ORIGINAL ARTICLES

IMPACT STRENGTH OF ACRYLIC HEAT CURING DENTURE BASE RESIN REINFORCED WITH E-GLASS FIBERS

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INTRODUCTION

Health assurance systems from many European countries are interested in acrylic removable denture base fracture. United Kingdom for example, spends approximately 18,000,000 £ annually for denture repairs. In our country denture base fracture is also a common problem. Our Prosthodontics Department deals with the prevention of acrylic denture base fractures too.

Fiber reinforced composites were used since 80’s in fields where reduced weight is critical and there must be also increased strength. These materials recognized applications ranging from mass-produced tennis rackets to relatively complex structures, such as the wings of the AV-9B Harrier aircraft.

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ABSTRACT

Introduction: Fracture of complete or removable partial acrylic dentures is a common problem in these patients. One reason for the occurrence is the low impact strength of the acrylic resin. Purpose: The purpose of this study was to measure the impact strength of a conventional heat cure acrylic resin reinforced with E-glass fibers (fibers Stick™ and Stick® Net). Material and methods: Preimpregnated woven E-glass fibers (Stick™ and Stick® Net, Stick Tech Ltd Oy) and unidirectional preimpregnated E-glass fibers (Stick™) were used to reinforce a conventional heat-curing denture base resin (Meliodent, Heraeus Kulzer GmbH&Co.KG). We used 6 unreinforced specimens and 22 reinforced specimens, 11 with Stick™ and 11 with Stick® Net. We used the Charpy impact testing method, measuring the absorbed impact energy. A one-way ANOVA was used to compare the data. Results: The absorbed impact energy was high for the specimens reinforced with Stick™ (W = 0.16 J), followed by those for the specimens reinforced with Stick® Net (W = 0.16 J) and unreinforced specimens (W = 0.12 J). Statistical analysis showed that the impact strength was higher in fiber-reinforced specimens (p < 0.05). Conclusions: The position and the type of reinforcement influenced the values of the impact strength. Reinforcing the denture base resin with E-glass fibers is obviously beneficial and the reinforcement with Stick™ is significant for improving the impact strength of the material.

Key Words: traditional acrylic resin, E-glass fibers, and impact strength

ARTICLE

Objectiv: Pacienții purtători de proteze totale sau parțiale acrilice se prezintă frecvent cu protezele fracturate. Una dintre cauzele acestor fracturi este reprezentată de rezistența mecanică redusă la impact. Scopul studiului: Determinarea rezistenței la fractură a unei rășini acrilice convenționale termopolimerizabile armate cu fibre de stică (fibre Stick™ și Stick® Net). Material și metodă: Fibre de stică preimpregnate sub formă de plasă (Stick® Net, Stick Tech Ltd Oy) și sub formă de mărunți de fibre unidirecionale (Stick™, Stick Tech Ltd Oy) au fost utilizate pentru armarea unei rășini acrilice termopolimerizabile convenționale (Meliodent, Heraeus Kulzer GmbH&Co.KG). Au fost realizate 6 probe nearmate (martor) și câte 11 probe armate cu Stick™ și Stick® Net). S-a folosit testarea la încovoiere prin impact Charpy măsurându-se energia absorbită (W). S-a realizat analiza statistică (ANOVA one-way) a datelor obținute. Rezultate: Cea mai mare energie a fost absorbită în cazul epruvetelor armate cu Stick™(W=0.76, J), fiind urmată în ordine descreșătoare de cele armate cu Stick® Net (W=0.16 J) și de cele nearmate (W=0.12 J). Analiza statistică a arătat că rezistența la impact a rășinii acrilice convenționale a fost crescută semnificativ de armarea cu fibre de stică (p<0.05). Concluzii: Tipul armăturii a influențat măsurările rezistenței la impact. Armarea rășinii acrilice cu fibre de stică determină în mod evident creșterea rezistenței la impact, această creștere fiind semnificativă în cazul armării cu fibre de stică unidirecționale (Stick™).

Cuvinte cheie: rășină acrilică convențională, fibre de stică, rezistență la impact

1 The first symposium on Fiber Reinforced Plastics in Dentistry was organized in Turku, Finland in August 1998.

Nowadays, PMMA is one of the most commonly used materials for processing complete dentures
and also removable partial dentures especially in our country. Despite not meeting all the necessary requirements, PMMA has gained widespread usage due to its ease of use and good aesthetics.

The transverse strength of PMMA can be slightly enhanced by using metal strengtheners, but they have poor aesthetics.\textsuperscript{2-4} Other researchers tried to reinforce the polymer with carbon/graphite fibers, ultra high modulus polyethylene and glass fibers.\textsuperscript{2,4,5-13}

Vallittu has determined the factors affecting the strength of fiber-reinforced composites:\textsuperscript{14}
1. Orientation of fibers;
2. Quantity of fibers;
3. Impregnation of fibers with the matrix polymer;
4. Adhesion of fibers to the matrix polymer;
5. Properties of fibers vs. properties of matrix polymer.

Complete removable acrylic dentures are subjected to stress. In particular, high impact stress occur when the denture is dropped since the patient cleans it, or even accidentally. Polyethylene fiber reinforcement was reported to improve impact resistance by 360\%.\textsuperscript{14} Carbon fibers reinforcement increased the impact strength of PMMA by 10 times but they have poor esthetics (they are yellow).\textsuperscript{6} Usually metal wires are used in dental laboratories, but they have also poor esthetics and there are some problems regarding adhesion between the acrylic resin and the metal wire.

High impact resins Lucitone 199 (Dentsply, York Pa), Trevalon HI (Dentsply, York Pa), GC Luxon (GC Tokyo, Japan) and Ivocap Plus (Ivoclar Vivadent Schaan, Lichtensein) demonstrated significantly higher fracture resistance, but they are expensive compared with heat cure resins.\textsuperscript{15-17}

Many recent studies have examined glass fiber reinforcements.\textsuperscript{18-20} Adherence of acrylic resin to dental fibers is good, the esthetic results are also good and the price is acceptable. The glass is light compared with metal.

The general thought is that glass is a brittle material and doesn't resist to impact. This study investigated the impact strength of acrylic denture base resin reinforced with E-glass fibers Stick\textsuperscript{TM} and Stick\textsuperscript{®} Net (Stick Tech Ltd Oy, Turku, Finland).

**MATERIALS AND METHODS**

The Charpy impact test was used in this study. The research was carried out in the Department of Materials Strength, Mechanical Engineering Faculty, Polytechnic University, Timisoara.

For the Charpy impact measurement, the ISO standard 179-1:2000 was followed.\textsuperscript{20}

The samples were manufactured using a heat cure acrylic resin Meliodent (Heraeus Kulzer GmbH & Co.) and glass fibers: Stick\textsuperscript{TM} (preimpregnated unidirectional glass fibers) and Stick Net\textsuperscript{®} (preimpregnated glass fabric) (Stick Tech Ltd Oy, Finland).

First, we waxed up (Modelling Wax, Astar Montero, Cluj-Napoca România) two specimens (80x48x10 mm, respectively 80x24x10 mm). Half of the wax up thickness was placed in one half of the flask and the other in the second half of the flask. The mold was done from plaster (Alabaster, Interdent\textsuperscript{®}, Slovenia). The isolation of the mold was done with alginic solution. The heat cure resin was used in a compression-molded technique. Glass fibers Stick\textsuperscript{TM} and Stick Net\textsuperscript{®} were wetted with a powder liquid mixture. Both products were wetted in a plastic foil, for about 10 minutes till they became transparent. Compression of the flask was done at 200 bar (CE Omec Muggio-MI-Italy). The flasks were immersed in water at 24ºC. Water temperature was progressive increased at 100ºC, and they were boiled for 30 minutes. The polymerized test specimens were cut out to final dimension (80x10x34mm) with diamond disks (Super flexible diamond disks, ISO-No. 806 104 377514 Meisinger, Düsseldorf, Germany) and finished using paper abrasive disks (Cuttlefish paper disks, regular grit 3-4 inch S.S. White Limited England). The notches were cut edgewise in the middle of the specimens (c=2 mm). The glass fibers were placed in the center of the specimens and they were not cut when making notches. In cross section the unidirectional glass fibers (Stick\textsuperscript{TM}) were placed in the middle of the specimens. The glass net (Stick Net\textsuperscript{®}) was placed perpendicular to the impact force so in cross section the number of glass fibers were reduced. The specimens where propped up at 60 mm. (Fig. 1) Each specimen was measured. Before testing, the specimens were stored in a water bath for two weeks at 37ºC and for one hour at 10 ºC.

**Figure 1.** Schematic illustration of the used specimen.

Charpy test was performed using a hammer
The impact speed was 50 cm/s (v=50 cm/s). The absorbed energy was calculated using the formula:

\[ W = mg(l \cos \beta - l \cos \alpha) \]

Where \( m \) (kg)=hammer weight, \( l \) (m)=hammer length, \( \beta \) and \( \alpha \) = initial and final position of the pendulum.

We also calculated the work of fracture \( W/A \) (kJ/m²).

The results were subjected to statistical analysis using one-way analysis of variance (ANOVA one-way).

RESULTS

Mean values for Charpy impact absorbed energy \( (W) \) were 0.1221 J for unreinforced specimens, 0.7691 J for specimens reinforced with Stick™ and 0.1673 J for specimens reinforced with Stick® Net. Testing results are represented in the Tables 1-3.

Absorbed energy values for specimens reinforced with unidirectional glass fibers (Stick™)

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<th>Width ( a ) (mm)</th>
<th>Width in the notch ( a_0 ) (mm)</th>
<th>Thickness ( b ) (mm)</th>
<th>Area ( A ) (mm²)</th>
<th>Initial angle ( \alpha ) (°)</th>
<th>Final angle ( \beta ) (°)</th>
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Mean values

0.1221                      4.73

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Mean values

0.7691                      29.27

The impact absorbed energy \( (W) \) and the fracture work were significantly increased for specimens reinforced with unidirectional glass fibers versus specimens reinforced with glass net and unreinforced specimens. The specimens reinforced with glass net (Stick® Net) had also increased impact strength versus unreinforced specimens.

One-way ANOVA statistical analysis revealed significant differences between the three materials (\( p<0.05 \)).
DISCUSSION

Impact strength is a measure of material absorbed energy when it suffers sudden fracture. Ideally, a complete denture resin must offer sufficient impact strength while extra orally high impact forces may occur as a result of dropping the prosthesis. This high impact strength must not interfere with other properties of the material.

Glass fibers are not very resistant to impact but their strength can be improved by using many glass unidirectional glass fibers (Stick™) or by using woven glass fiber (Stick® Net). Heat-polymerizing PMMA is a brittle material in the temperature of the oral cavity and the denture has low impact strength.

When a denture is dropped the speed exceeds the chewing speed (approximately 13.5 m/s). So, we used for this impact test a 50 cm/s speed.

The results of our study reveals a serious improvement of the impact strength for PMMA reinforced with Stick™ and Stick® Net. The impact strength for PMMA reinforced with Stick™ was 6.2 times bigger than the impact strength for the unreinforced PMMA. For Stick® Net the impact strength was 1.3 times bigger than for the un-reinforced PMMA. The differences between the two types of reinforcements are probably due to the number of glass fibers per section area of test specimen. The number of glass fibers is bigger in Stick™ test specimens than in Stick® Net test specimen.

Some researchers have reported increased values for the Charpy impact strength of the reinforced specimens. Uzun reported that the Charpy impact strength of resin reinforced with glass fiber was about 11-fold that of unreinforced resin, and Valittu and Narva reported an approximately 10-fold improvement. The direction of the fibers parallel to the long axis of the test specimen was also important. The same orientation was used by Vallittu. Stick® Net fibers are reinforcing the PMMA in all directions but the number of fibers on section area was lower than in Stick™ reinforcements.

Fracture of PMMA reinforced with Stick Net was easy. Fracture of PMMA and fibers were simultaneously, so we cannot talk about a real bonding problem between PMMA and glass fibers. In the fracture area we can see the low number of glass fibers. (Fig. 3)

In test specimens reinforced with Stick™, PMMA suffered initial fracture. After that, there was detachment of the glass fibers and in the end the glass fibers suffered fracture. (Fig. 4) This study reveals that transverse impact strength is the best in PMMA - Stick™ reinforced test specimens.

CLINICAL IMPORTANCE

The required amount of fiber is approximately 4-5 cm. The reinforcement ranges between 2nd premolars.
A package of Stick™ fiber costs 167 €. The package contains a total of 60 cm of fiber, and consequently, the price of the fiber is 2.8 € per centimeter. As for this project, the price of the reinforcement will be 5 x 2.8 €, totaling 14 €. The price is higher than that of traditional metal wire reinforcement. From the patient's point of view, it is advisable to make larger, initial investment in the fiber reinforcements, as there will be savings in restoring costs later on. The aesthetics should also be considered.

**Figure 4.** Fractured Stick™ reinforced PMMA test specimens.

**CONCLUSIONS**

Within the limitations of the study, the following conclusions can be made:

1. Reinforcement of heat-polymerized PMMA with glass fibers (Stick®, Net, Stick™) increases the impact strength of the material used for manufacturing complete denture bases.

2. Stick™ reinforcement increases significantly the impact strength of the resin when fibers are placed parallel to the long axis of the specimen, perpendicularly to the impact force direction.

3. Stick™ partial reinforcement is a reasonable practical alternative.

4. Aesthetics of glass fiber reinforcements (Stick®, Net, Stick™) is very good.

**REFERENCES**