Thermal Analysis of Dental Impression Waxes

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Ten dental impression waxes were characterized by penetration and differential thermal analysis. Penetration and initial transition temperatures were directly correlated. Penetration at 37 C ranged from 2.5 to 22% for bite waxes and was 100% for corrective waxes. Distortion of an impression wax may occur upon removal from the mouth.

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Differential thermal analysis (DTA) of commercial and dental inlay waxes has established the presence of solid-solid and melting transitions.[1] The phase changes associated with these transition temperatures were shown to influence the mechanical behavior of the wax.[2,3] Commercial and dental waxes that were resistant to flow at mouth temperature had no solid-solid transitions below 37 C or had high-melting ester components or both. The purpose of this study was to characterize the thermal and mechanical behavior of dental impression waxes, since these waxes are formulated to exhibit high flow and ductility.[4]

Materials and Methods

Commercial impression waxes, as received from the manufacturer (Table 1), were subjected to thermomechanical analysis (TMA) in the penetration mode and to DTA. Waxes D, E, and I are corrective waxes that record tissues in a functional state. Waxes F, G, H, and J are bite waxes. Waxes A, B, and C are compounded in varying consistencies representing soft, medium, and hard materials and are used to support D which actually contacts and registers the detail of the soft tissues. Cylindrical wafers (6.0 mm in diameter and 1.0 mm in height) of a wax were made in a stainless steel die. TMA* was carried out on three specimens each for stresses of 14.9 and 250† kPa (1.52 and 25.5 g/m^2, respectively) from 25 C to the temperature at which maximum (100%) penetration occurred for the various waxes. The quartz penetration probe has a diameter of 0.92 mm and a length of 0.72 mm; thus 100% penetration refers to a vertical displacement of 0.72 mm. The calibration procedure has been described elsewhere.[2] The analysis was conducted in air, and a linear heating rate of 5 C per minute was used. All TMA curves began 25 C with zero percent penetration. Temperatures at which 10, 50, and 90% penetration occurred and the percent penetration that occurred at 37 C were recorded. DTA** was carried out on three specimens from 25 C to 100 C in air with a heating rate of 20 C per minute as described elsewhere.[1]

Data were analyzed statistically by analysis of variance[6] and means compared by Scheffe intervals[7] computed from the analysis at the 95% level of confidence.

Results

DTA thermograms are shown in Figure 1 for the impression waxes in order of increasing temperature of the initial endothermic transition. The waxes E, D, I, C, and H had initial transition temperatures below 37 C, whereas the waxes B, G, A, F, and J had initial transition temperatures above 37 C. The peak temperatures reported for each curve were corrected for nonlinear response of the DTA thermocouples, whereas the curves themselves were not corrected. An analysis of variance of the initial transition temperatures indicated there were significant differences among the means ($F_{.95;\ 9,20} = 1420$). A comparison of means by a Scheffe interval of 1.5 C indicated there were no significant differences among the means of E, D, and I, nor between H and B.

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* DuPont 941 Thermomechanical Analyzer, E. I. du Pont de Nemours & Co., Inc., Instrument Products Division, Wilmington, De.

† The magnitude for this stress is equal to that specified in American Dental Association Specification No. 4 for Dental Inlay Casting Wax for the flow test.[5]

** Du Pont 900 Differential Thermal Analyzer, E. I. du Pont de Nemours & Co., Instrument Products Division, Wilmington, De.

TABLE 1

CODE, BATCH NUMBER AND MANUFACTURER OF COMMERCIAL IMPRESSION WAXES

Code	Product	Batch Number	Manufacturer
A	Kerr Korecta-Wax Extra Hard No. 1	171I658	Kerr Manufacturing Co. Div. of Sybron Corp. Romulus, Mi 48174
B	Kerr Korecta-Wax Hard No. 2	0784M569	Kerr Manufacturing Co.
C	Kerr Korecta-Wax Hard No. 3	0432B210	Kerr Manufacturing Co.
D	Kerr Korecta-Wax Extra-Soft No. 4	0703W085	Kerr Manufacturing Co.
E	Kerr Impression Wax Sticks	0801W123	Kerr Manufacturing Co.
F	S.S. White Yellow Bite and Impression Wax	7686912	S. S. White Division Pennwalt Corp. Philadelphia, Pa 19102
G	Hygienic Yellow Bite Wax	07281	Hygienic Dental Mfg. Co. Akron, Oh 44310
H	J. F. Jelenko Hi Fi Functional Bite Material	.....	J. F. Jelenko & Co. Pennwalt Corp. New Rochelle, NY 10801
I	Aluwax	.....	Aluwax Dental Products Co. Grand Rapids, Mi 49508
J	Kerr KWIK-WAX	1204Y513	Kerr Manufacturing Co.

Temperatures (corrected) at which penetrations of 10, 50, and 90% occurred are listed in Table 2 for the waxes at stresses of 14.9 and 250 kPa. The waxes are ranked in order of increasing temperature corresponding to 90% penetration at a stress of 250 kPa. An analysis of variance of the temperatures corresponding to 90% penetration at 250 kPa indicated there were significant differences among the means ($F_{.95;\,9,20} = 508$). A comparison of means by a Scheffe interval of 2.1 C indicated there were no significant differences between the means of E and D, C and I, I and B, H and G, nor A and J, as illustrated by underscoring in Table 2.

Penetration thermograms are superimposed on DTA curves in Figure 1 for the waxes. The penetration curves at the higher stress (curves 2, # 250 kPa) appeared to be related to the initial endothermic transitions for the waxes tested; therefore, a plot of the mean value of the temperature (T_p) at which 90% penetration occurred at 250 kPa versus the mean value of the initial transition temperature (T_i) was made (Fig 2). The correlation coefficient (r) for waxes A to J was computed[6] to be 0.919. The critical value of r above which the hypothesis of independence of T_p and T_i could be rejected was 0.632 at the 95% level of confidence.

The penetration curves at the lower stress level (curve 1, 14.9 kPa) were of two types as exemplified by waxes A and D in Figure 1. Waxes F, G, H, and I had penetration curves similar to wax A for which some initial penetration occurred at the initial transition, but for which the major penetration was related to the second transition. Waxes B, C, E, and J had penetration curves similar to wax D for which the major penetration at 14.9 kPa occurred over a temperature range nearer to the onset of the second transition than to the peak temperature as for wax A.

By inspection of Figure 1 and Table 2, it was observed that four waxes (C, D, E, and I) had values of temperature at which 90% penetration occurred at 250 kPa that were below 37 C. The mean values with standard deviations in parentheses of percent penetration that occurred at 37 C and 250 kPa in order of decreasing penetration were determined from the penetration curves to be: E, D, C, and I, 100; B, 79.3 (3.5); H, 22 (7); G, 8.0 (0.7); J, 5 (4); A, 4.4 (2.3); and F, 2.5 (0.2).

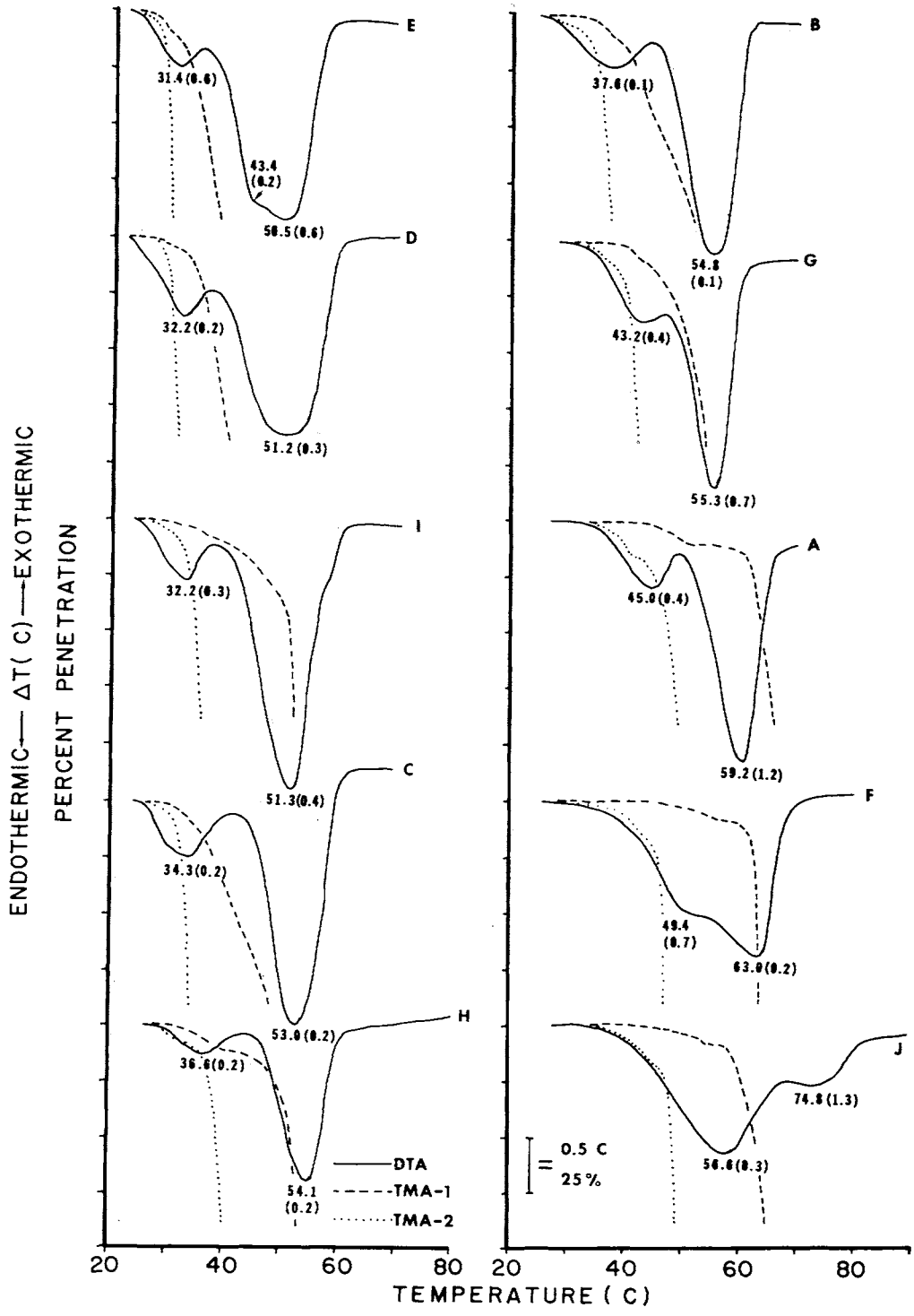

FIG 1.—DTA and penetration (TMA) curves of ten dental impression waxes. Stresses for TMA-1 and 2 are 14.9 and 250 kPa, respectively. Mean values for the peak transition temperatures (corrected) from DTA are indicated with standard deviations in parentheses.

TABLE 2

PENETRATION TEMPERATURES (CORRECTED) OF TEN DENTAL IMPRESSION WAXES AT TWO STRESS LEVELS

Stress, kPa	Penetration %	Penetration Temperatures of Waxes, C E	D	C	I	B	H	G	F	A	J
14.9	10	30.2*	33.1	34.0	37.9	38.1	40.7	44.2	59.2	53.9	56.5
		(0.2)	(0.7)	(0.7)	(1.4)	(1.3)	(2.5)	(0.8)	(1.2)	(3.7)	(1.0)
	50	36.0	37.6	42.0	40.5	46.0	52.6	51.5	62.2	63.8	62.3
		(0.4)	(0.0)	(0.6)	(0.6)	(1.0)	(1.8)	(0.1)	(0.1)	(0.8)	(0.6)
	90	38.7	40.0	47.7	41.8	51.3	54.6	53.2	62.4	66.2	64.3
		(0.6)	(0.1)	(0.3)	(0.3)	(0.4)	(4.5)	(0.3)	(0.0)	(1.0)	(0.4)
	10	27.8	29.0	31.4	30.5	33.3	34.0	37.9	42.9	41.0	41.1
		(0.2)	(0.2)	(0.2)	(2.1)	(0.2)	(1.2)	(0.2)	(1.5)	(3.5)	(3.5)
	50	29.3	30.4	33.3	34.2	36.2	38.7	40.9	46.6	47.9	48.8
		(0.2)	(0.2)	(0.1)	(0.2)	(0.1)	(0.3)	(0.4)	(0.3)	(1.3)	(0.2)
	90†	29.9	31.2	34.1	35.5	37.2	40.0	41.6	47.0	49.3	49.4
		(0.2)	(0.2)	(0.1)	(0.2)	(0.2)	(0.4)	(0.3)	(0.4)	(1.6)	(0.2)

* Mean (standard deviation) with sample size of 3.
† Underscoring indicates no significant difference at 95% level of confidence.

Discussion

The DTA thermograms (Figure 1) of the dental impression waxes tested, except F and J, are characteristic of hydrocarbon waxes such as paraffin and ceresin, in which the initial endothermic transition corresponds to a solid-solid phase transition and the large endothermic transition corresponds to melting.[1] The broad melting peaks associated with D and E suggest mixtures of these hydrocarbon waxes, whereas the sharp melting peaks of A, B, C, G, H, and I are characteristic of either of these waxes in high concentrations. Wax F has a thermogram characteristic of beeswax[1] and is identified as pure beeswax by the manufacturer on the pack-

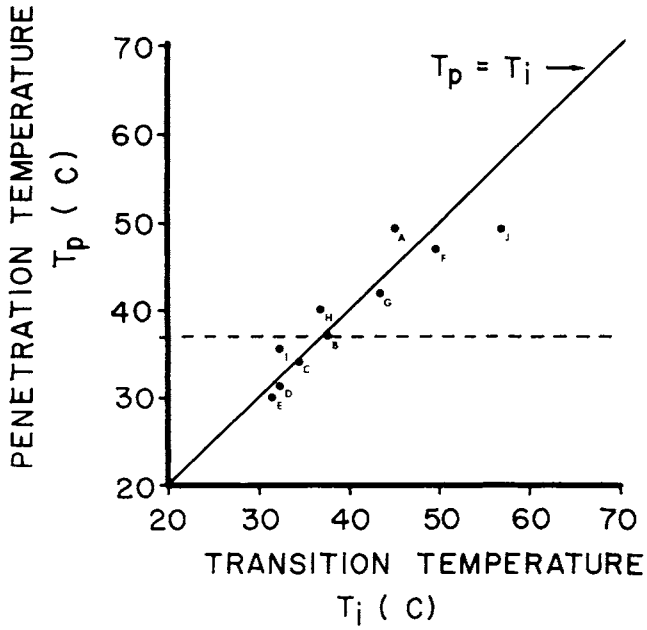

FIG 2. — Temperature (T_p, corrected) at which 90% penetration occurred versus initial DTA transition temperature (T_i, corrected). The solid line indicates a theoretical curve for which both temperatures are identical. The broken line indicates $T_p = 37$ C.

age. The initial transition (56.6 C) of J is characteristic of melting of a hydrocarbon wax such as paraffin. The broad melting transition and the lack of an endothermic transition corresponding to a solid-solid phase change suggest the presence of additional components. The transition at 74.8 C is characteristic of carnauba wax, a high melting ester wax.[1]

The penetration curves at the high stress level (Figure 1) of the impression waxes, except F and J, were related to the solid-solid phase transformations of the hydrocarbon components. The melting transition of the wax appears to have had little effect on penetration at 250 kPa. For wax F, which is a mixture of hydrocarbon and ester waxes, penetration at the high stress is related to melting of the hydrocarbon component, whereas at the low stress penetration is influenced by the melting transition of the ester component. For J, penetration at both stress levels is related to the broad melting transition of the hydrocarbon component of the wax.

Clinically, waxes D, E, and I are used to make impressions of the soft oral tissues. For this application high flow at mouth temperature is desirable and was observed at both stress levels. Waxes A, B, and C are used to support D and had less flow at mouth temperature than D. Waxes F, G, H, and J are used clinically to make impressions of the occlusal surfaces of the teeth. During removal of the impression, low flow is desirable to minimize distortion. At 250 kPa the penetration of F, G, and J was between 2.5 and 8%, but for H was 22%. The relatively high flow of H may be justified because of its use as a functional bite wax.

Conclusions

Ten dental impression waxes were characterized by penetration and DTA. Among the waxes that were compounded from hydrocarbon waxes, penetration at 250 kPa was correlated to the solid-solid phase transformation. Penetration at 250 kPa of the waxes containing both hydrocarbon and ester components was determined by the melting transition of the hydrocarbon wax. Penetration at 37 C ranged from 2.5 to 22% for bite waxes and was 100% for corrective waxes. Distortion of an impression wax may occur upon removal from the mouth.

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