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Denture base materials reinforced with glass fibres

Part 2 The effect of glass fibre contents on bending properties

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A study on laying glass fibres with different aspect and volume ratios into denture base resin is presented. Increased strength and toughness are found for the composites containing glass fibres with higher ratios. Their characteristics have prompted the inclusion of surface treated glass fibres in denture materials.

1. Introduction

It has been suggested that acrylic denture base materials reinforced with carbon fibre should be applied clinically to dental prostheses [1]. The fibres have inert and superior elastic properties, but the black colour in the resin is thought to be a disadvantage. A technique to mask the fibres with a pink veneer has been tried [1]. The denture base resin materials are reinforced with treated Kevlar fibre cloths [2–4] and derivatives of poly(p-phenylene terephthalamide) molecules [5–7]. Reinforcement with the rigid molecules increased the bending strengths of molecular composites by 10 to 15% that of the plain base resin material. In addition, the use of glass fibres is now continuing for clinical applications [8].

The purposes of the present study are to examine the bending properties of composite resins having various glass fibre characteristics and to determine the effect of surface treated fibres on the bending strength and bending elasticity of the base composites.

2. Materials and methods

Test specimens of acrylic resin composites were prepared as reported previously [4] for each resin composite. The heat-curing resin, Natural Resin (Nissin Co., Kyoto, Japan), served as a control, and was mixed at a ratio of 4 ml monomer to 10 g powder.

The composites were made as follows. Bundles of fibres, which contained approximately 2000 pieces of very small glass fibres of 10 μm diameter, were wetted with silane coupling treatment (Nippon Electric Glass Co., Shiga, Japan). The linear fibres were laid at the intermediate position of a plain heat-curing sheet of 2.5 mm thickness. The dimension of the plain sheet was 65 × 10 × 2.5 mm. The bundles treated were considered as one piece. The 2, 4, 6 and 8 pieces of glass fibres were laid side by side at an equal distance, as indicated in Table I. The test specimens denoted "E" are those which were surface-treated by Bisphenol-A-bis (2-hydroxypropyl)methacrylate (Bis–GMA) monomers after silane coupling treatment [8]. An aspect ratio of l/d is the size effect, and a volume ratio of V^*/V the volume fraction of glass fibres composed in the sheet specimen dimension.

3. Results

The bending elasticity for the glass fibre reinforced composites and the plain control are indicated in Table II. The bending elasticity of test specimens bent by the Instron Test Machine for the heat-curing resin controls was $271.6 \pm 2.4\,\mathrm{kg\,mm^{-2}}$ and the value for the composites (A, B, C, D and E) changed from 290.0 ± 9.9 to $569.9 \pm 21.8\,\mathrm{kg\,mm^{-2}}$. Application of Student's t-test indicated a significance between the control and composites D and E.

Such bending strengths as maximum strength and proportional limit were shown for l/d aspect ratio indicating size effect and V^*/V volume ratio, respectively (Figs 1a and b), where l and d represent length and diameter of a glass fibre, and V^* and V, volume fraction of glass fibre and specimen, respectively. Their values increased with increasing ratios. The proportional limit was $554.0 \pm 9.7\,\mathrm{kg\,cm^{-2}}$ for the control, and the bending strength $968.8 \pm 19.7\,\mathrm{kg\,cm^{-2}}$. Composite E reinforced with surface-treated glass fibres had, however, larger values than those composites with only silane coupling treatment.

TABLE I Materials tested

Composite	Number	Aspect ratio l/d	Volume ratio V^*/V
A	2	4.06×10^2	6.6×10^{-3}
B	4	8.13×10^2	12.8×10^{-3}
C	6	12.19×10^2	19.2×10^{-3}
D	8	16.25×10^2	25.6×10^{-3}
E	6†	12.19×10^2	19.2×10^{-3}

†Surface treated with monomers.

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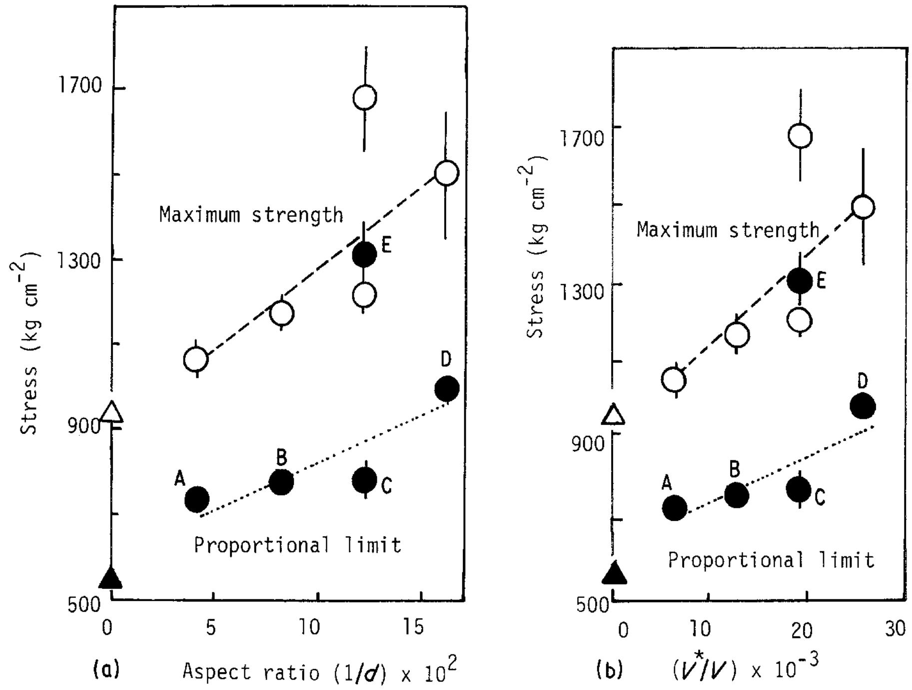

Figure 1 Maximum strength and proportional limit with respect to (a) aspect ratio, l/d and (b) volume ratio, V^*/V. △ and ▲, heat-curing resin without glass fibres (control); ○ and ●, composites A to E.

The strain energy during testing is shown for l/d aspect ratio and V^*/V volume ratio in Figs 2a and b. The strain energy at proportional limit increased linearly with increasing ratios. The strain energy at maximum load for composites B, D and E was greater than that for the control, but composites A and C had a smaller strain energy than the control.

4. Discussion

The bending elasticity and bending strength are important factors in the selection of denture base resins. The values (Table II and Figs 1a and b for the composites reinforced with glass fibres represent greater values than the control, and their glass fibres serve as an effective reinforcement against the plain base resin without glass fibres. The bending elasticity of composites A, B and C as tested showed the value of approximately 1.1 times that of the control, and the bending elasticity of composites D and E were approximately 1.4 and 2.2 times that of the control, respectively. When compared with composite C, composite E demonstrated a proportional limit and bending strength changing from 776.0 ± 49.5 to 1309.3 ± 80.2 kg cm^{-2} and from 1210.1 ± 43.0 to 1678.5 ± 117.9 kg cm^{-2}, respectively. Composite D, containing the largest amount of glass fibres, showed 991.4 ± 35.7 and 1497.8 ± 154.7 kg cm^{-2} for proportional limit and bending strength (maximum strength). These changes indicate that wetting the surface with Bis-GMA monomers after silane coupling treatment is an effective technique [9]. This supports the findings of Schreiber [1] that the wetted monomers between carbon fibres may increase the bond between the carbon fibre and the resin.

The strain energy at proportional limit increased linearly with aspect and volume ratios (Figs 2a and b). The strain energy at maximum load for composites B, D and E showed a rather greater value when compared with composites A and C. As strain energy at maximum load relates to the toughness of the resin materials the arrangement of glass fibres is an important factor in relation to toughness. Composites A and C had a smaller strain energy at maximum load than the control (Figs 2a and b). Thus the bond between glass fibres and resin material may not be coherent. It is suggested that the toughness of composites B, D and E is enough compared to the heat-curing control.

This study indicates that the resin composites reinforced with linear glass fibres are more effective than the resin composites containing 5 and 10% glass

TABLE II Bending properties of stress (proportional limit and maximum strength), strain energy and bending elasticity

Composite	Stress (kg cm^{-2})		Strain energy (kg cm^{-2})		Bending elasticity (kg mm^{-2})
	Proportional limit	Maximum strength	Proportional limit	Maximum load	
A	730.6 ± 1.2	1055.8 ± 36.1	5.9 ± 0.0	17.0 ± 1.9	294.7 ± 14.8
B	769.5 ± 25.9	1172.2 ± 39.2	7.0 ± 0.2	32.4 ± 2.8	291.9 ± 9.5
C	776.0 ± 49.5	1210.1 ± 43.0	7.2 ± 0.8	29.0 ± 4.6	290.0 ± 9.9
D	991.4 ± 35.7	1497.8 ± 154.7	8.8 ± 0.1	37.7 ± 9.9	379.2 ± 33.8
E	1309.3 ± 80.2	1678.5 ± 117.9	10.1 ± 1.2	18.6 ± 3.0	589.9 ± 21.7
Control*	554.0 ± 9.7	968.8 ± 19.7	2.4 ± 0.1	19.8 ± 3.6	271.6 ± 2.4

*Heat curing resin without glass fibres.

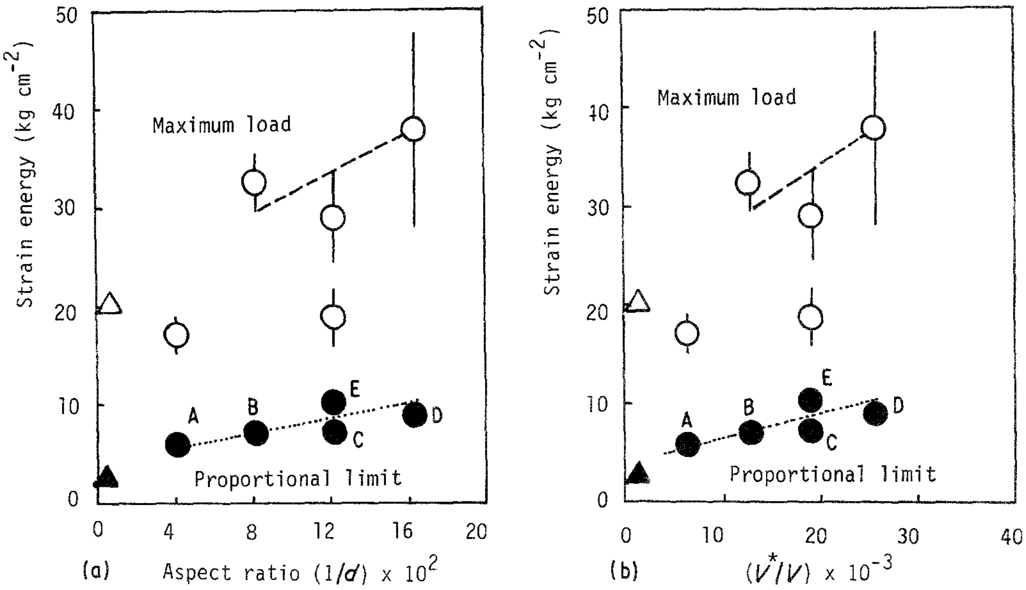

Figure 2 The variation of strain energy with aspect ratio of (a) l/d and (b) volume ratio of V^*/V. △ and ▲, heat-curing resin without glass fibres (control); ○ and ●, composites A to E.

fibres for thermoplastic and thermosetplastic uses observed by the authors [8], because the composite with glass fibres distributed at random showed only a 10% increase of bending properties, compared with the heat-curing control.

Other characteristics such as glass cloths and adhesive between glass fibre and resin need to be considered. It may be effective to use the high content glass cloths, because bundles of glass fibres increased the bending properties of the composites. Continued studies on the method of laying glass fibre cloths into the denture base resin are under way.

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