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ISOTHERMAL DIMENSIONAL CHANGES OF SOME DENTAL MATERIALS

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The isothermal dimensional changes of four types of dental amalgams during the setting and for the next 24 hours after condensation have been studied by means of a Heraeus TA 500 thermal analysis system. The four types of dental amalgams were the lathe-cut conventional low-copper amalgam (Amalcap), the spherical conventional low-copper amalgam (Spheralloy), the ternary unicomposition high-copper amalgam (Sybralloy) and the admixed high-copper (Dispersalloy) amalgam.

The dimensional changes of the four types of amalgams are explained on the basis of their particle sizes and shapes and their constitutions.

It is generally agreed that, at least for theoretical reasons, dental amalgams should expand slightly during hardening [1, 2]. The slight expansion of the amalgam will result in a restoration that seals the cavity against the ingress of oral fluids [3]. Excessive expansion, however, may result in protrusion of the prepared cavity and the introduction of mechanical stresses. It has been suggested that the amount of free setting expansion should not be less than 10 μm/cm in order just to eliminate the possibility of microleakage [3]. However, other studies have indicated no difference in the sealing properties of expanding and contracting alloys [4].

The composition and constitution of the amalgam affect the dimensional change of the amalgam during hardening. It has been pointed out that the most desirable composition for the amalgam is that of silver-tin, known as the γ-phase [5]; if free tin is present, the contraction may be unduly great. Graig [6] has reported that current amalgams have dimensional changes that are always positive. On the other hand there are several studies which indicate that the net dimensional change may be

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negative or positive depending on the amount of mercury remaining and on the type of the alloy particles [7–9].

In general, previous dimensional change measurements on dental amalgams have led to controversial results. Some of these results, obtained from measurements on many modern amalgams, have been discussed by Philips [10]. The situation has become more complicated following the introduction in recent years of high-copper amalgams, whose dimensional change patterns are still not well established.

The present work includes the results of dimensional change measurements during the setting of conventional and high-copper alloys.

Materials and methods

Four types of dental alloys were used, as follow:

a) Conventional lathe-cut alloy (Amalcap) from Vindant Co.; recommended alloy to mercury ratio 1 : 0.8.

b) Conventional Spherical alloy (Spheralloy) from Kerr Co.; alloy to mercury ratio 1 : 1.

c) A unicomposition ternary, high-copper alloy (Sybralloy) from Kerr Co., composed of spherical particles; recommended alloy to mercury ratio 1 : 1.

d) An admix dispersion, high-copper alloy (Dispersalloy) from Johnson and Johnson, composed of two parts by weight of conventional lathe-cut alloy and one part of spherical silver-copper eutectic, with an alloy to mercury ratio of 1 : 1.

The amalgams were triturated mechanically in an S.S. white cap master amalgamator, then manually pressed in a special die to produce a cylindrical specimen with dimensions 8×4 mm. The amalgam specimen was placed on a standard quartz holder and thermal analysis was carried out with a Heraeus TA 500 thermal analysis system. A predetermined weight (5 g) was applied to a tray on top of the quartz rod in order to ensure a continuous contact between the probe and the surface of the specimen.

The apparatus was adjusted to isothermal mode at a fixed temperature of 37° for 24 hours, with a scanning rate of 1 cm per 10 min. The measurements were started 5 minutes after trituration. Each run was repeated at least three times, to ensure the accuracy of the obtained results. Microscopic measurements of amalgam particles were carried out by scanning a 1 cm^2 field under a magnification of $63\times$. The number of intersections of particles with both a horizontal and vertical line were counted and the average particle size was calculated.

Results and discussion

1 Conventional lathe-cut alloy (Amalcap)

The dimensional changes shown in Fig. 1 are typical of the conventional lathe-cut, low-copper amalgam. The TMA curves show three distinct phases over a period of 24 hours. In the first phase, an initial contraction of about 7.5 μm/cm occurs during the first hour; the rate of contraction then becomes much slower, with an extra 1.25 μm/cm contraction during the second hour. This seems to be a characteristic observation for most of the conventional lathe-cut alloys that contain about 68% or less silver. In the second phase, continuous expansion takes place for several hours (about 5 hours) when the specimen gains a net elongation of 5 μm/cm. Thus, during setting of the conventional lathe-cut amalgam, the expansion usually reaches its maximum within a period of 7–9 hours.

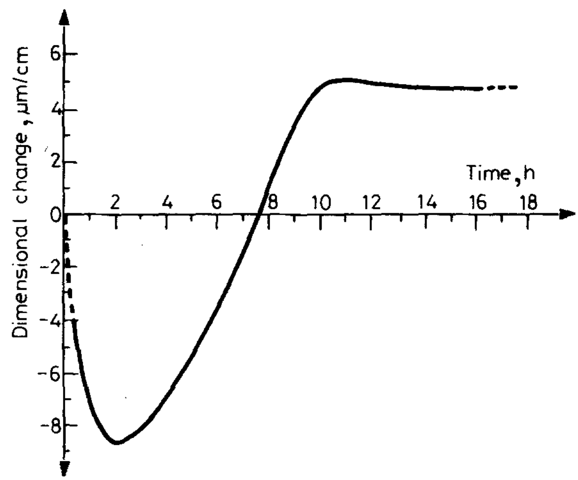

Fig. 1 Dimensional change curve of a lathe-cut conventional amalgam during the first 24 hours after condensation

In the last phase, the dimensional change curve becomes nearly constant, with only very slight shrinkage (about 1.25 μm/cm) during the last 15–17 hours of a total period of 24 hours.

These three distinct phases, which are easily identified from Fig. 1, may be explained as follow: During the initial stages of the reaction, mercury is absorbed by the matrix and an initial contraction takes place because of the resulting decrease in the overall volume. The following step is the formation of silver-mercury (γ_1) and tin-mercury (γ_2) crystalline phases, which presumably grow in dendritic forms. As the dendrites grow, they exert a certain outward pressure, which results in an expansion. Such crystal growth of γ_1 and γ_2 soon nullifies the initial contraction and results in an overall expansion, which continues for several hours until crystallization is complete. Finally, the remaining mercury diffuses into the silver-tin (γ) phase particles and a second slight contraction results.

2 Conventional spherical alloy (Spheralloy)

Figure 2 illustrates the dimensional change of Spheralloy during the first 24 hours of condensation. The TMA curves show an overall contraction of about 8.75 μm/cm. The contraction is fast at the beginning, reaching about 7.5 μm/cm during the first 7 hours; the rate of contraction then slows down as it takes 7 more hours to slope down another 1.25 μm/cm. In fact, Spheralloy, in spite of being a conventional low-copper amalgam, actually contracts during hardening with no evidence of expansion. The difference in the behaviour of Spheralloy and lathe-cut alloy may be explained by considering the shape and particle size distribution in both alloys.

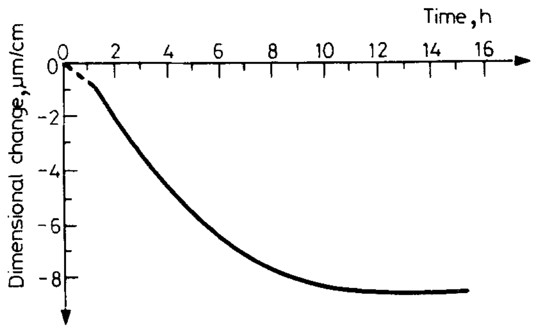

Fig. 2 Dimensional change curve of a spherical conventional amalgam during the first 24 hours after condensation

Lathe-cut alloy has an average particle size which is considerably larger than that of Spheralloy. The smaller particle size and larger surface area associated with spheralloy favour the rapid dissolution of the mercury into the alloy particles during condensation, with the result that a larger contraction may occur. The resemblance of the dimensional change curve in our case to that produced by Philips [5], while increasing the trituration time, suggests that amalgams of alloys with the smallest particle size are over-triturated in comparison with the trituration of the larger particles.

On the other hand, the greater voids existing in the packing of spherical particles will allow the growth of the newly formed γ_1 and γ_2 phases without exerting much pressure on the matrix, and hence no net expansion occurs.

3 High-copper Sybralloy

Figure 3 illustrates the dimensional change pattern of Sybralloy during 24 hours after condensation. The TMA curves exhibit a net contraction and no expansion is detected. The contraction rate slows down after the first 3 hours and after 10 to 13 hours the dimensional change becomes nearly constant.

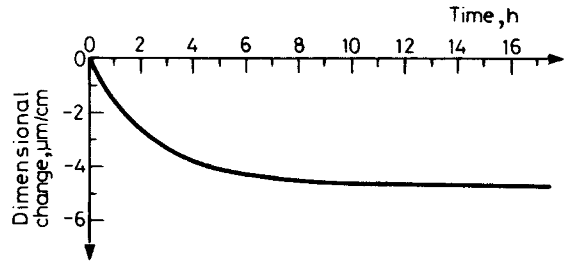

Fig. 3 Dimensional change curve of single composition high-copper amalgam during the first 24 hours after condensation

This shows that continuous contraction takes place in a very similar manner as for Spheralloy. However, the difference in the TMA curves between the two alloys may be explained by their relative particle size.

Microscopic examination shows an average particle size of about 8 µm for Sybralloy as compared to about 4.45 µm for Spheralloy. The larger particle size and consequently the smaller surface area of the Sybralloy particles favours the less rapid dissolution of mercury into the alloy particles, with the result that a smaller overall contraction may occur in this case.

Such a difference may also be attributed to the higher copper content (up to 30%) in Sybralloy, which impedes the wetting of alloy particles with mercury through the surface oxide layer on them.

4 High-copper admixed dispersion alloy (Dispersalloy)

The TMA curve for this alloy may be seen in Fig. 4. In spite of being a high-copper amalgam, Dispersalloy shows the classical picture of a dimensional change in which the specimen undergoes an initial contraction for about 40 minutes after the beginning of trituration and then starts to expand. The above behaviour could be explained in that Dispersalloy is a mixture of two parts by weight of flake-shaped alloy and one part of spherical-shaped Ag–Cu alloy. In addition, it contains about

0.6% zinc. The interaction of these two alloys produces the observed contraction-expansion curve. In fact, taking into account the relative ratio of the two alloys, the superposition of the two curves (Figs 1 and 3) may produce a curve which is qualitatively similar to that portraying the behaviour of the admixed alloy, shown in Fig. 4.

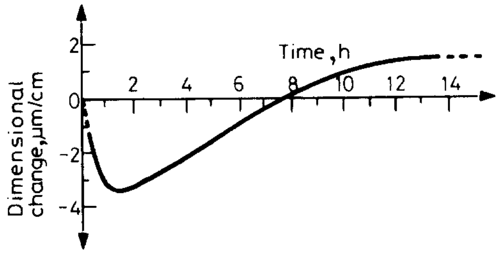

Fig. 4 Dimensional change curve of a high-copper admixed amalgam during the first 24 hours after condensation

The specific behaviour of Dispersalloy may also be attributed to the fact that Dispersalloy is the only alloy in this study that contains zinc. It is possible that the presence of zinc may promote other solid-phase transitions which promote the expansion of the amalgam [11, 12].

The results obtained in this study and the explanation proposed in the above discussion corroborate those of Greasly and Baker [13]. They pointed out that more mercury was needed with lathe-cut than with spherical alloys for wetting the particles and achieving plasticity in the amalgam mixture. The undesirable effect of excess mercury was also pointed out by Paffenberger [8], who concluded that the lower the residual mercury in the amalgam, the better. However, on the basis of the amount of residual mercury, it is again difficult to predict the clinical behaviour of amalgam of different compositions.

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Zusammenfassung — Mittels eines Heraeus TA 500 Thermoanalysensystemes wurden isotherme Größenveränderungen von Dentalamalgamen während des Setting und der 24 Stunden nach der Kondensation untersucht. Die Größenveränderungen der vier Amalgamgrundtypen (am Beispiel von Amalcap, Spheralloy, Sybralloy und Dispersalloy) wurden auf der Grundlage ihrer Teilchengröße und -form sowie auf der Grundlage ihrer Zusammensetzung erklärt.

Резюме — С помощью термической системы Хераус ТА 500 были изучены изотермические размерные изменения четырех типов зубных амальгам во время их отверждения и в последующие 24 часа после их конденсации. Изучены четыре типа зубных амальгам: обычная обточенная амальгама с низким содержанием меди (Эмелькеп), обычная сферическая амальгама с низким содержанием меди (Сфераллой), тройная однокомпозиционная с высоким содержанием меди (Сибраллой) и смешанная амальгама с высоким содержанием меди (Дисперсаллой). Изменения размеров этих четырех типов амальгам были объяснены на основе размера и формы их частиц, а также на основе их составных компонентов.