

Fracture strengths of provisional restorations reinforced with plasma-treated woven polyethylene fiber

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Statement of problem. Fracture strength of interim fixed partial prosthesis is of great concern, especially in long-span restorations or areas of heavy occlusal stress.

Purpose. Effects of a plasma-treated woven polyethylene fiber (Ribbond) on the fracture strength of polymethyl methacrylate (Coldpac) and a resin-based two-phase curing provisional restorative material (Provipont DC) were evaluated.

Material and methods. A polyvinyl siloxane template was used to fabricate three-unit posterior provisional prostheses on a stainless steel die with two abutments 22 mm apart. The reinforced groups were fabricated by affixing 3 mm wide pieces of fiber treated with methyl methacrylate monomer or polyisocyanate (activator part of Provipont DC) on the occlusal surfaces of abutments. The interim materials were mixed, according to the manufacturers' specifications, and placed in the template. The template was pressed on the die and held secure until complete setting of the material occurred by light curing (Provipont DC) or autopolymerization (PMMA). The specimens were divided into 4 groups of 10 each (A, reinforced Provipont DC; B, unreinforced Provipont DC; C, reinforced PMMA; and D, unreinforced PMMA). A central compressive load force was exerted on the specimen to determine the fracture load of the restorations.

Results. The data revealed mean fracture loads of A, 65.59 ± 11.27 kg; B, 46.59 ± 14.84 kg; C, 53.46 ± 7.76 kg; and D, 49.86 ± 14.44 kg.

Conclusion. Plasma-treated polyethylene reinforced PMMA restorations showed no significant increase in fracture loads when compared with unreinforced restorations ($p > 0.10$), whereas reinforced resin-based restorations revealed significantly higher fracture loads ($p < 0.01$) than the unreinforced resin-based and PMMA provisional restorations. (J Prosthet Dent 1997;78:447-50.)

CLINICAL IMPLICATIONS

The use of plasma-treated woven polyethylene fiber is an effective method of reinforcement of interim fixed partial restorations.

In clinical dentistry, provisionalization of fixed prostheses is an essential part of the treatment. Provisional restorative materials generally exhibit low fracture strengths, especially in cases of long-span fixed partial dentures, high stress areas, bruxism, and long-term provisional restoration before placement of the final restoration. Catastrophic failure of the interim prosthesis may cause great inconvenience for both the patient and the clinician and jeopardize the treatment. Reinforcement of resin-based materials with carbon, graphite, glass,

Kevlar, and other types of fibers have been studied to determine the effectiveness of fiber reinforcement on fatigue resistance. Even though most studies show higher mechanical properties with fiber reinforcements, such materials have not yet been used in routine clinical practice of dentistry.^{1,2}

The physical properties of fiber-reinforced materials are dependent on the type of matrix, type of fiber, fiber distribution, fiber/matrix ratio, diameter, and length of the fibers.³ Previous investigations in fiber reinforcement have favored the use of long continuous fibers, with strands perpendicular to the direction of applied load. This orientation exhibits higher specific strength (strength/weight) and high specific modulus (stiffness/weight) when compared with unreinforced materials.^{2,4} In dentistry, a number of different techniques for reinforcement of provisional restorations have been suggested; however, most have shown limited success. Kelly⁵ reported a decrease of fatigue fracture in nylon-reinforced

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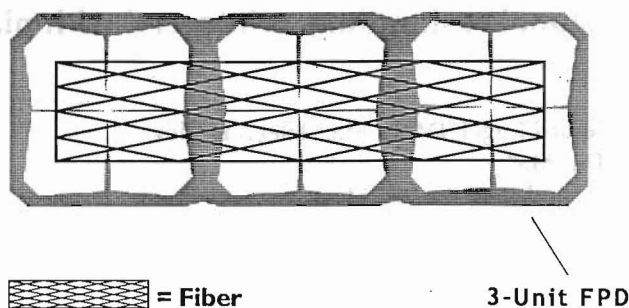


Fig. 1. Schematic diagram of Ribbond-reinforced specimen.

Table I. Reinforced Provispont DC prostheses

Specimen	Fracture load (kgs)	Type of fracture
1	51.88	Partial
2	67.95	Partial
3	63.97	Partial
4	72.01	Partial
5	83.70	Unseparated
6	60.12	Partial
7	78.31	Partial
8	51.45	Partial
9	72.43	Partial
10	53.77	Partial
Mean	65.59	
Std. Dev.	11.27	

denture base acrylic resins and Schreiber⁶ demonstrated increased impact and transverse strengths of carbon-reinforced polymethyl methacrylate. Previous investigations in reinforcement of acrylic resins with polyethylene fibers show improvements in fracture strength.^{7,8}

A ribbon reinforcement material (Ribbond, Inc., Seattle, Wash.) has been commercially available for the past 5 years. This material is composed of leno-woven polyethylene fibers that have been electrochemically treated to make the ribbon surface chemically reactive with composite or acrylic resins surrounding it, which permits bonding of the materials and reinforcing the polymers (Fig. 1). The leno-weave is a special pattern of cross-linked, locked-stitched threads, which increases the durability, stability, and shear strength of the fabric.⁹ The ribbon retains esthetic qualities because of the neutrality of the color of the reinforcing material.

The purpose of this study was to evaluate the effects of plasma-treated woven polyethylene fiber (Ribbond) on the fracture strength of polymethyl methacrylate and a resin-based two-phase curing provisional restorative material.

MATERIAL AND METHOD

A wax pattern of a three-unit fixed prosthesis was fabricated on a stainless steel die, with two full-coverage abutments placed 22 mm apart. The central fossa of the

pontic was positioned exactly in the middle of the two abutments. The wax pattern was duplicated with an irreversible hydrocolloid impression material (Jeltrate, J. D. Caulk, Milford, Del.) and poured in with an improved stone (Die-Keen, Columbus Dental, St. Louis, Mo.). Four templates of the stone model were prepared with a polyvinyl siloxane impression material (Imprint 3M, St. Paul, Minn.).

The 3 mm wide, plasma-treated woven polyethylene fibers (Ribbond, Inc.) were cut in pieces 35 mm long with special scissors supplied by the manufacturer. The fiber strips were treated with methyl methacrylate monomer or polyisocyanate (activator component of Provispont DC) and affixed to the abutments. The polymethyl methacrylate (Coldpac, Moltoid, Chicago, Ill.) was hand mixed at the ratio of 2:1 powder to monomer by weight until a smooth, doughy consistency was achieved and poured in the template. The template and its contents were then placed on the die and held secure until complete setting of the materials.

For the Provispont DC (Vivadent, Schaan, Liechtenstein) restorative material, the base and activator were mixed automatically in the cartridge system supplied by the manufacturer. The material was placed in the template with the application injector supplied in the kit. The template and its contents were placed on the die and held secure for 5 minutes, so that the material reached its elastic phase. The template was then removed and the specimens were light cured with a high intensity blue curing light with a tip diameter of 7 mm (Visilux 2, 3M) on the die for three increments of 1 minute each. The light tip was placed on the occlusal surface of each abutment or pontic during each increment. One template was used for each of four groups, because multiple use of a single template may cause dimensional distortion of the specimens.

The specimens were trimmed with acrylic resin burs to remove the excess material and to approximate all the specimens to same dimensions. A compressive load was applied to the central fossae of the pontics by using a universal testing machine (Model 4202, Instron Corp., Canton, Mass.) with a crosshead speed of 5 mm/minute and the load required to fracture the specimens was recorded. The statistical significance of the results between the groups was determined by the Student *t* test.

RESULTS

The experimental values for each of the four groups are shown in Tables I through IV. The Provispont DC specimens exhibited mean fracture loads of 65.59 ± 11.27 kg (Table I) and 46.59 ± 14.84 kg (Table II) for reinforced and unreinforced groups, respectively. Statistical analysis (Student *t* test) revealed a significant increase ($p < 0.01$) in fracture load in the fiber reinforced group. Apart from the increase in fracture load, a different pattern of fracture was noted between the two groups.

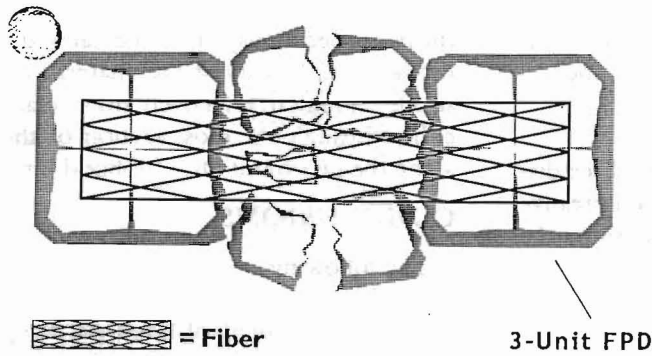


Fig. 2. Schematic diagram of specimen shows "catastrophic" fracture.

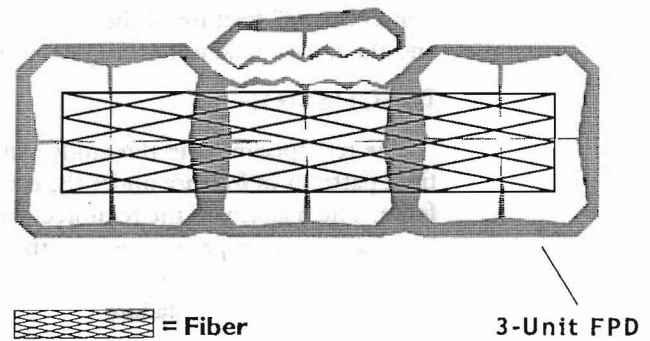


Fig. 3. Schematic representation of "partial" fracture. Fracture occurred at joints and did not propagate beyond fiber.

Table II. Unreinforced Proviopont DC prostheses

Specimen	Fracture load (kgs)	Type of fracture
1	32.70	Catastrophic
2	43.34	Catastrophic
3	53.45	Catastrophic
4	33.05	Catastrophic
5	41.44	Catastrophic
6	23.14	Catastrophic
7	51.72	Catastrophic
8	52.99	Catastrophic
9	72.99	Catastrophic
10	61.05	Catastrophic
Mean	46.59	
Std. Dev.	14.84	

Table III. Reinforced PMMA prostheses

Specimen	Fracture load (kgs)	Type of fracture
1	49.88	Partial
2	64.81	Unseparated
3	46.43	Partial
4	44.21	Partial
5	48.40	Unseparated
6	53.29	Partial
7	66.93	Unseparated
8	47.36	Unseparated
9	55.97	Unseparated
10	57.32	Unseparated
Mean	53.46	
Std. Dev.	7.76	

The unreinforced specimens displayed "catastrophic" fractures where the pontics were sheared off by the compressive load (Fig. 2). The reinforced samples, on the other hand, showed a "partial" fracture pattern, where the prosthesis remained intact at the joints and a portion of the pontics, either buccal or lingual, fractured off (Fig. 3). Only 1 of the 10 reinforced samples exhibited an "unseparated" fracture, where the joints cracked under the load; however, the polyethylene fiber remained

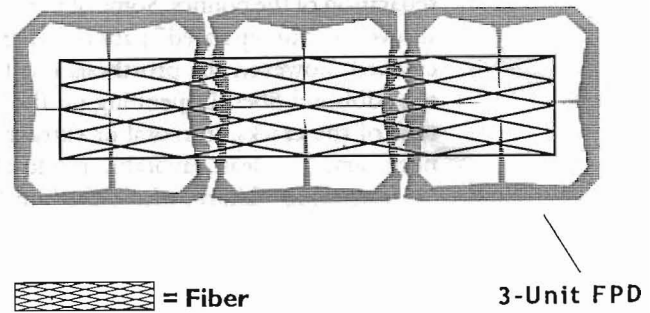


Fig. 4. Schematic representation of "unseparated" fracture.

Table IV. Unreinforced PMMA prostheses

Specimen	Fracture load (kgs)	Type of fracture
1	74.80	Catastrophic
2	36.87	Catastrophic
3	55.49	Catastrophic
4	44.24	Catastrophic
5	41.95	Catastrophic
6	64.30	Catastrophic
7	37.83	Catastrophic
8	67.30	Catastrophic
9	40.74	Catastrophic
10	35.03	Catastrophic
Mean	49.86	
Std. Dev.	14.44	

intact and the fracture did not propagate beyond the fiber (Fig. 4).

The polymethyl methacrylate-based groups showed mean fracture loads of 53.46 ± 7.76 kg (Table III) and 49.86 ± 14.44 kg (Table IV) for reinforced and unreinforced groups, respectively. The difference in the values was not statistically significant ($p > 0.10$) between the two experimental groups. The unreinforced samples demonstrated "catastrophic" fractures similar to the resin-based group (Fig. 2). Only four fiber reinforced specimens showed a "partial" fracture pattern (Fig. 4). The polyethylene fiber remained intact during the

"unseparated" fracture of the remaining six specimens and the fracture did not propagate beyond the fiber.

DISCUSSION

The test specimens in this study exhibited three distinct patterns of fracture under the central compressive force. The majority of the reinforced samples showed a "partial" fracture pattern, where the joints remained intact and a small portion of the pontics were separated as a result of cohesive failure of PMMA or Provispont DC materials. In a clinical situation, this is perhaps the most favorable mode of fracture of the provisional prosthesis because the restoration remains intact and the treatment is unlikely to be compromised by partial separation of the pontics. Some of the reinforced samples showed an "unseparated" pattern, where the joints were cracked; however, the prosthesis was held together by the Ribbond fiber. Depending on the location and extent of the cracks, intraoral or extraoral repair may be necessary. The least favorable mode of fracture is the "catastrophic" failure, where the joints are completely separated under the load. In this case, the fractured prosthesis must be removed and a new provisional restoration be fabricated.

All the catastrophic failures occurred on the unreinforced prostheses, both resin and PMMA based. In the unreinforced prostheses, cracks initiated by excessive load application are able to propagate, unhindered, through the cross-section of the restoration and thus cause a complete fracture of the material.

The use of Ribbond reinforcement fibers with a polymethyl methacrylate-based provisional restoration showed no significant increase in the average load failure. However, the presence of the fibers did prevent the catastrophic crack propagation present in the unreinforced samples. Instead of a crack traveling throughout the entire cross-section of the restoration, it would stop or slow down at the fiber/PMMA interface and direction so that it continues along the fiber interface, thus the majority of samples in this group showed an "unseparated" failure, where the PMMA slipped along the fiber surface. This indicated that, although the fibers prevented a catastrophic failure of the restoration, the adhesive strength of the fibers to the surrounding PMMA was not great enough to improve the overall strength of the restoration.

A significant increase in the average load to failure was observed when the Ribbond reinforcement fibers were used with Provispont DC material. The mode of failure on these provisional prostheses was almost exclusively a "partial" failure, in which a portion of the pontics fractured off. Therefore a crack never propagated through the cross-section of the restoration, nor did the interface between the resin and the reinforcement fail

(in nine specimens). This indicates that the adhesion between the Provispont DC material and the fiber was strong enough to effectively stop a crack from traveling either through the cross-section of the restoration or along the Provispont DC/Ribbond interface.

CONCLUSIONS

The following conclusions were drawn from the results of this study.

1. Reinforcement of fixed partial prostheses with Ribbond is effective in increasing the fracture strength of Provispont DC material.
2. Ribbond reinforcement alters the mode of fracture of Provispont DC material under compressive load from a catastrophic failure, where complete separation of pieces occurs to a partial fracture pattern where the pontic-abutment joints remain intact.
3. Reinforcement of PMMA restorations with Ribbond fibers does not increase the fracture strength of the prosthesis; however, the mode of fracture is changed from complete separation of segments to partial separation, leaving the unit in one piece.
4. Use of plasma-treated woven polyethylene fiber is an effective method of reinforcement of interim fixed partial restorations.

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