An application of non-asbestos papers to the dental field: mechanical properties and structural change

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New non-asbestos papers composed of glass fibres and ceramic fibres were examined for dental application. The fibre liners showed a larger deformation ability than conventional asbestos paper, and had a smaller water uptake than the conventional liner. In addition, the setting expansion in new non-asbestos papers was increased at 60 min after investing, similarly to the setting expansion behaviour in a conventional liner. After casting a silver alloy using the new fibre liners, a microstructure mainly of primary solid formed, with a smaller amount of complex phases. The microstructures formed were similar to those in the conventional asbestos liner.

1. Introduction

As toxicity in asbestos paper composed of fibrous minerals has been reported [1–4], ceramic ring lining materials have been introduced as asbestos substitutes in environmental exposure. Thus, ceramic liners have been largely used as so-called asbestos-substitute casting-ring liners in the dental field. Of the greatest concern are those with health hazards from asbestos and its substitute. It has been reported that fibres in ceramic casting-ring liners generated during simulated dental casting procedures were few in number and considerably less than the Occupational Safety and Health Agency permissible exposure limit [5]. Experimental studies have produced little evidence that glassy fibres cause pulmonary fibrosis or pulmonary carcinomas [6, 7].

It is generally known that a wet casting-ring liner increases the setting of an investment and that water absorbed during setting has the same effect as water in the original mix [8, 9]. In a lined casting ring the effective water/powder ratio could be found for the ring lining material. On the contrary, ceramic fibre lining materials have low thermal conductivity and heat storage [10]. As addition properties, they have both resistance to thermal shock and flexibility [10–12].

In this study casting-ring lining materials were available for an asbestos substitute in dental casting. The lining materials were examined for compressive strength and the effect of the lining materials on the setting expansion behaviour was checked using a gypsum-bonded investment along with the uptake of water from the fibre liners. In addition, the change in microstructure after dental casting was examined for the fibre liners.

2. Materials and methods

The compressive strength of casting-ring lining materials was measured, using a Shimadzu DCS-500 (Shimadzu Co., Kyoto, Japan). The control materials were a conventional asbestos paper (GC Co., Tokyo, Japan) and a commercial ceramic paper (Kaolin; Dentsply Co., York, USA). Newly tried non-asbestos papers consisting of glass fibres represented as paper, twill, 3T and ceramic fibre (NEG) were supplied by Nippon Electric Glass Co. (Shiga, Japan). The specimens of compressive strength had a 1 mm × 1 mm rectangular cross-section and thickness 0.35 to 1.50 mm, depending on the lining material [13], and the specimen was immersed in distilled water for 3 min to determine the water uptake. Before the compressive test the ring lining materials were treated dry (as received), wet and heated to 700°C.

A gypsum-bonded investment (cristobalite P; Shofu Inc. Kyoto, Japan) mixed in the water/powder ratio 0.33 was used for setting expansion. The investment set in two troughs of 50 mm diameter and two different heights of 10 and 25 mm at 20 ± 1°C, the troughs being lined with the casting ring liners. After the investment specimen was poured into the trough, two marking points were laid on the top surface of the investment, and the displacement (setting expansion) was measured until 60 min after investing. At least five tests were performed so that the mean expansion value could be obtained for each ring lining material.

The structural change was examined by optical microscope (Olympus MTZ; Olympus Co., Tokyo, Japan) for cast specimens when lined with six different ring lining materials and when unlined. The microstructures were etched for 30 sec with Nital [14]. In the above study, the measurements of compressive strength, water uptake, setting expansion and microstructure microscopy were made on the lining materials, such as asbestos paper, glass and ceramic fibres.

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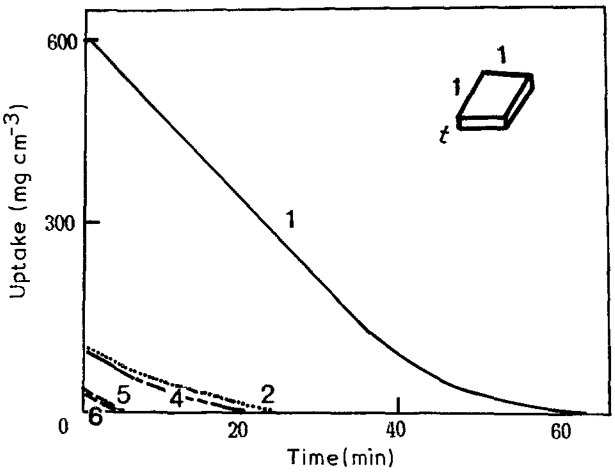

Figure 1 The change of the amount of water uptake in casting-ring liners (used dry) with time after immersion in distilled water for 3 min. 1, Asbestos paper; 2, glass fibre (paper); 3, glass fibre (twill); 4, glass fibre (3T); 5, ceramic fibre (Kaolin); and 6, ceramic fibre (NEG).

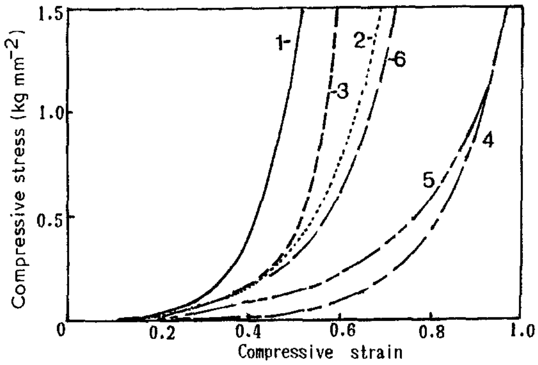

Figure 3 Compressive stress–compressive strain curves for wet fibre liners (for key, see Fig. 1).

3. Results

Fig. 1 shows the amount of water uptake for five of the fibre liners (not glass fibre (twill)). The uptake was measured every 5 min when the liners were placed on the plastic sheet. The value decreased with increasing holding time at 20 ± 1°C, and the initial uptake of water within the liner was highest for asbestos paper. The two ceramic fibres had smaller values than the other fibres. The compressive stress and strain curves in the six kinds of ring liners are shown in Figs 2 (used dry), 3 (used wet) and 4 (glass fibre (paper); used dry, wet and heated to 700° C). After gradually increasing compressive strength from a compressive strain of 0.4 to 0.6, the strength increased rapidly with compressive strain. For the fibre liners measurements of setting expansion are shown in Figs 5 (diameter 50 × 10 mm stainless steel ring) and 6 (diameter 50 × 25 mm). After mixing the gypsum-bonded investment, the setting expansion behaviour was measured within rings lined by each lining material. Each ring liner followed a similar pattern, with a minimum value between 15 and 30 min, indicating a gradual increase until setting expansion reached a constant value after 40 min. At 60 min after investing, the setting expansion ranged from −0.2 to +0.2% (diameter 50 mm × 10 mm), and from −0.2 to +0.6% (diameter 50 mm × 25 mm). In using vaserinum for asbestos paper, the setting expansion was the smallest for the ring liners tested. Compared with the setting expansion within an unlined ring (NO) with those with a fibre liner, the expansion for all ring liners was larger.

Fig. 7 shows an illustrated scheme to analyse the amount of etched microstructures, such as primary solid and complex phases indicated as grey (dark area due to etching) and white (not etched) regions on optical micrography. Optical micrographs are shown in Figs 8a (within a ring lined without asbestos paper and b (with asbestos paper), 9a to c (when glass fibres denoted as paper, twill and 3T were used), and 10a and b (ceramic fibres indicated by Kaolin and NEG). On the optical micrograph, P, Cg and Cw denote primary solid and complex phases of grey and white regions as illustrated in Fig. 7. The amounts of microstructures are shown in Figs 11 and 12. The size of the primary solid ranged from about 20 to 35 μm, occupying an area of about 90% of all microstructures (Fig. 11). The complex phases (grey and white areas) distributed less than 10%, but the amount of white area was less than the amount of the grey area (Fig. 12).

4. Discussion

The values determined in this study for the mechanical properties have been reported little, and the cast structures after casting dental alloys using different ring lining materials have not been clarified. A rapid increase of stress with the strain from 0.5 to 0.6 in the compressive stress–compressive strain curve for asbestos paper (Figs 1 and 2) was seen, but new non-asbestos fibre liners were deformed plastically. This

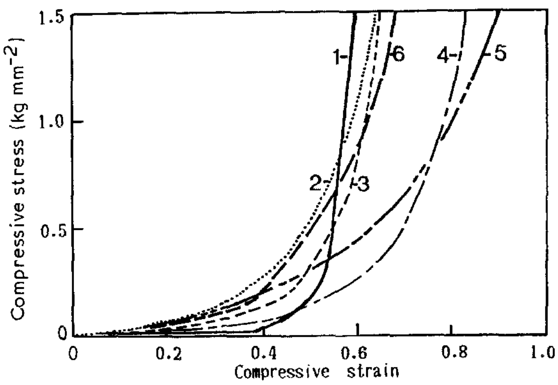

Figure 2 Compressive stress–compressive strain curves for casting-ring liners (used dry). (For key, see Fig. 1.)

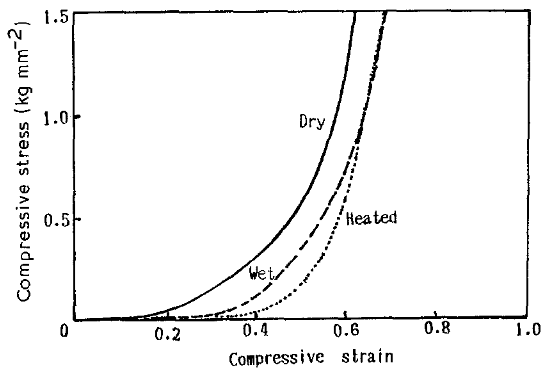

Figure 4 Stress–strain curves for three different treated glass fibres (paper).

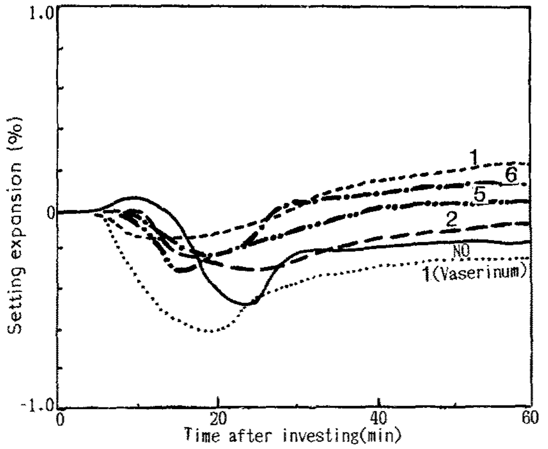

Figure 5 Setting expansion curves for casting-ring liners within a stainless steel ring of diameter 50 mm × 10 mm (NO denotes an unlined ring with asbestos paper and 1 (vaserinum) asbestos paper coated with vaserinum).

means that fibre liners with larger plastic deformation have a greater cushioning effect than asbestos paper. When used wet, the effect was found to be remarkable (Fig. 3). In addition, the heated glass fibre (paper) showed the same behaviour as fibre liners (used wet) (Figs 3 and 4). As reported for the accuracy of a metal crown [13], the non-asbestos fibre liners were useful in dental casting, showing almost the same shrinkage as in a lined ring with asbestos paper. That is, the stress level of fibre liners in the ring was high enough to deform easily when the mixed investment expanded. The value when the investment set was evaluated to be below approximately 0.1 kg mm^{-2} [14, 15]. The level of applied stress was deduced to be an initial proportional region in the compressive stress–compressive strain curve (Figs 2 and 3).

As the setting expansion behaviour in Figs 5 and 6 shows, the effect of the lining of the stainless steel ring on the setting expansion was remarkable compared with when the ring was not lined by asbestos paper and when it was lined by asbestos paper coated with vaserinum to prevent the uptake of water from the investment mix. For the non-asbestos liners such as glass fibre and ceramic fibre the setting expansion was less than 0.6%, indicating a smaller uptake of water than with asbestos paper (Figs 4 to 6).

In Figs 7 to 10 the microstructural changes were

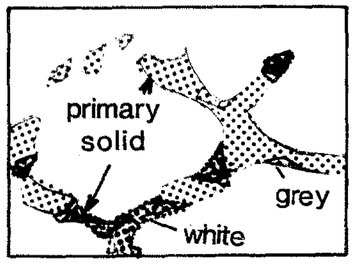

Figure 7 Schematic figure of microstructures in silver alloys tested (primary solid is indicated by P on the micrograph and grey and white complex phases by Cg (etched) and Cw (not etched).

observed for the silver alloy when lined by ring fibre liners according to the schematic instruction [16]. After primary solid (P) initially solidified, the complex phases (Cg and Cw) formed along the boundary between the primary solids. This finding gave the change of microstructure quantitatively (Figs 11 and 12). The larger size of primary solid than in the cases of unlined rings agrees with smaller percentages of complex phases. No significant difference in the percentage of primary solid was noted in a comparison of results from the unlined metal ring and the fibre-lined metal ring. It is possible that the ring liner provided sufficient retention of temperature within the ring and also that fibre liners such as asbestos paper, glass and ceramic fibres make the formation of complex phases easier than in an unlined ring. Thus, glass and ceramic fibre liners had the same effect on the formation of microstructures as conventional asbestos paper.

The difference in stress applied to the investment during setting expansion should be pointed out [14, 15]. Any constraint on the investment will be affected by the kind of fibre lining material, because the compressive stress against strain curves show different behaviour in the lower-strain region. The ring lining materials also had an effect on the cooling rate of the cast structures, as seen especially for the size of the primary solid. As reported [13], the shrinkage of a silver alloy became larger than in an unlined ring and was almost the same as the shrinkage with asbestos paper.

The following can be concluded from the findings in

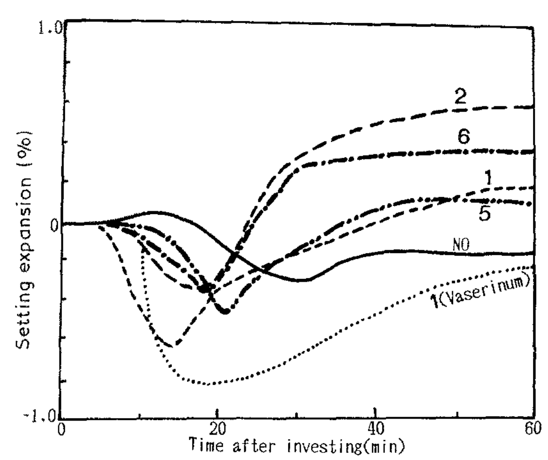

Figure 6 Setting expansion curves within a stainless steel ring of diameter 50 mm × 25 mm.

Figure 8 Microstructures after casting (Nital etching). (a) An unlined ring with asbestos paper and (b) a ring lined with asbestos paper.

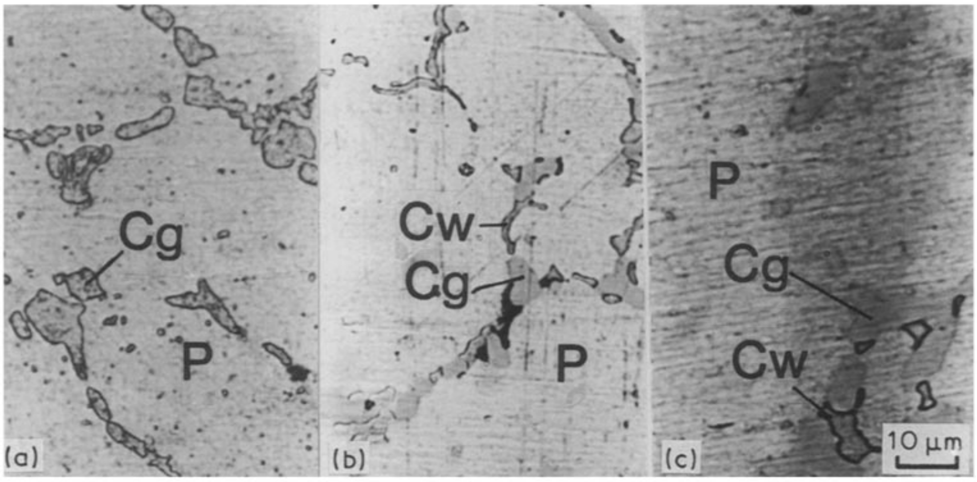

Figure 9 Microstructures when lined by (a) glass fibre (paper), (b) glass fibre (twill) and (c) glass fibre (3T).

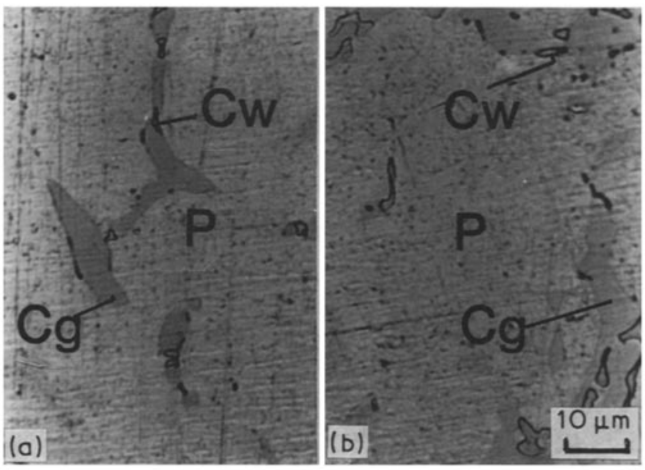

Figure 10 Microstructures when lined by (a) ceramic fibre (Kaolin) and (b) ceramic fibre (NEG).

this study. The non-asbestos fibre liners gave larger deformation than asbestos paper, even though they were used dry, wet and heated. The lower water uptake than asbestos paper was characteristic, and thus the amount of setting expansion ranged from 0.2 to 0.6%. In casting of a silver-based alloy which was lined by non-asbestos fibre liner, the metal crown with appropriate fit contained almost the same microstructural change as that lined by asbestos paper. It was thus deduced that non-asbestos liners could be used for dental casting.

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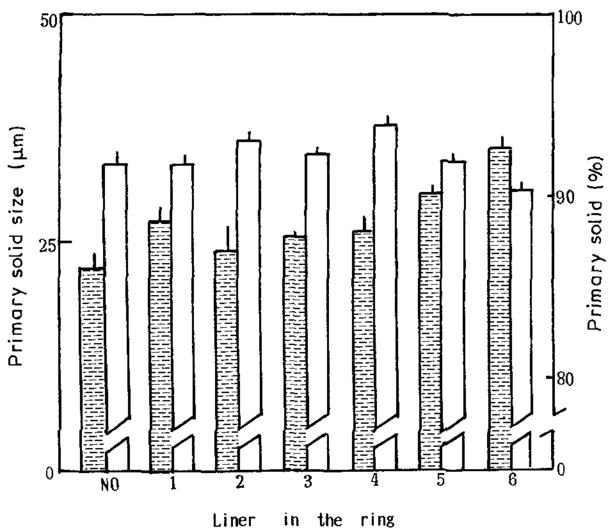

Figure 11 The size of primary solid and the percentage of primary solid for each casting-ring liner. NO, unlined.

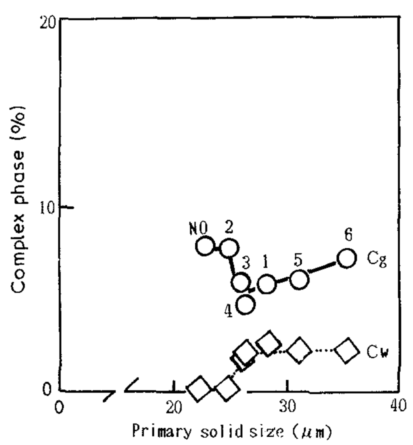

Figure 12 The relationship between primary solid size and the amount of complex phases (grey and white phases) for the casting-ring liners tested.

References

1. R. DOLL, *Brit. J. Indust. Med.* **12** (1955) 81.
2. M. R. BECKLAKE, *Amer. Rev. Respir. Dis.* **114** (1976) 187.
3. P. C. ELMES, *R. Soc. Health J.* **6** (1976) 248.
4. M. F. STANTON and C. WRENCH, *J. Natn. Cancer Inst.* **48** (1972) 797.
5. G. J. TULACHKA *et al.*, *J. Prosthet. Dent.* **57** (1987) 108.
6. J. M. G. DAVIS, *Ann. Occup. Hygiene* **24** (1981) 227.
7. *Idem, Scand. J. Working Envir. Health* **12** (1986) 12.
8. T. FUSAYAMA, *J. Prosthet. Dent.* **9** (1959) 468.
9. R. EARNSHAW, *Aust. Dent. J.* **12** (1967) 123.
10. G. BARNARD, *Met. Australasia* **13** (1981) 10.
11. M. ITO, S. NAGASAWA and S. TAKAHASHI, *Matsumoto Shigaku* **4** (1978) 9 (in Japanese).
12. Y. TOUNOU *et al.*, *Shika Gikou* **10** (1982) 553 (in Japanese).
13. K. WAKASA, H. MATSUI and M. YAMAKI, *J. Mater. Sci.* (1989) in press.
14. A. NAKATSUKA, K. WAKASA and M. YAMAKI, *ibid.* **24** (1989) 3059.
15. A. NAKATSUKA, K. WAKASA and M. YAMAKI, *ibid.* **24** (1989) 3065.
16. I. MIURA and H. HONMA, *Shika Rikougaku Zasshi* **1** (1960) 34 (in Japanese).

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