TRANSVERSE STRENGTH OF ACRYLIC RESIN DENTURE BASE MATERIAL AFTER THE ADDITION OF DIFFERENT FIBRES

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ABSTRACT

The aim of the present study was to investigate the effect of addition of different types of fibres on the transverse strength of acrylic resin denture base material. The addition of glass fibres (strand) and polyethylene fibres produced a non significant increase in the modulus of elasticity, compared with the control of conventional heat-cured acrylic resin. The addition of glass fibres (woven and strand), polyethylene and carbon fibres to acrylic resin produced a non significant increase in the modulus of rupture. Within the limitations of this study the addition of silk fibres did not produce an improvement in the mechanical properties.

INTRODUCTION

The most commonly used material for the construction of denture is poly methyl methacrylate. However, this material is still far from ideal and because of its relatively low mechanical strength, fracture of denture is an unresolved problem. Over the years several attempts have been made to improve the mechanical properties of acrylic resin including the addition of various fibres[1-4].

Fibres can vary in diameter, length and form. Fibre reinforcement is dependent on many variables including, fibre type, length, form, arrangement and the fibre matrix bond.

The length of the fibre is of importance because the end of the fibres does not carry loads and as the fibre length increases the ineffective portion of the fibre has smaller effect. The orientation and distribution of the fibres is also of importance. For example, randomly oriented, discontinuous fibres have lower fracture strength than continuous fibres. The interface between fibres and matrix can not be over emphasized and it has been suggested that poorly bonded fibres to which little load is transferred can act as voids[7]. Various suggestions have been made to improve the interface between the denture base material such as sandblasting[8], silanisation[9], the use of metal adhesive resing[10], plasma treatment[12] and other forms of pre-treatment or pre-impregnation of fibres[12]. However, failure at the interface between acrylic resin and the reinforcement material is a problem.

Although the literature has reported the effects of different fibres on mechanical properties of acrylic resin, it is often difficult to compare results between studies because of differences in the test methods used. The aim of the present study was to investigate the effect of the addition of different types of fibres on the transverse strength of acrylic resin denture base material.

MATERIALS AND METHODS

Minacryl Universal heat-cured cross linked acrylic denture base resin was used to produce the specimens. It was supplied in polymer/monomer-powder liquid form (Minerva Dental Ltd. Cardif, England).

Poly (methyl methacrylate) fibres unidirectional 0.75mm in diameter, (Lite-tec Lite-tec Ltd. Rochford, Essex, UK). Glass fibres were supplied by Stick Tech. They were supplied in both unidirectional and bidirectional form. The fibres are a semi manufactured product made from glass fibres in a highly porous polymer matrix. Stick™ is made of unidirectional fibres. Net is made of a thin fiber glass fibric in bidirectional form, (Stick Tech, Turku, Finland). The polyethylene fibres were supplied on a continuous reel of woven fibre referred to as ultra high strength reinforcement rib-

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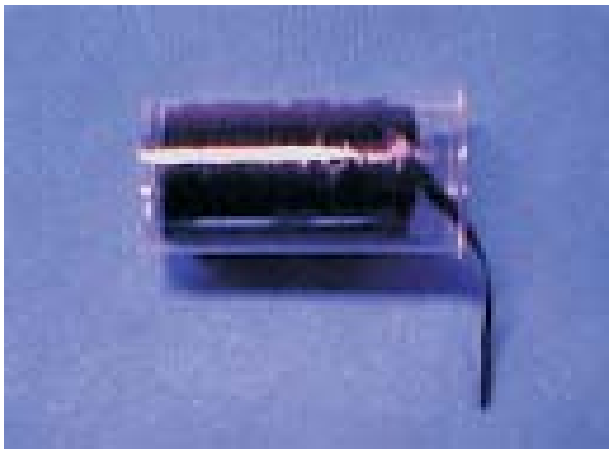
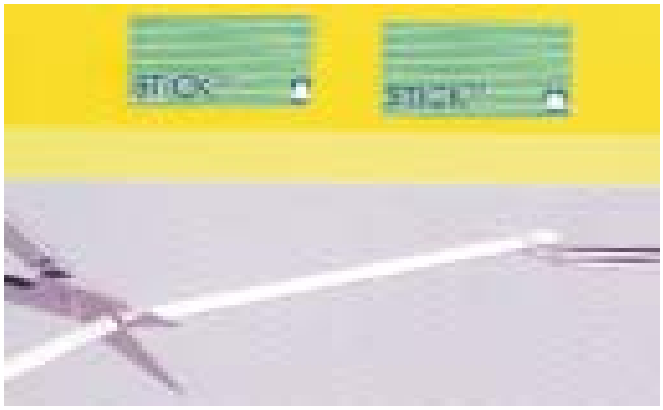
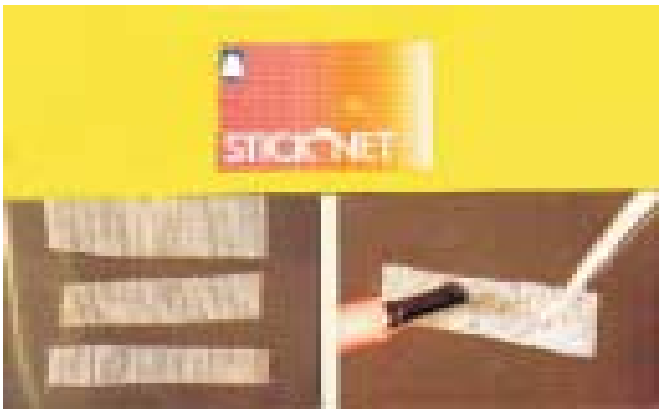
Polyethylene fibre



Carbon fibre



Glass strand fibre



Glass woven fibre

bon, (Connect, SdsKerr, Peterborough UK). The silk fibres were supplied in a woven sheet form, (George Well, Bradford, UK). The carbon fibres were supplied as a continuous reel of multiple unidirectional fibres with a total width of 1.5-2.0mm (Accord Dental Laboratories, Chippenham, UK).

TEST METHOD

Transverse strength test

The transverse bend test was carried out using a Lloyd's instruments material testing machine, model L2000R (Lloyd's Instrument PLC) using the three-point loading method. The test rig is described in British Standard Institution specification (BS 2487:2000). The test rig consisting of a loading wedge and a pair of supporting wedges placed 50mm apart which represent the average inter-molar distance of a denture. Each test specimen was centered on the testing rig so that the loading wedge, set to travel at speed 5mm/mm, engaged the specimen broke. Ten specimens of each group were tested in a water bath at 37°C, to simulate oral conditions. The peak load at the moment of fracture and moduli of rupture and elasticity were recorded.

RESULTS

The transverse bend test was carried out using a Lloyd. The results of the impact test for specimens are presented in table 1. The results were subjected to a one way analysis of variance. Multiple range test are presented in table 2.

For the impact test the highest value was recorded for specimens with polyethylene fibres, glass strand fibres followed by carbon fibres, woven glass fibres, silk fibres and the lowest for poly (methyl methacrylate) fibres. A one was analysis of variance demonstrated that there was a significant difference between the groups $p<0.05$.

This table applies a multiple comparison procedure to determine which means are significantly different from which others. The bottom half of the output shows the estimated difference between each pair of means. Homogeneous groups are identified using columns of X's. Within each column, the levels containing X's form

TABLE 1: THE EFFECT OF THE ADDITION OF DIFFERENT FIBRES ON THE MODULUS OF ELASTICITY (MPa) OF HEAT-CURED POLY (METHYL METHACRYLATE) ACRYLIC RESIN. SPECIMENS TESTED IN AIR AT ROOM TEMPERATURE 37ºC FOR 50 HOURS.

Material N=10	Modulus of elasticity Mean MPa	±Standard Deviation
Control (C)	2614.91	98.15
C+ PMMA fibres	2556.51	120.59
C+ Carbon fibres	2591.82	146.83
C+ Glass fibre (woven)	2596.08	92.35
C+ Glass fibres (strand)	2721.73	116.03
C+ Polyethylene fibres	2630.78	96.05
C+ Silk fibres	2371.75	177.08

A one way analysis of variance demonstrated that there was a significant difference between some group $p<0.05$.

TABLE 2: THE EFFECT OF THE ADDITION OF DIFFERENT FIBRES ON THE MODULUS OF RUPTURE (MPa) OF HEAT-CURED POLY (METHYL METHACRYLATE) ACRYLIC RESIN. SPECIMENS TESTED IN AIR AT ROOM TEMPERATURE 37ºC FOR 50 HOURS.

Material N=10	Modulus of rupture Mean MPa	±Standard Deviation
Control (C)	81.91	3.83
C+ PMMA fibres	78.78	3.48
C+ Carbon fibres	83.10	6.04
C+ Glass fibre (woven)	82.08	4.41
C+ Glass fibres (strand)	86.34	5.13
C+ Polyethylene fibres	82.73	2.03
C+ Silk fibres	75.52	6.15

A one way analysis of variance demonstrated that there was a significant difference between some group $p<0.05$.

a group of means within which there are no statistically significant differences. The method currently being used to discriminate among the means is Fisher's least significant difference (LSD) procedure. With this method, there is a 5.0% risk of calling each pair of mean significantly different when the actual difference equals 0.

TABLE 3: MULTIPLE RANGE TESTS FOR THE MODULATION OF ELASTICITY. METHOD: 95.0 PERCENT LSD.

Material (n=10)	Mean MPa	Homogenous groups
C+ Silk fibres	2371.75	X
C+ PMMA fibres	2556.51	X
C+ Carbon fibres	2591.82	X
C+ Glass fibre (woven)	2596.08	X
Control (C)	2614.91	XX
C+ Polyethylene fibres	2630.78	XX
C+ Glass fibres (strand)	2721.73	X

TABLE 4: MULTIPLE RANGE TESTS FOR THE MODULATION OF RUPTURE. METHOD: 95.0 PERCENT LSD.

Material (n=10)	Mean MPa	Homogenous groups
C+ Silk fibres	75.52	X
C+ PMMA fibres	78.78	XX
Control (C)	81.91	XX
C+ Glass fibre (woven)	82.08	XX
C+ Polyethylene fibres	82.73	XXX
C+ Carbon fibres	83.10	XX
C+ Glass fibres (strand)	86.34	X

This table applies a multiple comparison procedure to determine which means are significantly different from which others. Homogeneous groups are identified using columns of X's. Within each column, the levels containing X's form a group of means within which there are no statistically significant differences. The method currently being used to discriminate among the means is Fisher's least significant difference (LSD) procedure. With this method, there is a 5.0% risk of calling each pair of mean significantly different when the actual difference equals 0.

DISCUSSION

The present study investigates the effect of addition of different fibres in continuous and woven form on the transverse strength of heat-cured acrylic resin denture base material.

The transverse bend test was considered relevant to the loading characteristics of a denture base in the clinical situation. The machine chosen for the tests, the Lloyd's Instruments material Testing machine is routinely used and widely accepted as a recognized method.

The transverse (flexural) strength of a material is a measure of stiffness and resistance to fracture. The ISO 1567 and BSI 2487 for denture base resins have specified transverse deformation limits of from 1 to 2.5mm for a force of 15 to 35N and from 2 to 5mm for a force of 15 to 50N. The mean breaking force of acrylic resin should not be less than 55N. In this respect the control and the reinforced specimens with different fibres satisfied the standards.

The modulus of elasticity is a measure of stiffness of a material and is equal to the ratio of the stress to strain in the linear portion of the stress-strain curve (Combe, 1986). A one way analysis of variance for the modulus of elasticity showed a significant difference between the groups. For the modulus of rupture a one way ANOVA demonstrated a significant difference in the modulus of rupture between the groups, the P-value of the F-test was less than 0.05. The maximum difference was 10.8 MPa between specimens containing glass strand fibres demonstrating the highest value and the specimens containing silk fibres demonstrating the lowest value. Visual examination of the fractured specimens demonstrated that the bond between the silk and the acrylic resin was poor with the evidence of the fibre pull out and separation from the surrounding matrix. The non strengthening effect of silk fibres may be explained on the basis that the fibres occupied a space in the specimen that should be occupied by the base material and effectively act as if there is a hollow spaces in the specimens. There was a significant difference between the specimens containing glass strand fibres and the specimens containing PMMA fibres. For the specimens containing PMMA fibres on visual and microscopic examination the bond between the PMMA fibres and the matrix appeared to be strong with no evidence of fibre pull out. A possible explanation of the failure of reinforcement is that within the composite material the complete integration of the fibres within the matrix is such that the material behaves as homogenous acrylic resin with similar mechanical properties to conventional heat cured poly (methyl methacrylate). The interface between the fibres and the matrix is thought to play an important part in reinforcement. The fibres may act as areas of stress concentration and actually weaken rather than strengthen the matrix. A variety of techniques have been used to modify the interface, such as sandblasting, salanisation, plasma treatment and pre-soaking. It has been suggested that for glass fibres they should be pre-treated with a poly (methyl methacrylate) mixture to reduce the polymerization shrinkage of poly (methyl methacrylate). In the present study the glass fibre treated and soaked in a poly (methyl methacrylate) mixture before the insertion of the fibres into the acrylic resin visual and electron microscopic examination showed a good integration between the fibres and the acrylic resin matrix. The addition of glass fibres did produce improvement in the modulus of rupture and modulus of elasticity compared to the control. For the poly (methyl methacrylate) fibres the fibres spanned the length of the specimens however for the other types of fibres the inserts were 20mm length. For all types of fibres reinforcement the fibres were positioned as close as possible to the middle of the thickness of the specimen.

There was no significant difference between the control specimens ad specimens containing polyethylene, woven glass and carbon fibres but all of these were significantly different from the specimens containing silk fibres.

CONCLUSIONS

Within the limitations of this study the addition of the experimental untreated silk fibres did not produce an improvement in the mechanical properties of acrylic resin and can not be recommended as a method of reinforcement. Polyethylene fibres and glass strand fibres have produced exciting results. They have produced a significant improvement in term of strength.

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