ORIGINAL RESEARCH

Flexural Strength of Resin Based Composites Reinforced with Commercially available Polyethylene, Woven Fiber: An In-Vitro Study

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ABSTRACT: *Background:* Resin based composite materials, in spite of their numerous advantages are still limited in usage due to lack of certain mechanical properties. Lack of flexural strength is one such weakness. Reinforcing the resin composites with fibres have been shown to improve the strength. This study was conducted to assess the flexural strength of resin composite material reinforced with commercially available polyethylene woven fiber (Ribbond, U.S.A). *Methodology:* Two groups were made. Group 1 consisted of 30 resin based composite rectangular bar specimens of dimension 25x2x2 mm of length, width and height respectively. Group 2 consisted of 30 resin based composite bar specimens of similar dimension, but reinforced with polyethylene fibers at the middle of the specimen (neutral zone). All the specimens were subjected to three-point bend test and the maximum load at which fracture occurred were recorded and flexural strength were calculated. *Results:* The mean flexural strength with standard deviation of the group 1 and group 2 were 81.55 ±7.2 MPa and 95.04 ±2.6 MPa respectively. *Conclusion:* The study concluded that reinforcement of resin based composites with polyethylene, woven fibers significantly increased the flexural strength by 17%.

Key words: *flexural strength, polyethylene fiber, woven fiber, fiber reinforced composite, ribbond*

Resin composites are the most widely used restorative material in the clinical practice of restorative dentistry. Since its inception, resin composites have undergone various improvisations in dimensional stability, optical and mechanical properties. Manufacturers have manipulated the size, form, chemistry of filler and also the resin matrix to achieve clinically acceptable properties[1,2]. However, the direct resin composite materials are still not suited for restorations in the stress bearing areas because of their inferior mechanical property when compared to indirect restorations [3,4].

Incorporation of fibers in polymer based materials to improve their structural properties, is an established concept in the field of structural engineering. Fiber reinforced composites (FRC) for dental applications are being used in the clinical practice of prosthodontics, periodontics, orthodontics, endodontics and restorative dentistry [5 - 10]. Incorporation of fiber in resin matrix leads to improvement of mechanical property and reduction in polymerization shrinkage by decreasing the volume of resin matrix[11].

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The mechanical property of fiber reinforced composites depends upon the fiber, resin matrix and its interface. Inadequate adhesion between the fiber and resin matrix was the cause of inferior performance of initially introduced fiber reinforced composites[12]. Pre-impregnation of fiber with resins or impregnation of resin (resination) into the fiber as chair-side procedure has markedly improved the mechanical properties of FRC.

Reinforcement of FRC will depend upon the type, orientation and geometric configuration of the fiber [6,10,12]. Fibers can be made of kevlar, carbon, glass or polyethylene. It can be short fibers or long continuous strand. Incorporation of short glass fibers in the restorative resins during the manufacturing process has not performed to a clinically acceptable level because of surface roughness, water sorption and poor adhesion at the fiber-resin interface[12]. Laboratory fabricated reinforcements are usually done with various types of glass fibers and as a chair side procedure, polyethylene is usually used.

FRC exhibits maximum mechanical properties in the direction parallel to the fiber orientation[6, 13]. Hence multi directional fiber with woven or braided pattern has better mechanical properties than unidirectional fiber pattern.

Ribbond is a commercially available polyethylene fiber with patented leno weave pattern and lock stitch design. This patented design seems to increase the mechanical and manipulative properties of the fiber reinforced restorations[12].

Flexural strength is one of the important properties that determines the success of fiber reinforced prosthesis, such as periodontal splints, restorations and endodontic posts, as they all are subjected to bending forces in a clinical situation.

Hence this study was planned to measure the flexural strength of resin based micro-fine hybrid posterior composite (Solare-P, GC Asia, Japan) with and without incorporation of woven polyethylene fibers (Ribbond inc,U.S.A.). It was hypothesized that there will be no difference between both the study groups.

MATERIALS AND METHODS

<u>Preparation of specimen :</u>

Micro-fine hybrid posterior resin based composite material (Solare P, GC Asia, Japan.) was tested for its flexural strength after reinforcing it with polyethylene fibers(Ribbond inc, USA). Materials used in this study are shown in Fig-1 & Table 1. Two groups were made:

Group 1: Posterior resin composite

Group 2: Posterior resin composite reinforced with fiber

Each group consisted of 30 rectangular bar specimens of resin-based composite material of dimension 25x2x2 mm of length, width and height respectively. They were prepared from prefabricated stainless steel split molds. All specimens were prepared in two increments of 1mm. A mylar strip was placed above the mold while curing the final increment to ensure a smooth surface. Light curing was done with the curing tip diameter of 8 mm with the conventional light curing unit (coltolux 75, coltene whaledent, U.S.A.). Starting from either ends, each increment was cured for 4 times of 20 seconds duration with overlapping section of 3.5 mm. This curing protocol ensured complete curing of 25mm span of the specimen. The power density of the curing light was 800 mW/cm2 and the same was verified using a radiometer for every

Fig 1: Materials used

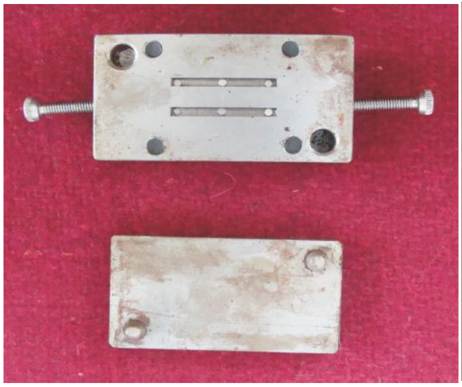
set of five specimens. After complete curing, each specimen was carefully removed from mold. The excess flash was trimmed with sharp blade and the specimens were finished with aluminium oxide strips (Soflex, 3M-ESPE, U.S.A.)

While the group 1 specimens were prepared in the above mentioned protocol, the group 2 specimens were subjected to following modification for incorporation of fiber. After placement of first increment of 1mm of resin composite material, ribbond fiber of 2 mm width and 25 mm length was placed. As per the manufactures guidelines, the fiber was wetted with bonding agent (Prime & Bond NT, Dentsply, U.S.A.) and infiltrated with flowable composite (Esthet X, Dentsply, U.S.A.) and the similar curing protocol was adopted. This was followed by layering the final 1mm thickness of composite material to complete the sample preparation.

<u>Flexural strength testing :</u>

The dimensions of the specimens were confirmed with a gauge (Mitutoyo, Japan, Model No.2046-08). Specimens were then stored in light proof (amber colour) containers at 37 ºC for 24 hours prior to testing.[14] The flexural strength was determined on a universal testing machine (Hounsfield, UK H5KS-0195) with a crosshead speed of 0.5 mm/min. A three-point bending test apparatus was used and the test span was 20 mm.[15] The load was applied midway between the points in a plane perpendicular to the specimen with a hardened steel rod 2 mm in diameter. Each specimen was tested to the point of fracture and the maximum load on fracture was recorded from the digital screen of the testing machine.

The flexural strength was calculated with following formula: $S = 3\ WL/2\ bd^2$, Where, S is the flexural



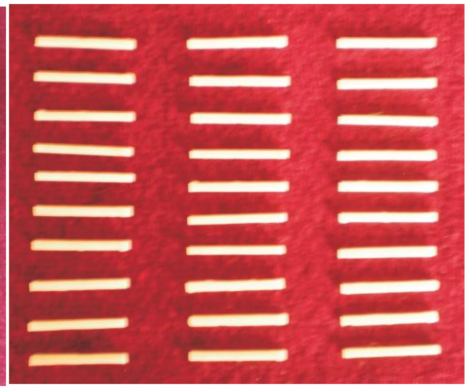


Fig 2: Stainless steel split mold **Fig 3: Experimental group** **Fig 4: Universal Testing machine**

Material	Composition	Company	Lot No.
Solare P	silica, fluoroaluminosilicate glass and pre-polymerised resin fillers	GC Asia, Japan	0806111
Ribbond	Woven polyethelene fibers	Ribbond Inc., U.S.A.	9567
Esthet X-flow	Polymerizable dimethacrylate resin, Bis-GMA, Urethane Modified Bis-GMA Dimethacrylate, Barium Boron Fluoroaluminosilicate Glass, Silica Amorphous, Titanium Dioxide	Dentsply, U.S.A.	081020
Prime and Bond NT	Di and trimethacrylate resins, functionalized amorphous silica, PENTA (dipentacrythirtol penta acrylate monophosphate), photoinitiator, stabilizers, cetylamine hydrofluoride, acetone.	Dentsply, Germany	0901000595

Table 1: Detailed description of the materials used in the study

strength; L is the test span; b is the width of specimen; d is the thickness of specimen and W is the mean maximal load at fracture.

RESULTS

Student's 't' test was used to examine the sources of variation of the mean flexural strength values between the two groups. The results are presented in Table 2 .

The percentage increase in flexural strength of group 2 when compared to group 1 is 17%.

The null hypothesis was rejected as the inclusion of leno-weave fiber, Ribbond has significantly increased the flexural strength of the specimen.

DISCUSSION

Reinforcement of resin composite material to improve the mechanical properties is constantly explored by both the manufacturers and the operators. Incorporation of fibers in the resin composite material by manufactures is usually limited to laboratory resin composites. Post cure technique [16] as laboratory procedure and fiber reinforced technique [13] as chair side procedure are usually attempted to improve the mechanical properties.

This study was conducted to find the efficacy of fiber in improving of flexural strength of the resin composite. The methodology used in this study followed the protocol in accordance with the International Standard for flexure strength test procedure for dental resin based composite material, ISO 4049[17]. This widely used three-point flexural strength test is recently being questioned for its reliability. In a recent study, it was concluded that bi-axial flexural testing is more reliable than three-point

Parameter	Group I (No ribbond)	Group 2 (with ribbond)	Mean difference	% change	P* value
Mean	81.55	95.05	13.50	17.00	P<0.001 HS
SD	7.28	2.69			

Table 2: Intergroup comparison by student 't' test.

flexural strength testing. Statistically significant increase in the flexural strength was observed with bi-axial flexural test than three-point flexural tests. The possible reason for this difference can attributed to the curing regime used in sample preparation for three-point flexural strength study, where overlapped curing of specimens is done, which may lead in-homogeneity in the resin specimens[18].

Most of the presently available resin based composites have flexural strength ranging from 58 Mpa to 126.3 Mpa[19]. The minimum required flexural strength as stipulated by ISO 4049 for direct filling resin composites to be used in occlusal areas is 80Mpa. In the present study, the mean flexural strength of resin composite without reinforcement is 81.55(±7.2) Mpa. This low flexural strength obtained with this material can be better understood by correlating a study which analyzed filler particles of various composites with Energy Dispersive Xray-flouresence analysis and another study which analyzed the influence of type of filler particle on flexural strength of the resin composite[4,20]. In yet another study, it was concluded that resin composites with micro fine filler particles possess lowest flexural strength followed by nano fillers and the maximum was observed with hybrid fillers[4].

Solare P composite, that was used in this study is a micro-fine hybrid composite containing pre-polymerized and splintered filler particles [20]. The lower limit of the flexural strength observed in this study can be due to this reason. Even though the flexural strength recorded in this study is at lower limit, the results can be considered reliable because of minimal standard deviations in the both the groups.

Incorporation of fiber to improve the flexural strength has been reported with varied success in many studies[21,22]. Literature review of most of the studies conclude that there is a significant increase in the flexural strength of the fiber reinforced resin composites, but the increase in the flexural strength depends on type, orientation, position and pretreatment of fibe[16,23].

All the chair side technique for fiber placement is done by hand lay-on technique, which depends upon the skill of the operator. Moreover when the fiber is cut to specific size, the free end of the braids can open up during the lay-on process, thus changing the orientation of the fibers to unfavorable direction that cannot resist the masticatory load. The fiber used in the present study is the patented leno-weave pattern with lock-stitch feature, which allows the fiber to be cut at any level without opening up. Hence it can provide more predictable results than the other types of fibers.

Position of fiber in the fiber reinforced structure will influence the mechanical property of the structure. In a very exhaustive study about fiber position in simple as well as various complex geometric configurations, it was concluded that there was statistically significant reinforcement of FRC regardless of its position. However, the reinforcement of resin on tension side with ultra-high molecular weight polyethylene fiber increased the load to initial failure by 60% in contrast to complex geometric reinforcement, which increased the load to initial failure by 220%. They also categorized the failure mode to instantaneous, step wise or statistical. All the unreinforced specimens exhibited instantaneous failure and most of the reinforced specimens with polyethylene, unidirectional and woven glass fiber reinforcement exhibited stepwise or statistical failure[12]. Even though the failure mode was not recorded in this study, the same observation was noted. Thus it can be stated that reinforcement with the fiber definitely acts as crack stoppers, thus increasing the mechanical property of the structure.

In another study by the same group of authors, it was concluded that modulus of elasticity increased when glass fibers were reinforced on the compression side and the toughness was increased when glass fibers were reinforced on the tension side of the resin specime[24]. In this study, the fiber reinforcement done on the neutral zone or in the middle of the specimen resulted in statistically significant increase in the flexural strength of the specimens by 17%.

Further extensive studies have to be conducted to explore the best combination of the type of fiber and the position of the fiber for the chair-side, hands lay-on process. This information could be very useful in clinical practice to reinforce complex restorations for predictable performance.

CONCLUSION

Within the confines of this study, it can be concluded that 17% of increase in flexural strength was observed in the resin composite specimens reinforced with ultra-high molecular weight polyethylene fiber in neutral zone.

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