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The static strength and modulus of fiber reinforced denture base polymer

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Summary *Objectives*. Partial fiber reinforcements have been employed to strengthen dentures both during repair and in the manufacturing process. The reinforcing fibers can be evenly distributed in the denture base polymer or alternatively fiber-rich phase in the denture base polymer can form a separate structure. The aim of this study was to determinate static three-point flexural strength and modulus of denture base polymer that had been reinforced with different fiber reinforcements.

Methods. The test specimens ($3\times5\times50$ mm) were made of auto-polymerized denture base polymer and reinforced with different fiber reinforcements. The test groups were: (A) no fibers; (B) non-impregnated polyethylene fibers; (C) light-polymerized monomer impregnated glass fibers; (D) porous polymer preimpregnated glass fibers and (E) light-polymerized monomer–polymer impregnated glass fibers. The fibers were oriented parallel to the long axis of the specimen and embedded into the denture base resin on the compression side ($n=7$) or tension side ($n=7$). Dry specimens were tested with three-point static flexural strength test set-up at crosshead speed of 5 mm/min.

Results. The statistical analysis by two-way analysis of variance showed that the brand and the location of the fiber reinforcements significantly influenced the flexural strength ($p<0.0001$). However, the location of the fiber reinforcements did not influence the flexural modulus ($p<0.722$).

Significance. The results suggest that impregnated and preimpregnated fibers reinforce denture base polymer more than non-impregnated fibers. Fiber reinforcements placed on the tensile side resulted in considerably higher flexural strength and flexural modulus values compared with same quantity of fibers placed on the compression side.

Introduction

Acrylic resin, based on polymethylmethacrylate (PMMA), is one of the materials routinely used for

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the manufacture of removable dentures. The favorable working characteristics, ease of manipulation and polishability, its use in combination with inexpensive equipment, stability in the oral environment and the aesthetics of acrylic resin have resulted in its extensive us as a denture base polymer. However, the acrylic resin denture base polymer has not fulfilled all the requirements in terms of optimum mechanical properties [1] due to its brittle nature under its glass transition temperature (T_g) of approximately 110 °C [2], and its susceptibility to cyclic loading. For this reason, fatigue fracture of dentures is a common clinical manifestation [3–13]. It is unlikely that a complete denture would be broken by one heavy biting cycle due to the high volume of the denture base polymer and the geometry of the base plate [10]. However, the thin denture base plates of removable partial dentures can fracture by one loading cycle as a result of a poorly balanced occlusion [12] and a fracture of this kind could result from a static load.

Conventional methods employed to reinforce denture base polymers generally involve the use of either metal wires or plates, however, their influence is minor [3–6]. Fiber-reinforced composites (FRC) have been introduced [14–32] to overcome the problem of denture factures by improving the mechanical properties of the denture base polymer. Partial fiber reinforcements, namely accurate placement of a relatively small quantity of fibers in the denture base polymer, have been employed to strengthen dentures both during repair and in the manufacturing process [5,6].

The types of fibers that have been used to reinforce denture base polymers include aramid fibers [14,15], carbon/graphite fibers [16], ultra-high molecular weight polyethylene (UHMWP) fibers [17–20] and glass fibers [5,6,14,21–32]. Although UHMWP fibers have relatively good mechanical properties, there are reports that poor adhesion of the fibers to the polymer matrix, even with the aid of plasma treatment, does not considerably increase the mechanical properties of the denture base polymer [18]. It has been previously shown that glass fibers can be adhered to the resin by silane coupling agents and can be used as an effective reinforcement [32]. In recent years, several brands of fiber reinforcements have become available, however, in the opinion of the authors there is a distinct lack of comparative information of the reinforcing effect of the various fiber reinforcements available in the dental literature. Therefore, the aim of the current study was to determine the static three-point flexural strength and flexural modulus of a denture base polymer that has been reinforced with fiber reinforcements commonly available to dentist and dental technicians.

Materials and methods

The test specimens utilized in the current study ($3 \times 5 \times 50$ mm) were manufactured from clear auto-polymerizing denture base resin (Palapress, Heraeus Kulzer GmbH & Co. KG, Wehrheim, Germany) and reinforced with four different brands of fiber reinforcements (Table 1, Fig. 1). The powder/liquid ratio of resin was 107 g/ml and the resin was polymerized in distilled water maintained at 55 ± 2 °C under air pressure of 300 kPa for 15 mins in a pneumatic curing unit (Ivomat Typ IPR, Ivoclar,

Table 1 Classification of test groups and the fiber reinforcing materials used in the current study.

Group	Manufacturer	Fiber type	Type	Preimpregnation resin
A. Control		None		
B. Ribbond	Ribbond Inc., Seattle, USA	Woven ribbon polyethylene UHMWP[a]	Non-preimpregnated	-
C. FibreKor	Jeneric/Pentron, Wallingford, USA	Continuous unidirectional S-glass fiber	Light-polymerizing resin impregnated Shade Clear 2K bundle, 3 mm wide	Bis-GMA[b]
D. Everstick	StickTech Ltd, Turku, Finland	Continuous unidirectional E-glass fiber	Light-polymerizing resin impregnated	Bis-GMA with, PMMA[c]-bis-GMA matrix
E. Stick	StickTech Ltd, Turku, Finland	Continuous unidirectional E-glass fiber	Porous polymer preimpregnated fiber	PMMA

[a] Ultra-high molecular weight polyethylene fiber.
[b] 2, 2-bis[4-(2-hydroxy-3-methacryloxypropoxy)phenyl]-propane.
[c] Polymethylmetacrylate.