The effect of plasma-treated polyethylene fiber on the fracture strength of polymethyl methacrylate

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The effect of a plasma-treated polyethylene fiber on the fracture strength of polymethyl methacrylate was evaluated in this study. Sixteen treated and 16 untreated polymethyl methacrylate bars were tested by use of a three-point compression loading apparatus. Under the conditions of this experiment the treated bars showed a mean fracture strength of 12.56 MPa compared with 9.81 MPa for the untreated samples. In addition to the increased fracture strength, the treated bars also demonstrated resistance to crack propagation. The bars remained in one piece, held together throughout the compression loading by the polyethylene fiber. The clinical implication of these findings is a reduced incidence of fixed provisional restoration failure.
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In clinical situations a fixed partial denture (FPD) may be subjected to a variety of forces. El-Ebrashi et al.[1] reported that the force on an FPD includes compression at the point of load application and tension and shear force at points that resist the load. Because provisional restorative materials have inherent weaknesses, any method that would effectively add strength is welcomed.[2] Fracture strength of these materials has been increased as a result of the decrease in the size and number of porosities in the polymerized product under the influence of pressure.[3] Also, metal, carbon-graphite, sapphire, silane-treated glass, and polyethylene (PE) have all been used with varying degrees of success.[4-10] Long-term use of fixed provisional restorations has been suggested in implant hybrid cases in which periodontally involved abutments are retained for a period of time to allow osseointegration of implants.[11] These fixed provisional restorations will reduce transmucosal loading during the healing phase and therefore improve long-term prognosis.[2] In this situation a provisional restoration that is less susceptible to fracture would be beneficial.

The purpose of this study was to determine the effect on fracture strength of polymethyl methacrylate (PMMA) re inforced with a plasma-treated PE fiber that is 0.4 mr thick and manufactured in various widths and lengths.

METHODS AND MATERIAL

One type of autopolymerizing PMMA (Jet, Lang Dentε Mfg. Co., Inc., Wheeling, Ill.) was tested for flexura strength with and without the woven PE fiber (Ribbon Inc., Seattle, Wash.). A silicone mold (Extrude, Kerr Mfg Romulus, Mich.) and a vacuum-formed matrix was used t make 32 resin specimens measuring 60 × 5 × 5 mm. Sam ple size was determined by use of an a priori α of 0.05 an β of 0.20 with a minimal clinical significance of 5%. Th mold was marked at a point two thirds from the base. Thi marking was used to control the placement of the fiber int the unpolymerized resin so that during testing the fibe would be placed under tension.

At a 2.5:1 polymer-to-monomer ratio all the specimen were made by mixing the polymer-monomer and pourin the resultant mixture into the silicone mold. This mixtur was used in a previous study,[10] and it provided a smoot consistency for incorporating the PE fiber. The vacuur formed matrix was then placed over the mixture, secure with a rubber band, and allowed to polymerize in a pres sure bath at 110° F and 20 pounds per square inch. Sixtee specimens had the PE fiber added to the mixture when th mold was two thirds full. The remainder of the mold wa then filled, covered, and allowed to polymerize in the pres sure pot. A 4 mm wide fiber was selected and cut to a lengt of 60 mm. When the polymerized specimen was remove from the mold, it was examined to determine whether th two-third mark was visible on its side (Fig. 1). In this wa the specimen could be properly placed in the testing appa ratus with the material away from the point of compres sion. According to the manufacturer, Ribbond PE fiber ha been reported to increase fracture strength of resins whe it is placed on the tension side. The specimens were store

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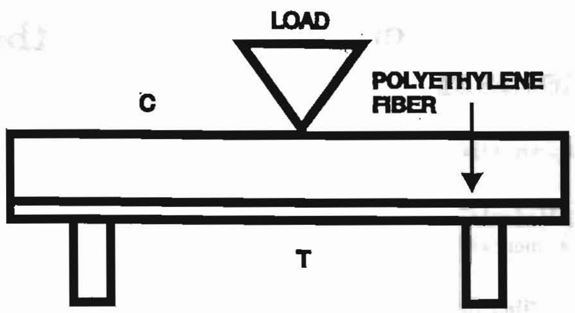

Fig. 1. Diagrammatic representation of destruct test, resultant forces, and positioning of PE fiber to resist tension. *C*, Compression; *T*, tension.

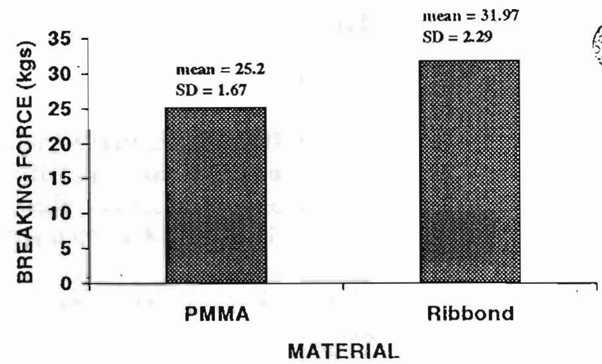

Fig. 2. Comparison of mean fracture strengths of treated and untreated PMMA bars.

in normal saline solution at room temperature for 12 to 24 hours before testing.

Each specimen was loaded with an Instron testing machine (Instron Corp., Canton, Mass.) with a crosshead speed of 5 mm per minute. The force required to fracture the specimens was noted. The test specimens were placed under the load cell so that a central area of 20 mm was loaded and it was unknown which samples were treated and which were not treated with the PE fiber. Treated and untreated fractured specimens were examined under a scanning electron microscope. No porosities were noted in any of the samples. The data were analyzed with a two-sample t test.

RESULTS

The mean experimental values and SDs are illustrated Figure 2. The difference in the mean values between the two groups is greater than would be expected by chance. The mean value of the force required to cause a fracture in the untreated samples was 9.81 MPa, and the mean value for the treated sample was 12.56 MPa. A t test between the two groups revealed a statistically significant difference ($p < 0.001$).

DISCUSSION

Treating a polymer with plasma can increase its surface energy by modifying the chemistry of its surface.[12] Plasma is a partially ionized gas that contains ions, electrons, and other neutral species at many different energy levels. When energized by an electrical field, free radicals, ions, and atoms are formed that can interact with solid surfaces that have been placed in the plasma. This results in modifications of the surface chemistry of the solid. In this situation the solid is the PE woven fiber. The increase in surface energy is responsible for the greater chemical reactivity and compatibility with other materials.[12]

Larson et al.[10] found the use of carbon graphite to be promising for the reinforcement of long-span provisional FPDs; however, the poor esthetic result was a major drawback. On the other hand, PE is virtually invisible once incorporated into the PMMA.

One of the interesting outcomes of this experiment was that the treated PMMA bars would not be a catastrophic failure. In fact, a crack would occur on the tension side but would not propagate through to the compression point. The embedded fiber could not be stretched enough for the crack in the resin to continue. The fiber appeared to hold the two pieces together. Because a fracture failure is usually related to the initiation of a crack and its subsequent propagation until displacement,[13] a complete failure with the embedded fiber may not occur. If a provisional FPD fractures in the mouth, it is difficult if not impossible to repair. This presents an inconvenience to both the dentist and the patient because the provisional prosthesis must often be refabricated. If a fracture occurs in the resin with the plasma-treated PE reinforcement, the repair would be simpler because the fractured joint could easily be approximated and repaired.

In this study scanning electron micrographs were inconclusive regarding whether a bond occurred between the PMMA and the Ribbond PE fiber. The increase in fracture strength and resistance to crack propagation may be attributed to an actual chemical bond, mechanical interlocking of the PMMA to the fiber, or both.

Use of the fiber is simple; however, there are some handling requirements. When PMMA is used, the fiber must first be wetted with the monomer before it is placed in the mixture of monomer and polymer. To avoid contamination of the plasma-treated surface, a pair of cotton gloves are provided in the package, along with a pair of scissors designed for cutting the fiber to the required length.

CLINICAL IMPLICATION

Repairing or remaking provisional restorations can be a time-consuming endeavor. The added strength of the PMMA with the fiber can reduce clinical failures of provisional FPDs. Esthetics are not compromised if used in the anterior region because the fiber becomes invisible once incorporated into the PMMA.

SUMMARY AND CONCLUSION

Provisional restorations made with PMMA are strengthened by the addition of this plasma-treated PE fiber. The fiber is simple to place into the acrylic resin, although there are some handling requirements to prevent contamination of the plasma treatment. No attempt was made to vary the monomer/polymer ratio to see what effect this might create with the incorporation of the fiber. This study attempted to standardize samples and to focus on the effect of the addition of Ribbond PE fiber. Follow-up studies could examine this variation, differences in cross-sectional design, or the relation of the width of the fiber to the width of the specimen.

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