Replacement of missing teeth with fiber-reinforced composite FPDs: clinical protocol

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Abstract

The concept of minimally invasive preparation protocols has resulted in reduced loss of critical tooth structures and maintenance of optimal strength, form, and aesthetics. While various treatment options have been described for single-tooth replacement, fiber-reinforced composite (FRC) fixed partial dentures (FPDs) provide a viable treatment alternative with proven mechanical properties, aesthetics, and function. This article presents several clinical scenarios in which minimally invasive adhesive FRC FPDs are provided to deliver enhanced predictability, strength, and durability.

Reference


PMID: 12956045
The concept of minimally invasive preparation protocols has resulted in reduced loss of critical tooth structures and maintenance of optimal strength, form, and aesthetics. While various treatment options have been described for single-tooth replacement, fiber-reinforced composite (FRC) fixed partial dentures (FPDs) provide a viable treatment alternative with proven mechanical properties, aesthetics, and function. This article presents several clinical scenarios in which minimally invasive adhesive FRC FPDs are provided to deliver enhanced predictability, strength, and durability.

Learning Objectives:
This article details potential indications of minimally invasive adhesive fiber-reinforced composite (FRC) bridges made with preimpregnated glass fibers. Upon reading this article, the reader should:
- Appreciate the clinical parameters for placement of fixed partial dentures.
- Comprehend the use of FRC restorations for single-tooth replacement.

Key Words: fiber-reinforced, composite, fixed partial denture, single-tooth

Many therapeutic options have been described for the replacement of single teeth lost by dental caries, periodontal disease, fracture, or missing by congenital aplasia. The use of implant-supported crowns to treat single missing teeth is increasingly becoming the primary restorative technique for such conditions. Clinical observations confirmed by research findings have reported a 97.5% survival rate for implant-supported porcelain-fused-to-metal (PFM) crowns 6 to 7 years postoperatively.1 Disadvantages, however, have been associated with this technique. A complex clinical protocol...
is required to allow for soft tissue healing and osseointegration prior to second-stage crown placement. In order to develop biologic and aesthetic results, many preprosthetic reconstructive procedures (eg, bone grafting, soft tissue surgery) may be required. This has been shown to increase chairtime, expense, postoperative pain, and potential complications associated with wear of the provisional restorations.

Conventional FFM fixed partial dentures (FPDs), which consist of cast metal frameworks covered by ceramic, have been used for many years to replace missing teeth, and an 87% survival rate has been associated with FFM FPDs after 12 years of service. The excessive tooth reduction required for full-crown restorations, however, is considered a limitation for this technique, particularly when abutment teeth are caries-free. In addition, the cost of this type of treatment, which includes laboratory and clinical fees, might be a limiting factor for some patients.

The use of resin-bonded FPDs has also been proposed as an alternative treatment for single-tooth replacement with minimal or no preparation of the abutment teeth. Despite significant modifications in design, materials, and preparation design, the long-term survival rates of resin-bonded FPDs do not exceed 76% after 5 years. The most common type of clinical failure is the debonding of the FPD, which results in patient discomfort and increased treatment costs. It has been speculated that FPD frameworks fabricated with less rigid materials would better absorb concentrated stresses at the adhesive interface and promote premature debonding of the reconstruction.

A more recent approach based on the concept of minimal tooth preparation is the use of fiber-reinforced composite (FRC) FPDs. Research findings have shown that the stiffness, strength, and toughness of composite resin can be significantly increased through the addition of a suitable amount of reinforcing fibers to the polymer matrix. The ability to bond these materials to tooth structure has further increased the applicability of fiber-reinforced polymers. Glass fibers, UHMW polyethylene fibers, carbon/graphite fibers, and aramid fibers have all been used for the fabrication of FRC FPDs. Silanated glass fibers are preferred by many clinicians due to their mechanical properties, aesthetic qualities, and ability to be chemically bonded to composite resin materials. The orientation and volume of the fibers contained in
Figure 5. The FRC FPD was light-cured to ensure proper adhesion and polished.

Figure 6. The internal aspect of the FRC FPD was sandblasted and silanated to ensure proper adhesion.

Figure 7. The rubber dam was punctured to ensure proper placement and isolation prior to acid-etching.

Dental applications, unidirectional fibers are generally used for FRC FPD construction. These longitudinal fibers exhibit high mechanical properties along their axes and can be purposely oriented within the restoration to resist the highest clinical stresses. The literature has also indicated that increasing the volume content of fibers in the polymer matrix also significantly increases the mechanical properties of the fiber-reinforced polymer. While Göhring et al. reported a 90% survival rate after two years for glass fiber-reinforced bridges placed on posterior teeth, delamination of the veneering composite from the fiber framework remains a significant concern. Clinical failures of this type were partly attributed to the presence of voids inside the resin-reinforced polymer that resulted from improper fiber impregnation during fabrication. Polymer-pre-impregnated glass fibers may have improved this type of clinical application. This article details potential indications of minimally invasive adhesive FRC FPDs fabricated with preimpregnated glass fibers (e.g., EverStick, StickTech, Turku, Finland; Targis/Vectris, Ivoclar Vivadent, Amherst, NY) and illustrates their use in a variety of clinical scenarios.

Case Presentations

Case 1

A 45-year-old female patient presented with severe periodontal compromise in both central incisors. As part of the initial periodontal treatment plan, scaling, root planing, and mucogingival surgery were performed. During periodontal reevaluation, the clinical and radiographic examinations revealed that the maxillary lateral incisor was hopeless (Figures 1 and 2). This tooth was scheduled for extraction and replacement using an FPD.

Following the administration of local anesthesia, the palatal surfaces of the adjacent teeth were prepared as abutments. A careful examination of static and dynamic occlusion was performed using articulating papers to determine the external limits of the preparations from contact point areas. Although preparation design was based on the concept of maximum preservation of sound tooth structure, sufficient tooth reduction was required to ensure space for adequate material thickness. Approximately 0.5 mm of palatal enamel was removed using superfine
diamond burs (eg, Intensiv, Lugano, Switzerland; Brasseler USA, Savannah, GA) and the gingival margins were finished supragingivally with a 0.5-mm rounded chamfer. A rest seat was also created at the cingulum area to facilitate seating of the restoration during cementation.

An impression of the prepared teeth was taken using a polyvinylsiloxane impression material (eg, Aquasil Xtra, Dentsply/Caulk, Milford, DE; True 1, Kerr/Sybron, Orange, CA) (Figure 3). Since the preparations were strictly confined to the enamel, provisionalization of the abutment teeth was not necessary. Bite registration and an opposing arch impression were sent to the laboratory with a detailed prescription and intraoral photographs for shade selection.

The impressions were poured with high-strength dental stone for master model fabrication (Figure 4). According to the manufacturer's instructions, a thin layer of composite resin (eg, Inlay, 3M ESPE, St. Paul, MN; Targis, Ivoclar Vivadent, Amherst, NY) was applied to the preparations on the master model prior to insertion of the glass fiber reinforcement material (eg, EverStick, StickTech, Turku, Finland; Vetric, Ivoclar Vivadent, Amherst, NY). The appropriate length of glass fiber was pressed on the preparations with the transparent silicon holder and light-cured for 10 seconds. The pontic of the FRC FPD was then fabricated using a layering technique. Each layer was light-cured for 20 seconds. When completed, the FRC FPD was postcured using an MBA 2000 unit (Biophoton, St. Alban, France) at 110°C for 180 seconds. Final polishing was performed with rubber points, nylon brushes, and cotton wheels (Figure 5).

During the second appointment, the maxillary lateral incisor was extracted under local anesthesia. The FRC FPD was tried in for fit and controlled for color match. After try-in, the internal part of the FRC FPD was sandblasted with 50-μm Al2O3, air-cleaned for 5 seconds, silane-coated (eg, Monobond S, Ivoclar Vivadent, Amherst, NY; Silane, Ultradent Products, South Jordan, UT), and allowed to dry in ambient air (Figure 6). Approximately 10 minutes was allowed for moisture control, and the adjacent teeth were isolated with a rubber dam. Care was taken to place a hole at the location of the pontic to avoid displacement of the FRC bridge during cementation as a result of excessive tension on the rubber dam. The tooth preparation surfaces of the...
material was light cured through the remaining tooth substrate for 120 seconds at 1200 mW/cm² (eg, Astralis 10, Ivoclar Vivadent, Amherst, NY; Optilux 501, Kerr/Sybron, Orange, CA).

Flame- and pear-shaped fine diamond burs (eg, Intensiv, Lugano, Switzerland; Brasseler USA, Savannah, GA) and polishing discs (eg, Soflex XT, 3M ESPE, St. Paul, MN; Flexidisc, Cosmedent, Chicago, IL) were used to complete finishing and polishing. The occlusion was controlled with articulating paper and adjusted with diamond finishing burs (Figure 8).

Case 2

A 65-year-old female patient presented with root fracture of the second maxillary right premolar. Both adjacent teeth were vital and previously restored with amalgam fillings that required replacement (Figure 9). While implant placement was discussed during the initial planning stage, this option was declined by the patient due to financial considerations. A fiber-reinforced inlay FPD was, therefore, presented as a treatment option to simultaneously replace the tooth to be extracted and the preexisting amalgam restorations. Once the patient accepted the proposed treatment plan, the fractured root was scheduled for extraction.

During the following appointment, the teeth were isolated with a rubber dam, and the preexisting amalgam fillings were removed using high-speed tungsten carbide burs. Adhesive inlay preparations were placed with...
a 2-mm isthmus depth, butt joint margins, and rounded internal line angles. The dentin was then covered with adhesive resin to protect the pulp of the tooth during the provisionalization period.14 The dentin surfaces were conditioned with a primer for 20 seconds prior to adhesive application (e.g., Syntac, Ivoclar Vivadent, Amherst, NY; Optibond Solo Plus, Kerr/Sybron, Orange, CA) on the conditioned dentin. The solvent was evaporated with air, and a layer of adhesive resin (e.g., Heliobond, Ivoclar Vivadent, Amherst, NY; Nexus, Kerr/Sybron, Orange, CA) was brushed onto the dentin surfaces and polymerized with a halogen light for 30 seconds (Figure 10). Then the external margins of the inlay preparations were finished with superfine diamond burs prior to impression capture. The provisional restorations were fabricated (e.g., Ferrit, Ivoclar Vivadent, Amherst NY; Cavit LC, 3M ESPE, St. Paul, MN). Bite registration, opposing arch impressions, and intraoral photographs for shade selection were forwarded to the laboratory. The FRC FPD was fabricated according to the aforementioned protocol (Figure 11). Care was taken to place the reinforcing fiber close to the lower portion of the pontic in order to resist tensile stresses.

At the cementation appointment, the provisional restorations were removed, and the abutments were cleaned with nylon brushes and pumice, then rinsed thoroughly with water for 30 seconds. The FRC FPD was tried on and controlled for color match prior to placement of the rubber dam. Once the internal aspect of the FRC FPD was treated according to the aforementioned protocol, the enamel margins of the inlay preparations were acidetched for 30 seconds, rinsed, and air-dried (Figure 12). A layer of adhesive was brushed onto the cavity walls and air-thinned. A thin layer of luting cement (e.g., Variolink, Ivoclar Vivadent, Amherst, NY; Calibra, Dentsply/Caulk, Milford, DE; Nexus, Kerr/Sybron, Orange, CA) was applied to the internal aspect of the bridge that was subsequently seated on the preparations and held in place under firm pressure. Excess luting material was removed by the clinician with a composite brush and floss. The luting composite was light-cured for 120 seconds. Upon verification of the occlusion, treatment was completed (Figure 13).

Figure 14. Case 3. Preoperative occlusal view of the reduced edentulous space due to previous premolar extraction.

Figure 15. Tooth preparation was performed for proper FRC FPD replacement.

Figure 16. The reinforcing fiber was inserted into the preparations to provide sufficient strength for the definitive restorations.

Case 3
A 45-year-old female patient presented for treatment of an edentulous space located between the second
Figure 17. Various composite layers were applied to the glass fiber in order to fabricate the pontic.

Figure 18. Magnified occlusal view of the master model exhibits the completed FRC FPD.

Figure 19. Postoperative view following cementation. Occlusion was controlled with articulating paper and adjusted with diamond burs.

maxillary premolar and the second maxillary molar. The first molar was previously extracted due to endodontic failure, and drifting of the second molar resulted in a reduced edentulous space (Figure 14). The proximal surfaces of the adjacent teeth exhibited superficial carious lesions localized at the contact point area.

Although implant therapy was considered, the position of the maxillary sinus and the size of the edentulous space contraindicated implant placement. An FRC FPD was selected to conserve natural tooth structures and treat the reduced edentulous space. A preparation design with slot cavities was selected for the reduction of the abutment teeth (Figure 15). This facilitated a minimally invasive design while allowing sufficient tooth reduction to provide adequate space for the reinforcing fiber. Slot preparations were cut 2 mm in depth, and featured butt joint margins and rounded internal line angles. A polyvinylsiloxane impression material was taken, and the provisional restorations were fabricated using a flexible vinyl chloride provisional material. Bite registrations, opposing arch impressions, and intraoral photographs were subsequently forwarded to the laboratory.

The external limits of the preparations were traced with a red pencil on the master model. Due to the limited space available, the reinforcing fiber was vertically oriented and folded at 90° at both ends to fit inside the slot cavities (Figure 16). The fiber was light cured, and the pontic of the FRC FPD was fabricated (Sintfony, 3M ESPE, St. Paul, MN) using a layering technique (Figure 17). When completed, the FRC FPD was further post-cured using an MPA 2000 unit (Biophoton, St. Albain, France) at 110°C for 180 seconds. Final polishing was performed with rubber points, nylon brushes, and cotton wheels (Figure 18).

At the delivery appointment, the provisional restorations were removed, and the cavities were cleaned with pumice and rinsed. The FRC FPD was seated and evaluated for adaptation and color match prior to rubber dam isolation. In preparation for cementation, the enamel margins were acid etched with 37% phosphoric acid. Self-etching adhesive was then applied to the dentin surface in order to increase bonding performance to enamel without reducing the bonding characteristics of the self-etching adhesive to dentin. When the bonding procedure was complete, a thin layer of adhesive material was applied to the interval aspect of the FRC FPD.
that had been previously air-abraded. The resin cement was applied to the prepared surfaces, and the FRC FPD was covered with the luting composite prior to insertion. Excess luting material was then removed with small brushes, and the composite material was light-cured through the remaining tooth substrate for 120 seconds. Finishing and polishing were performed according to aforementioned protocol. Occlusion was controlled with articulating paper and adjusted with diamond finishing burs following removal of the rubber dam (Figure 19).

Discussion
Recent developments in the dental industry have facilitated the development of a reliable bond to enamel and dentin, therefore reducing the risks of debonding. In contrast to non-reinforced composite FPDs, glass fiber-reinforced composite FPDs may be even more fracture resistant than minimally invasive, all-ceramic adhesive bridges. Delamination of the veneering composite from the fiber-reinforced framework, however, remains the primary complication associated with FRC FPDs. This concern can be partially addressed by use of an Interpenetrating Polymer Network structure (IPN structure) that can be dissolved by the veneering resin during laboratory fabrication. This material has been shown to promote micromechanical bonding in addition to chemical bonding between the silanated glass fibers and the veneering composite, which results in improved mechanical properties. Additional research is needed to evaluate whether such methods of glass fiber-composite connection will be reliable.

Delamination can also occur when glass fibers are exposed to the oral environment as a result of incorrect laboratory fabrication. Under such conditions, moisture and solva contact will induce the hydrolysis and the degradation of the organic matrix. Micromechanical care must, therefore, be taken to avoid exposure of reinforcing fibers. Since glass fibers are generally abrasive against the opposing dentition, adjustment of the occlusion should be carefully performed to avoid exposure of the reinforcing fibers. Additional areas of concern when using FRC FPDs include the color stability of the veneering composite material.

Conclusion
Although several concerns remain associated with the use of FRC FPDs, this treatment modality may offer a conservative alternative to traditional invasive treatments (e.g., PFM, implant-supported crowns) in a number of clinical conditions. Incorporation of this option represents a reduced expense, minimal invasion, and natural aesthetics that may justify its continued application in the clinical practice.

Acknowledgment
The authors declare no financial interest in any of the products cited herein.

References
CONTINUING EDUCATION (CE) EXERCISE NO. 7

To submit your CE Exercise answers, please use the answer sheet found within the CE Editorial Section of this issue and complete as follows: 1) Identify the article; 2) Place an X in the appropriate box for each question of each exercise; 3) Clip answer sheet from the page and mail it to the CE Department at Montage Media Corporation. For further instructions, please refer to the CE Editorial Section.

The 10 multiple-choice questions for this Continuing Education (CE) exercise are based on the article “Replacement of missing teeth with fiber-reinforced composite FPDs: Clinical protocol” by Serge Bauilloquet, DMD, PhD, Andrea Schütt, DMD, Isabelle Marin, DMD, Leila Etchami, DMD, Giancarlo DiSalvo, CDT, and Ivo Krejci, DMD, PhD. This article is on Pages 195-202.

1. Concerning the replacement of single missing teeth, recent research indicates that:
   a. The survival rate for implant-supported PFM crowns is 97.5% after 6 years.
   b. The survival rate for conventional PFM fixed partial dentures is 87% after 1.5 years.
   c. The survival rate for fiber-reinforced composite fixed partial dentures is 90% after 5 years.
   d. The survival rate for conventional resin-bonded FPDs is 76% after 10 years.

2. The primary advantage of using fiber-reinforced composite FPDs is:
   a. To reduce the loss of critical tooth structures.
   b. To reduce laboratory expenses.
   c. To provide a visible treatment with proven aesthetics and function.
   d. All of the above.

3. Which type of fiber is NOT USED to reinforce composite resins?
   a. Silk fibers.
   b. Polyethylene fibers.
   c. Glass fibers.
   d. Aramid fibers.

4. The use of silanated glass fibers is preferred for the fabrication of FRC FPDs because:
   a. Glass fibers exhibit good aesthetic qualities.
   b. Glass fibers can be chemically bonded to composite materials.
   c. Glass fibers exhibit good mechanical properties.
   d. All of the above.

5. Which factor DOES NOT influence the mechanical properties of FRC FPDs?
   a. The orientation of the fibers in the polymer.
   b. The volume of fibers contained in the polymer.
   c. The color of the veneering composite.
   d. The correct impregnation of the fibers by the resins.

6. The preparations of abutment teeth for the placement of FRC FPDs must:
   a. Be confined within the enamel.
   b. Have rounded angles.
   c. Should be significantly widened to ensure space for adequate material thickness.
   d. Should be at least 5 mm deep.

7. Concerning the fabrication of an FRC FPD, which proposition is NOT true?
   a. The FRC FPD is fabricated on a master model.
   b. The fibers can be purposely oriented within the restoration to resist the highest clinical stresses.
   c. The pontic of the FRC FPD is fabricated using a layering technique.
   d. The internal part of the FRC FPD must be sandblasted with 200 μm aluminum oxide.

8. Concerning the bonding procedures:
   a. The use of a rubber dam is recommended.
   b. Selfetching adhesives are preferred to total-etching adhesives.
   c. The adhesive can be applied prior to taking the impression.
   d. All of the above.

9. The materials used for the cementation of FRC FPDs are:
   a. Zinc phosphate cements.
   b. Glass-ionomer cements.
   c. Composite luting cements.
   d. ZOE cements.

10. The major clinical problems that may occur with FRC FPDs are:
    a. The delamination of the veneering composite from the fiber-reinforced framework.
    b. The abrasion of the opposing dentition after exposure of the reinforcing fibers in the oral cavity.
    c. The color stability of the veneering composite material.
    d. All of the above.