

Flexural properties of some experimental dental glass fiber reinforced composites with different resin matrices

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There was prepared a series of 12 experimental fiber reinforced composites (FRCs) based on continuous unidirectional bundles of E glass fibers and resins consisting of Bis-GMA₀ monomer- 2,2-bis[4-(2-hydroxy-3-methacryloyloxypropoxy) phenyl]-propane-, Bis-GMA_{0,2} superior oligomers having 81 mol % Bis-GMA₀ monomer, 17 mol % Bis-GMA₁ dimer and 2 mol % Bis-GMA₂ trimer, a cycloaliphatic urethane dimethacrylate monomer, and triethyleneglycol dimethacrylate in different ratios. The relationship between the resin composition, the quantity of fibers and the flexural properties of harden FRCs has been investigated. The values of flexural properties obtained for the FRCs originated from experimental resins and one bundle of fibres (4000 fibres) were in the range of 295-407.5 MPa for flexural strength and 7.3-8.9 MPa for Young's modulus. For the composites originated from two bundles of fibres (8000 fibres) and investigated resins, the flexural strength ranged between 675-738 MPa, and the Young's modulus ranged between 16.37-19.47 MPa. The results pointed out a slight tendency of increasing the flexural properties in the case of using (Bis-GMA)_{0,2} oligomers instead of (Bis-GMA)₀ monomer. It can be noticed that the flexural strength of FRCs which contain two bundles of fibers was about 1.5 up to 2 times higher than that of FRCs with the same resin matrix and one bundle fibers.

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Keywords: Fiber reinforced composites, Dental, flexural properties

1. Introduction

The technology and materials available to today's restorative dentists offer various solutions to many complex problems. Missing tooth structure can be replaced through the use of adhesives or metal-ceramic crowns, and missing teeth can be replaced with any of a variety of fixed prostheses supported by teeth or implants. Porcelain-fused-to-metal substructures continue to be mainstay of fixed prosthodontics, and polymethyl methacrylate polymer remains the material of choice for complete denture bases.

As popular and successful as these materials are, they exhibit shortcomings that frequently cause clinical problems. The metal alloys used to make substructures that reinforce crowns and fixed prostheses are strong and rigid, but they are not esthetic and present corrosion phenomena, leading to an allergic reaction of some patients [1].

Ceramic materials such as porcelain may exhibit good optical qualities, but they are also brittle, and they sometimes abrade or fracture the opposing teeth. The acrylic polymer materials such as methyl methacrylate that are used to make removable and provisional fixed prostheses offer desirable handling qualities and physical properties, but they are susceptible to fracture in many clinical circumstances.

The actual research activities are focused on the developing of new materials, technologies and principles of realization of dental prostheses that can eliminate the mentioned shortcomings. The achievement of total polymeric restorations and the reinforcement of the resins with fibres for the obtaining of the prosthesis frameworks represents one of the actual purposes that begins to impose [2]. These materials could be used in any situation in which the main purpose is esthetics, because they present excellent esthetic properties. The mechanical properties

increase very much because of the reinforcing fibers, getting ahead of the values obtained for the metal alloys which are used today in dentistry [3].

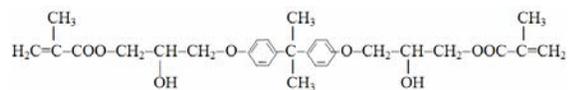
For a single crown or fixed partial denture (FPD), the FRC framework replaces the classic metal framework of a porcelain-fused-to-metal prosthesis, while the application of a particulate composite over this FRC framework corresponds to that of porcelain over a traditional metal substructure. The FRC framework provides strength and rigidity beneath the outer layer of particulate composite. This two-component polymer prosthesis combines the best characteristics of the FRC (strength and rigidity) with the best characteristics of the particulate composite (wear resistance and esthetics) [4].

The aim of this study is to prepare a series of FRCs based on continuous unidirectional bundles of E glass fibers and different resin matrices and to investigate the influence of the resins composition and of the quantity of fibers upon the flexural properties of the resulted FRCs. The biocompatibility of the cured FRC is also investigated.

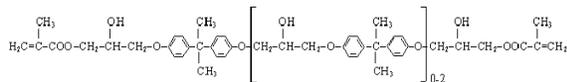
2. Experimental

2.1. Obtaining of the experimental glass fiber reinforced composites

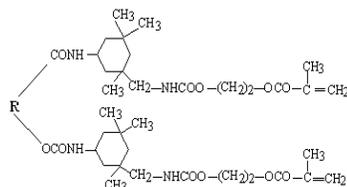
The resins were prepared using Bis-GMA₀ monomer; (Bis-GMA)_{0,2} aromatic dimethacrylic oligomers mixture, having 81 mol % Bis-GMA₀ monomer - 2,2-bis[4-(2-hydroxy-3-methacryloyloxypropoxy) phenyl]-propane, 17 mol % Bis-GMA₁ dimer and 2 mol % Bis-GMA₂ trimer; polyethyleneoxid diurethane-ethyl methacrylate and TEGDMA in different ratios. The formula of monomers and oligomers are presented below:



2,2-bis[4-(2-hydroxy-3-methacryloyloxypropoxy)phenyl]propane (Bis-GMA)₀

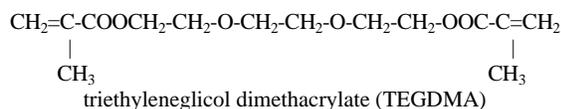


Bis-GMA_{0.2}



R: $-\text{[CH}_2\text{CH}_2\text{O]}_n$ ($n=22,3$)

CAUDMA



In the composition of the monomers mixtures, besides the methacrylic oligomers and monomers, a photosensitizer, camphorquinone, and an accelerator dimethylaminoethyl-methacrylate, were added.

Continuous unidirectional bundle of E glass fibers containing 4000 fibers and respectively two bundles containing 8000 fibers were silanated with A 174 silane and A 1100 silane and used in order to obtain the experimental FRCs.

For the obtaining of cured specimens, the FRCs were first light-cured by exposing to a visible radiation in the wavelength range of 400-500 nm for 240 sec (Optilux stomatological lamp). After initial polymerization, the specimens were postcured by barro-thermic treatment at 135 °C temperature and 60 psi pressure, for 20 minutes, using a "belleGlass" oven.

Table 1. Composition of the resin matrices in the experimental fiber-reinforced composites.

No.	Bis-GMA ₀ %	Bis-GMA _{0.2} %	CAU-DMA %	TEG-DMA %
C1.	35%			65%
C2.	65%			35%
C3.		35%		65%
C4.		65%		35%
C5.	45%		20%	35%
C6.		45%	20%	35%

$$FS = 3 Fl / 2bh^2$$

where F is the applied load (N), l is the span length (20 mm), b is the width (2.0±0.1) mm of the test specimen. Young's modulus (Y (GPa)) of the test specimens was calculated from the following formula:

$$Y = Fl^3 / 4bh^3d$$

where d is the deflection (mm) corresponding to the load F , at a point on the straight-line portion of the trace.

2.2. Structural investigations of the experimental FRCs by scanning electron microscopy

The fracture appearances of the glass fiber/organic resin interfaces as the consequence of the flexural stresses has been investigated by SEM.

2.3. Biocompatibility

The biocompatibility was studied using the test of tolerance by the intramuscular implantation of the cured FRC specimens.

3. Results and discussion

3.1. Determination of flexural properties

The values of flexural strength and Young's modulus determined for the experimental composites originated from C1-C6 resins reinforces with one continuous unidirectional bundle of E-glass fibers and respectively two bundles of the same fibers are shown in Fig. 1 and Fig. 2.

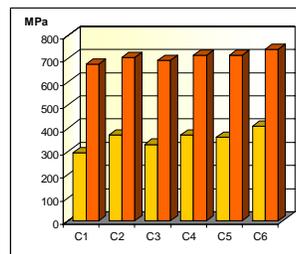


Fig. 1. The flexural strength of the experimental FRC with one and respectively two bundles of E-glass fibers
■ One bundle of fibers, ■ Two bundles of fibers.

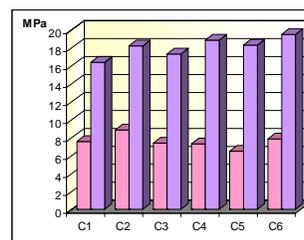


Fig. 2. The Young's modulus of the experimental FRC with one and respectively two bundles of E-glass fibers
■ One bundle of fibers, ■ Two bundles of fibers.

3.2. Structural investigations of the experimental FRCs by scanning electron microscopy

The glass fiber/organic resin interfaces as the consequence of the flexural stresses are presented in the Figs. 3a-h:

3.3. Biocompatibility

The implantation test was conducted on two species of experimental rats using the fiber reinforced composites.

Tissue fragments were processed by classic histological technique. Fig. 4 shows the relationship between cured C4 and the subcutaneous conjunctive tissue of the rat.

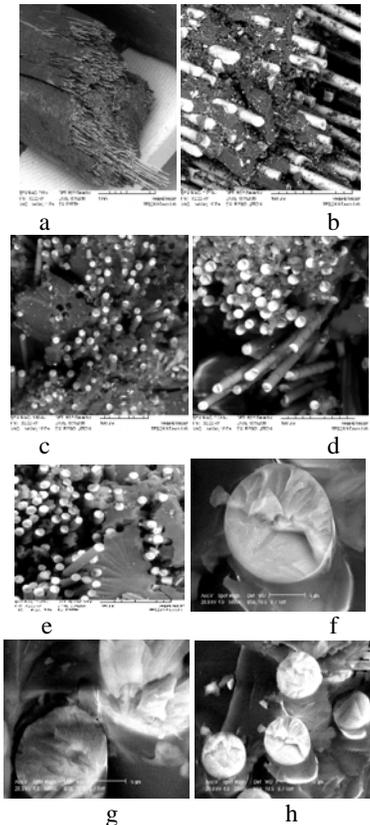


Fig. 3. SEM photomicrographs. a. Fracture appearance of C1; b. Fracture appearance of C2; c., d. Fracture appearance of C3; e. Fracture appearance of C4; f. The silanated E-glass fibers fixed in the resin matrix in C4; g. The silanated E-glass fibers fixed in the resin matrix in C5; h. The silanated E-glass fibers fixed in the resin matrix in C6.



Fig. 4. Relationship between the implant (cured C4) and the subcutaneous conjunctive tissue of the rat at 21 post implant days. Morphological aspect (left) and histological aspect (right).

Fig. 5 shows the relationship between cured C4 and the muscular tissue of the rat.

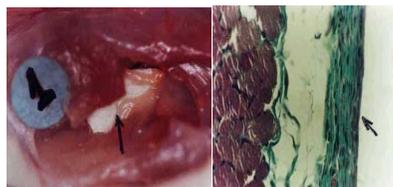


Fig. 5. Relationship between the implant (cured C4) and the muscular tissue of the rat at 21 post implant days. Morphological aspect (left) and histological aspect (right).

4. Discussion

The values of flexural properties obtained for the FRCs originated from C1-C6 resins and one bundle of fibres were in the range of 295-407.5 MPa for flexural strength and 7.3-8.9 MPa for Young's modulus.

For the composites originated from two bundles of fibres and C1-C6 resins, the flexural strength ranged between 675-738 MPa, and the Young's modulus ranged between 16.37-19.47 MPa. It can be noticed that the flexural strength of FRCs which contain two bundles of fibres was about 1.5 up to 2 times higher than that of FRCs with the same resin matrix and one bundle fibers. The results pointed out a slight tendency of increasing the flexural strength and Young's modulus in the case of using (Bis-GMA)_{0.2} superior oligomers instead of (Bis-GMA)₀ monomer. The addition of CAUDMA to the resin matrix also increased the flexural properties. The highest flexural strengths were determined for C6 composite.

The SEM photomicrographs showed an uniform distribution of fibers in the composites. The best wetting of the glass fibers was achieved in the case of using the (Bis-GMA)_{0.2} superior oligomers and CAUDMA monomer in the resin.

The test of biocompatibility proved that the fiber reinforced composites didn't contain toxic substances that could provoke reject phenomenon at a local level or an alteration of the anatomical integrity of the implant zone.

5. Conclusions

There was prepared a series of 12 experimental FRCs based on continuous unidirectional bundles of E glass fibers and monomer mixtures consisting of Bis-GMA₀ monomer, Bis-GMA_{0.2} superior oligomers, a cicloaliphatic urethane dimethacrylate monomer, and triethyleneglycol dimethacrylate in different ratios. The relationship between the resin composition, the quantity of fibers and the flexural properties of hardened FRCs has been investigated. We came to the conclusion that the chemical composition of the resin and especially the quantity of fibers influences the flexural properties of the FRCs.

Biological tests lead to the conclusion that the elaborated FRCs are well tolerated by the organism without any systemic or local rejection manifestation.

Acknowledgement

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References

- [1] M. A. Freilich, J. C. Meiers, J. P. Duncan, G. A. Ion Fiber-reinforced composites in clinical dentistry, Ed. Quintessence Publishing Co, Ltd., 1-15 (1999).
- [2] M. Vakiparta, A. Yli-Urpo, P. K. Vallittu, Journal of Materials Science. Materials in Medicine **15**, 7 (2004).
- [3] L. Lassila, P. K. Vallittu, The Journal of Contemporary Dental Practice, **5**, 2, (2004).
- [4] S. Debnath, R. Ranade, S. L. Wunder, J. McCool, K. Boberick, G. Baran, Dental Materials **20**, 677 (2004).

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