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Denture base materials reinforced with glass fibres

Part 1 *The application of industrial glass fibres distributed at random*

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Glass fibres for industrial use were laid on denture base materials such as self-curing and heat-curing resins to reinforce them. The use of heat-curing rather than self-curing resin as a base resin indicated a superior effect on bending properties.

1. Introduction

The denture base which is used as a portion of a complete or removable partial denture is commonly an acrylic resin, i.e. polymethyl methacrylate (PMMA). Acrylic resins have excellent aesthetic properties, adequate strength, low water sorption and low solubility [1, 2]. They have a rigid, nonelastic, smooth property that provides firm support for false teeth. Acrylic dentures are, however, apt to become damaged, and the expense of repairs necessitated by breakage is high. Tests to make composite dentures with greater rigidity and strength than the conventional ones have been done [3]. Their rigidity and strength have recently been improved by using fibre mat [1]. They are reinforced with (i) carbon fibres [4, 5], (ii) aromatic polyamid [6] and (iii) glass fibres [7]. They are called composite PMMA resins reinforced with fibres.

This study investigated the bending properties of the composite PMMA resins, and the standard powder–liquid acrylic resins of a self-curing resin and a heat-curing resin were compared to these fibre-reinforced composite resins. In addition, the composite resins reinforced with different types of industrial fibres were measured to evaluate the glass fibres which contributed to the increase in bending properties.

2. Materials and methods

The bending specimens were of two different types of self-curing resin and heat-curing resin, of 10 mm width, 65 mm length and 2.5 mm thickness, according to ADA specification No. 12[8]. The self-curing resin was a conventional self-curing resin of Polybase S (Nissin Co., Kyoto, Japan) and the heat-curing resin was Natural resin (Nissin Co., Kyoto, Japan). The mixing ratio of monomer and polymer including glass fibres was 6 ml 10 gm^{-1} in the former resin, and in the latter 4 ml 10 gm^{-1}. Their composite resins were composed of different amounts of glass fibres for industrial use (Nippon Electric Glass Co., Shiga, Japan). These were four kinds of E type glasses: ECS06TA-1 for thermoplastic use (G-1), 6 μm diameter; ECS03B-154 (G-2) for thermosetplastic use, 3 μm diameter; ECS06B-154 (G-3) for thermosetplastic use, 6 μm diameter, and unwoven fabric ECS06I-33G (G-4) of 6 μm diameter. They all were 6 μm in length. The glass fibres which were treated by a silane coupling to strengthen the binding strength between resins and glass fibres were non-alkali glass containing CaO–Al_2O_3–B_2O_3–SiO_2, because the alkali content is less than 0.8%. The tensile strength of the fibres had more than 48 kg for roving. The glass fibres were laid at random within the acrylic resins, and the sheet of resin, which had a dough-like consistency after 10 min, was approximately 2.5 mm thick.

The specimens of self-curing resins were prepared only by G-1 glass fibres with different amounts of 0.5, 0.75, 1.0 and 2.0 wt %. The specimens of heat-curing resins were made from reinforced composite resins containing G-1, G-2, G-3 and G-4 glass fibres with 5 and 10 wt %.

Transverse deflection values were measured at 3.5 and 5.0 kg according to the test specifications [9]. The bending specimens were set on the testing apparatus and subjected to increasing loads (crosshead speed, 2 mm min^{-1}) until fracture occurred. Peak load values at fracture were collected by means of graph and bending stress–bending strain curves were written in a bending test. The bending properties of proportional limit and bending elasticity were obtained in order to evaluate the effect of glass fibres on the strength and elasticity of composite resins.

3. Results

3.1. Self-curing acrylic resin

Transverse deflection is indicated in Table I. The values for the deflection at 3.5 and 5.0 kg for the composite resins reinforced with glass fibres (G-1), are

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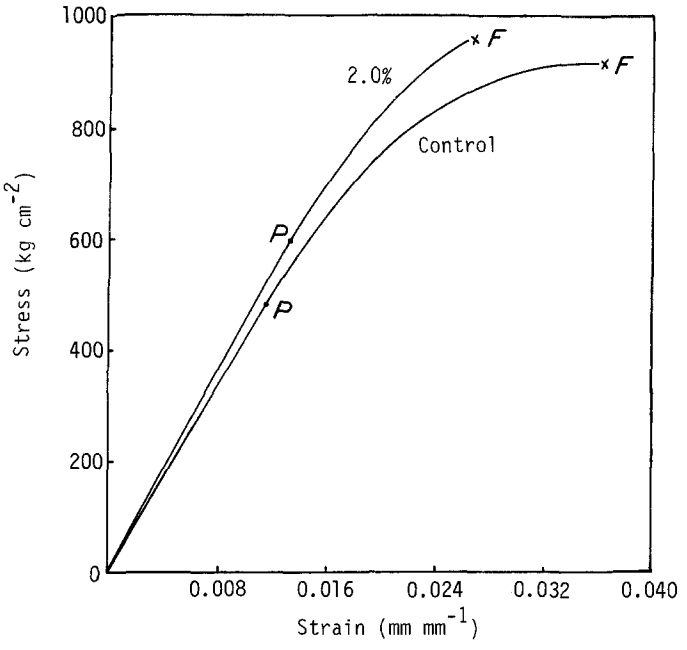

Figure 1 Bending stress–strain curves of the composite reinforced with G-1 glass fibre in self-curing resin and plain self-curing resin (control). *P*, proportional limit; *F*, fracture.

small compared with those values described in ADA specification No. 12 [8]. The composites had almost the same deflection values as the self-curing acrylic resin for the deflection at 3.5 and 5.0 kg. The bending stress–bending strain curves at fracture for the control and the fibre-reinforced PMMA resins containing 2.0% glass fibres is shown in Fig. 1. The bending strength which corresponds to fracture strength for the glass fibre reinforced resin is 951.4 kg cm^{-2} and for the self-curing control resin 904.4 kg cm^{-2}. At point *P*, which indicated proportional limit, the reinforced resin showed a larger proportional limit than the control.

Bending properties, proportional limit, bending strength and bending elasticity are shown for the G-1 glass fibre reinforced resins of 0.5, 0.75, 1.0 and 2.0 wt % (Figs 2–4). In Fig. 5, the relation is shown between proportional limit and bending strength.

3.2. Heat-curing acrylic resin

When different types of glass fibres, G-1, G-2, G-3 and G-4, were added to a heat-curing resin as the standard control the proportional limit and the bending elasticity were as shown in Figs 6a and b. As shown in Fig. 7, a different relation between proportional limit and bending strength was found for the heat-curing resin, compared with the self-curing resin. The control of heat-curing acrylic resin had a proportional limit of 393.6 ± 9.4 kg cm^{-2}, bending strength of 919.6 ± 18.1 kg cm^{-2} and bending elasticity of 285.9 ± 6.5 kg mm^{-2}. Each composite resin including different glass fibres had greater values than the control.

TABLE I Transverse deflection for the composites reinforced with G-1 glass fibres containing 0.5, 0.75, 1.0 and 2.0 wt % in self-curing resin material

Amount of glass fibres (wt %)	Transverse deflection (mm)	
	3.5 kg	5.0 kg
0.5	1.81 ± 0.08	3.60 ± 0.12
0.75	1.81 ± 0.03	3.55 ± 0.02
1.0	1.80 ± 0.02	3.50 ± 0.03
2.0	1.76 ± 0.13	3.39 ± 0.25
Control	1.77 ± 0.02	3.60 ± 0.03
ADAS	2.5	5.5

4. Discussion

Figs 1–4 indicate that the silane coupling treated G-1 glass fibre specimens have a greater proportional limit, and the greatest value of proportional limit exceeded that of a self-curing acrylic resin control by as much as about 25%. On the contrary, the other values of bending strength and bending elasticity increased by as much as 5 to 10%. Increasing G-1 glass fibres from 0.5 to 2.0%, proportional limit changed linearly, whereas the value *s* of bending elasticity and strength showed an only slight change with increased glass fibres. It is deduced that the optimum

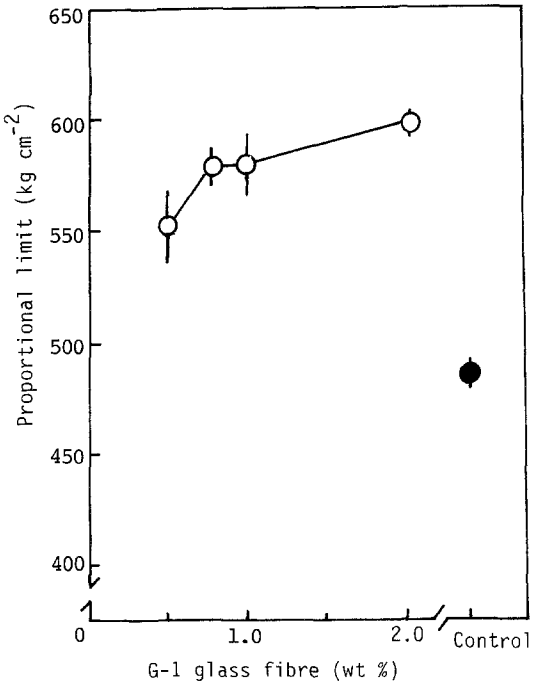

Figure 2 Variation of proportional limit with G-1 glass fibre contents in self-curing resin.

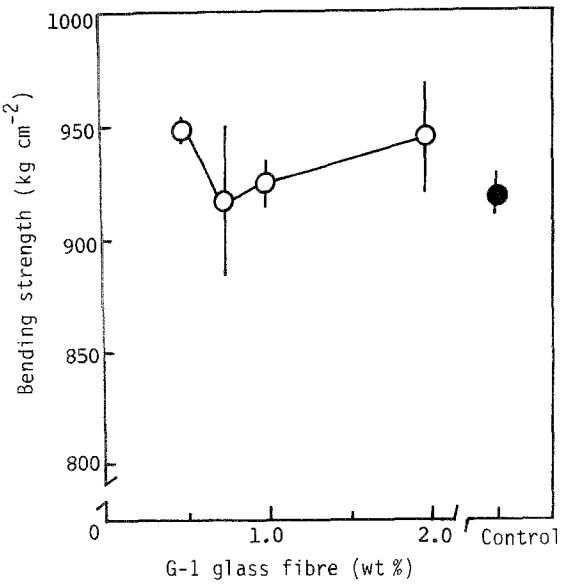

Figure 3 Variation of bending strength with G-1 glass fibre contents in self-curing resin.

amount of G-1 glass fibres may be 0.5 wt % in the self-curing acrylic composite, because the composites including 1.0 to 2.0 wt % of glass fibres showed a slight change in bending elasticity and strength.

Figs 6a and b indicate that heat-curing acrylic composites with different types of glass fibres have greater bending properties than those of plain acrylic resin (control). In the heat-curing acrylic resin, the laying of glass fibres on composite resin was easy compared to the self-curing resin, and thus the greater percentage of 5 and 10 wt % glass fibres was chosen. The proportional limit and bending elasticity in the glass fibre-reinforced composites had greater values than those of plain heat-curing acrylic, whereas the maximum strength, i.e. bending strength, showed the same tendency as bending elasticity for the different types G-1, G-2, G-3 and G-4. The following observations were made:

1. The composites G-1 and G-2 containing 5 and

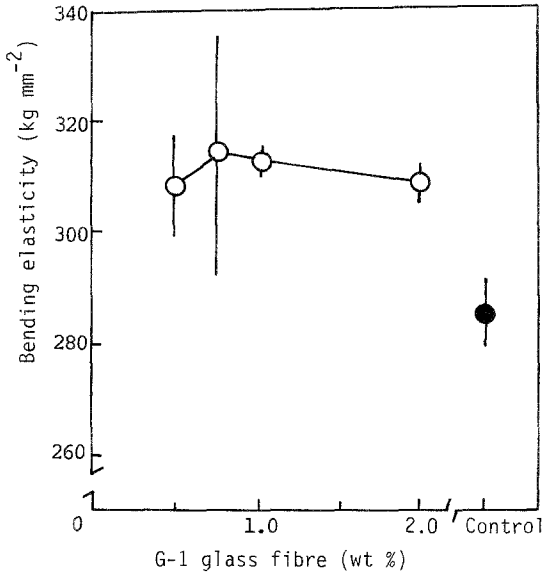

Figure 4 Bending elasticity for the composites containing various amounts of G-1 glass fibres in self-curing resin.

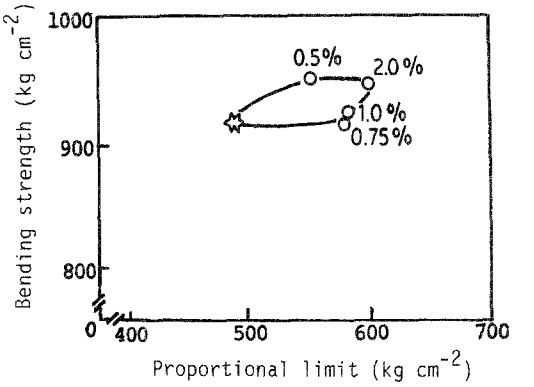

Figure 5 The relationship between proportional limit and bending strength for self-curing resin containing G-1 glass fibre. ○, G-1 glass fibre; ✱, control.

10% glass fibres showed a larger value of proportional limit than that of the control. The composite with 5 and 10% (G-3; 6 μm length) had the same value of proportional limit as the control.

2. The composite with thermoplastic glass fibre (G-1) had the almost same value of proportional limit and bending elasticity as that of the composite G-2.

3. Considering the bending properties, the composite with 10% unwoven glass fibres (G-4) was notably less than that with 5% unwoven ones. It is of interest to note that the bending properties in the composites with G-1 and G-2 were greater than those of the others, and G-1 and G-2 glass fibres had a remarkable effect on the bending properties in glass fibres increased from 5 to 10%.

The relation between proportional limit and bending elasticity is found for the self-curing and heat-curing resins as base resins (Figs 5 and 7). The effect was larger in heat-curing resin than in the self-curing resin, considering the kind of curing system as the base resin. In the heat-curing acrylic resin, the wettability and the consistency with glass fibres were better than for self-curing acrylic resin. The self-curing resin containing more than 2% glass fibres was not obtained in the present study. Discussing the change of bending properties with glass fibre content, the heat-curing acrylic resin may be expected as a base resin rather than the self-curing resin. Both glass fibres for thermoplastic use (6 μm diameter) and glass fibres for thermosetplastic use (3 μm diameter) were better than the other glass fibres of G-3 and G-4, because greater bending properties were obtained for G-1 and G-2 composites than for G-3 and G-4 composites. The composite resin reinforced with 10% unwoven glass fibre (G-4) gave a less good result than that with 5% G-4 glass fibres.

In a preliminary report on the application of carbon fibres to reinforce denture base resin [5], a very strong denture resulted when carbon fibres were incorporated in the base resin, but the deflection of transverse test specimens showed less value than that of the acrylic resin. Additionally, the black colour of carbon may cause a certain amount of difficulty if carbon fibres are involved in the base resin. Carbon fibres may thus be limited to use for lower and upper dentures.

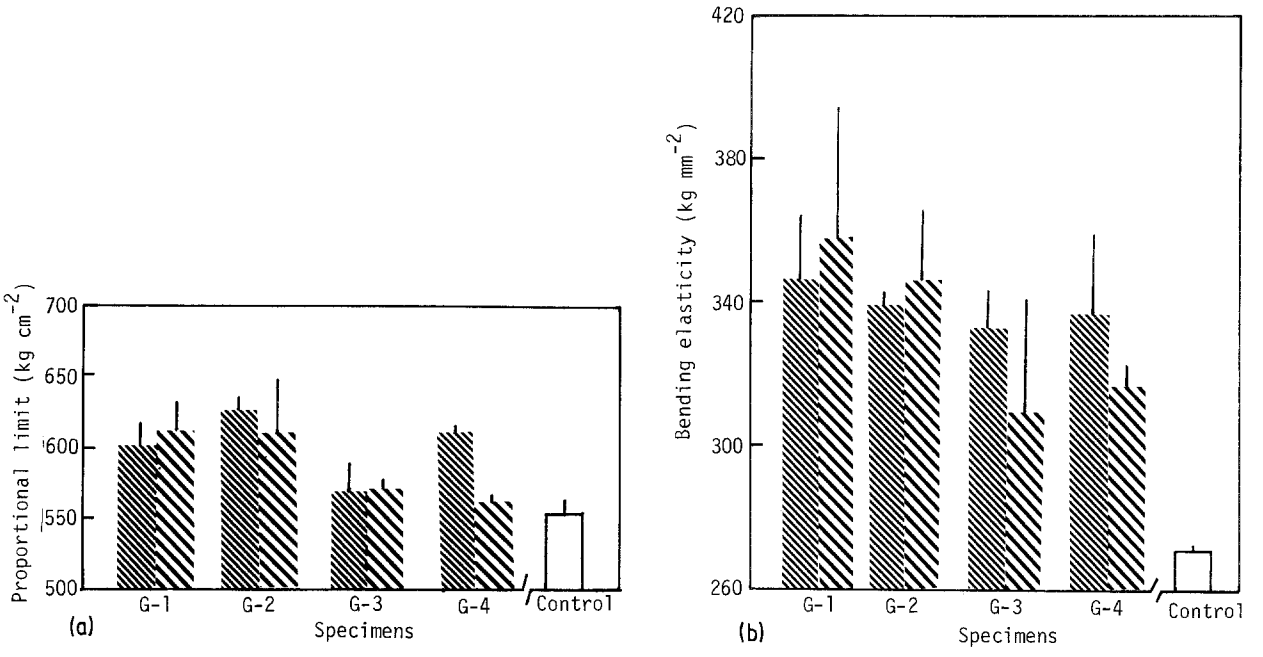

Figure 6 Bending properties of heat-curing resins with G-1, G-2, G-3 and G-4 glass fibres (5 and 10%) and the control. (a) Proportional limit, (b) Bending elasticity. ▨, 5%; ▨, 10%.

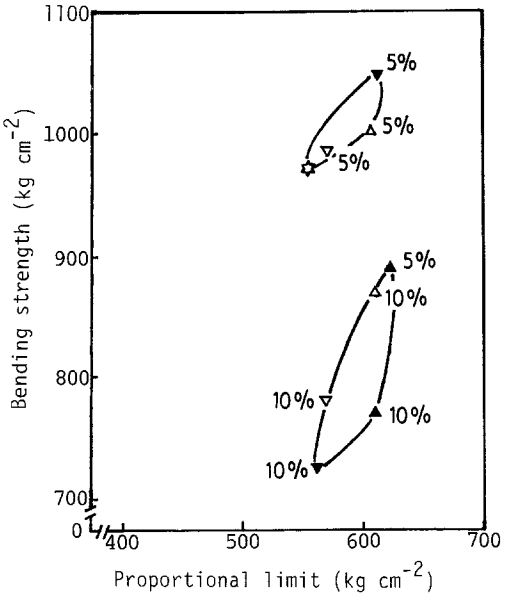

Figure 7 The relation between proportional limit and bending strength for heat-curing resin materials containing △, G-1, ▲, G-2, ▽, G-3 and ▼, G-4 glass fibres and ✡ plain heat-curing resin (control).

Further trials are continuing with the glass fibre-reinforced composites to determine the kinds of glass fibres and the surface treatment of glass fibres useful for clinical applications.

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