increased the wax or chemically-cured pattern resin within the investment mould, and the magnitude of increased temperature in ethyl silicate-bonded investment was smaller than did the gypsum-bonded and phosphate-bonded investments, and also did the gypsum. Wax pattern had no distortion during setting, because ethyl silicate-bonded investment mould had not a little the increase of temperature in dental waxes used for the casting of high-fusion metal alloys or glass ceramics. Thus, the combination of dental waxes and cast investment is applied effectively for their high-fusing materials.

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