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Fiber-reinforced composites in fixed partial dentures

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ABSTRACT

Fiber-reinforced composite resin (FRC) prostheses offer the advantages of good aesthetics, minimal invasive treatment, and an ability to bond to the abutment teeth, thereby compensating for less-than-optimal abutment tooth retention and resistance form. These prostheses are composed of two types of composite materials: fiber composites to build the framework and hybrid or microfill particulate composites to create the external veneer surface. This review concentrates on the use of fiber reinforcement in the fabrication of laboratory or chairside-made composite-fixed partial dentures of conventional preparation. Other applications of FRC in dentistry are briefly mentioned. The possibilities fiber reinforcement technology offers must be emphasized to the dental community. Rather than limiting discussion to whether FRC prostheses will replace metal-ceramic or full-ceramic prostheses, attention should be focused on the additional treatment options brought by the use of fibers. However, more clinical experience is needed.

INTRODUCTION

Traditional metal reinforced bridges are characterized by certain disadvantages. These disadvantages culminate in the bonding and aesthetic problems of metal frameworks. Fortunately, these problems can now be overcome, to a large extent, by the use of fiber reinforced composite (FRC). In fact, the bond strength between the prostheses and the abutment teeth obtained when using FRC materials is 50-100 % higher than the bond strength achieved when using metal framworke.1 In addition, in FRC restorations the glass fibers are translucent and covered with veneering composites, resulting in good aesthetic restorations, which do not increase plaque accumulation.2

Metal-free prostheses continue to gain interest. Although the metal alloys contribute great strength to the prostheses, they do so at a considerable aesthetic liability. Two somewhat different metal-free approaches to fixed tooth replacement continue to be developed for a variety of clinical applications. These are all-ceramic and all-composite systems. Composite or polymeric prostheses are the subject of this article and generally consist of a particulate composite veneer supported by a FRC-substructure (framework). With FRC prostheses, there are two approaches in using fibers: one is based on conventional tooth preparation and laboratory-made restorations while the other is based upon using fibers in minimally invasive restoration by direct or indirect fabrication.

FRC-supported prostheses have undergone much testing recently in the laboratory and in the patient's mouth.3-7 The FRC prostheses can be fabricated indirectly in the prosthetic laboratory by a dental technician, chairside in the dental clinic by the dentist, or directly in the patient's mouth. Veneer materials used for the chairside-fabricated prostheses are light cured hybrid or microfill composites typically found in the dental clinic. Laboratory-made prostheses, including the FRC-framework, are also light cured but may have an additional heat polymerization stage with the optional use of vacuum or pressure to enhance polymerization. Deep polymerization improves mechanical properties, especially the flexural strength of the FRC framework and wear resistance as well as color stability of the veneering composite.8

The FRC material is a combination of fibers and a resinous matrix. Different types of FRC materials exhibiting a wide variety of mechanical flexural properties are commercially available. The mechanical properties of FRC materials are primarily dependent upon fiber type (glass, carbon, aramid, or polyethylene), quantity of fibers in the matrix resin (maximum is 15x103 in a bundle), fiber architecture (unidirectional, woven, or braided), and quality of impregnation of fiber with resin. Examples of different fiber architecture are shown in Figure 1.

Some manufacturers produce dry fibers that require hand impregnation by the technician or the dentist, e.g. Ribbond, Glas Span, and Construct. Some of the commercially available FRC materials are machine impregnated with resin by the manufacturer, e.g. everStick, FiberKor, and Vectris. These machine-impregnated materials are also known as pre-impregnated FRC materials. The mechanical and handling properties of machine-impregnated FRCs are better than those of the hand impregnated FRCs. Rigidity of the FRC framework is crucial for the integrity of the veneer, made from a brittle material, such

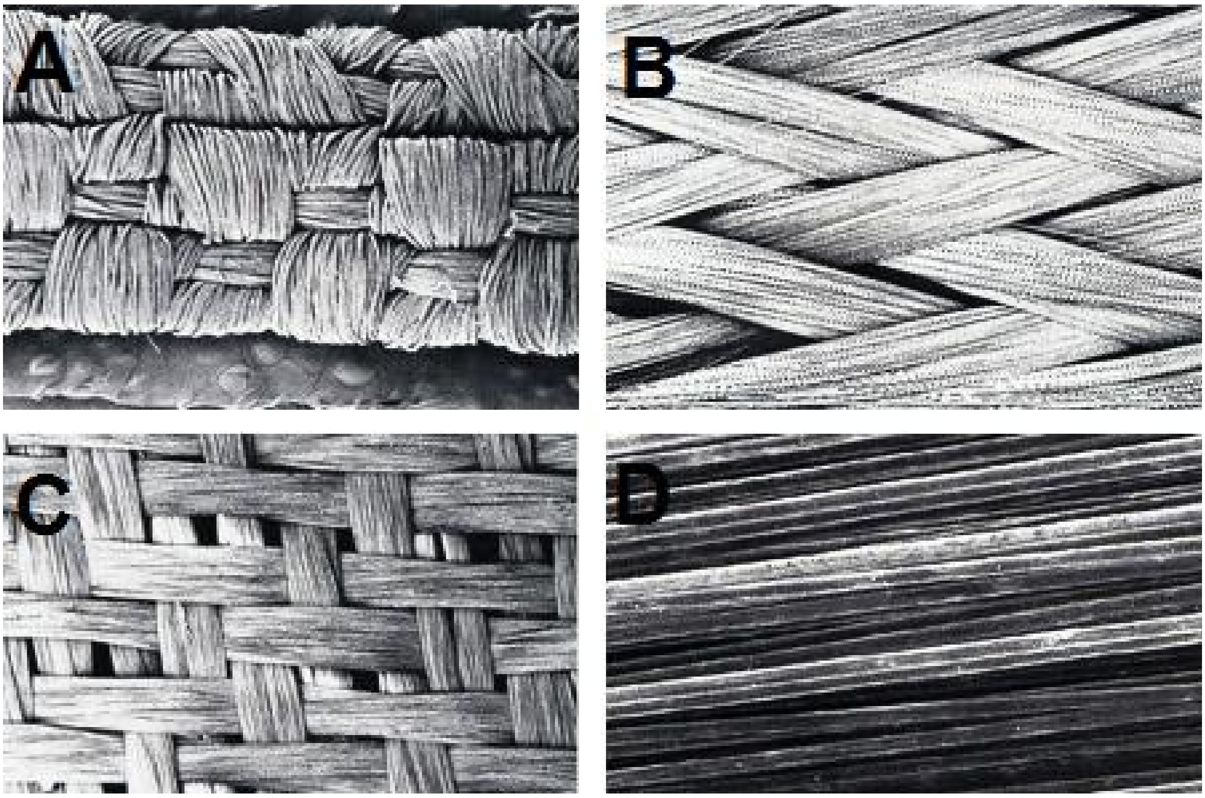

Figure 1. Scanning electron micrographs of various fiber architectures. (A) woven polyethylene fibers; (B) braided glass fibers; (C) woven (bidirectional) glass fibers; (D) unidirectional glass fibers. (From Fiber-reinforced composite in clinical dentistry, Chicago: Quintessence; 2000).

Table 1: Case selection for fiber-reinforced prostheses

Indications	Relative Contraindications
Patients who desire an optimum esthetic result	Patients in whom it is impossible to maintain fluid control.
Patients who require or desire a metal-free prosthesis	Patients with para-functional habits.
Cases in which easy fabrication in the laboratory is desired	Patients with poor oral hygiene
Patients in whom it is desirable to decrease wear of opposing teeth	
Patients in whom it is desirable to use an adhesive luting technique	
Patients having dentition with unknown prognosis	

as particulate filler composite. The ultimate flexural strength of manufacturer-impregnated (pre-impregnated) unidirectional glass FRC material ranges from 500 to 1200 MPa. This is greater than the flexural strength of noble alloys.9 For polyethylene fiber composites, flexural strength values are lower than glass or carbon fiber composites.

Clinical tooth replacement applications of FRC-reinforced prostheses are organized into two categories: laboratory-fabricated prostheses and chairside prostheses. There are several indications for selecting FRC prostheses which are summarized in Table 1.

This article focuses on describing laboratory and chairside made prostheses that have conventional abutment tooth preparation rather than describing fibers in minimal invasive approach, which will be reported in the near future.

Laboratory-fabricated Prostheses:

Laboratory-fabricated FRC prostheses can be retained by teeth or implants. Composite prostheses include a surface that does not wear opposing tooth enamel, and the FRC framework does not require waxing, casting, or soldering procedures during fabrication. Supported by a strong metal-free framework, the aesthetic qualities of the FRC prostheses can be outstanding.

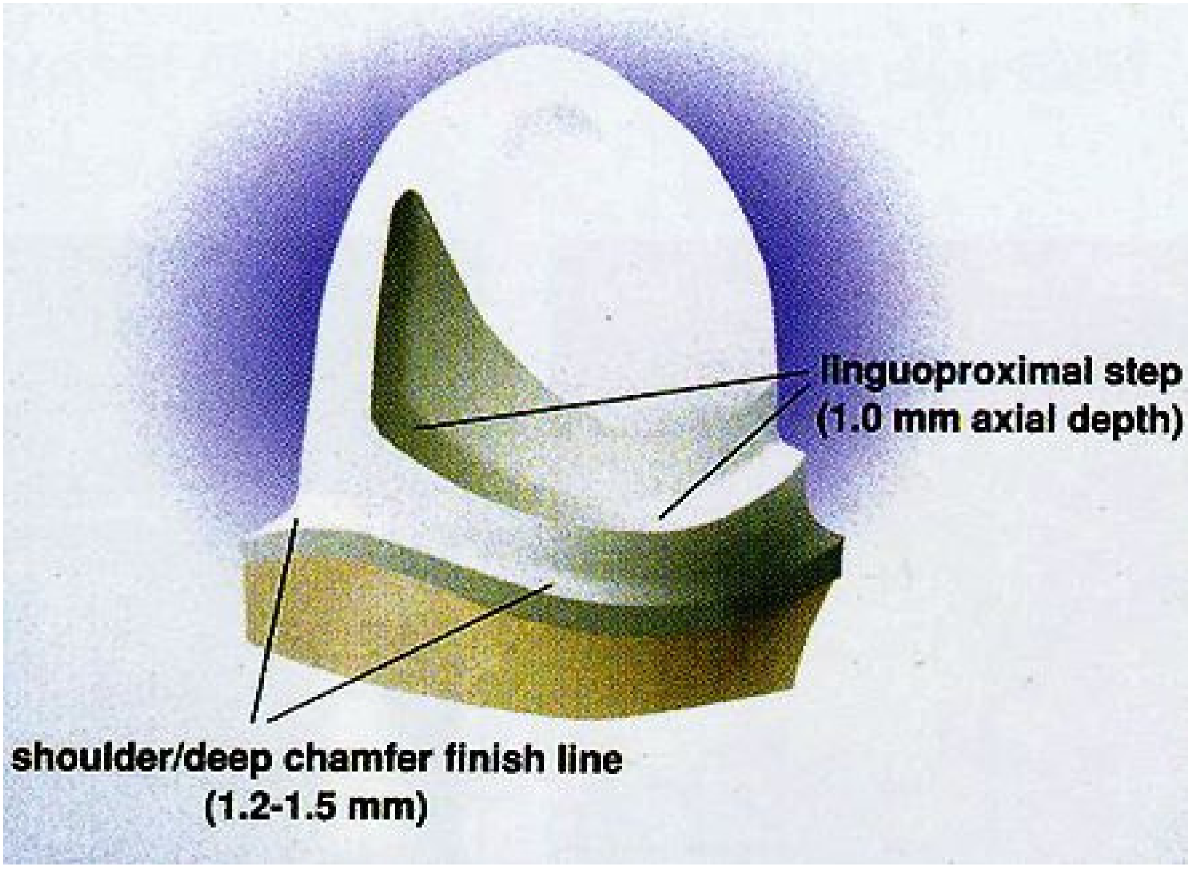

Figure 2. Schematic drawing of anterior abutment tooth preparation for the extracoronal full coverage FRC-prostheses. (From Fiber-reinforced composite in clinical dentistry, Chicago: Quintessence; 2000).

Potential concerns for these prostheses are water absorption, loss of surface shine, fatigue resistance over time, and the technique's sensitivity associated with cementation by using resin cement.

For tooth-retained FRC prostheses, the composite retainers can be bonded to the abutment teeth. This allows maximum retention for the available axial wall height. This also permits the use of conservative tooth replacement prosthesis, where intracoronal (inlay) preparation is made on minimally restored abutment teeth. Inlay bridge design has proven unsuccessful where a metal alloy framework is used and retainers have not been bonded to the abutment teeth. Tooth preparation designs of full and partial coverage FRC prostheses are shown in figures 2-4.

clinical success of FRC prostheses.7, 10 Increased framework bulk added at the pontic region (high volume design) provides additional rigidity along with greater vertical support of the ve-

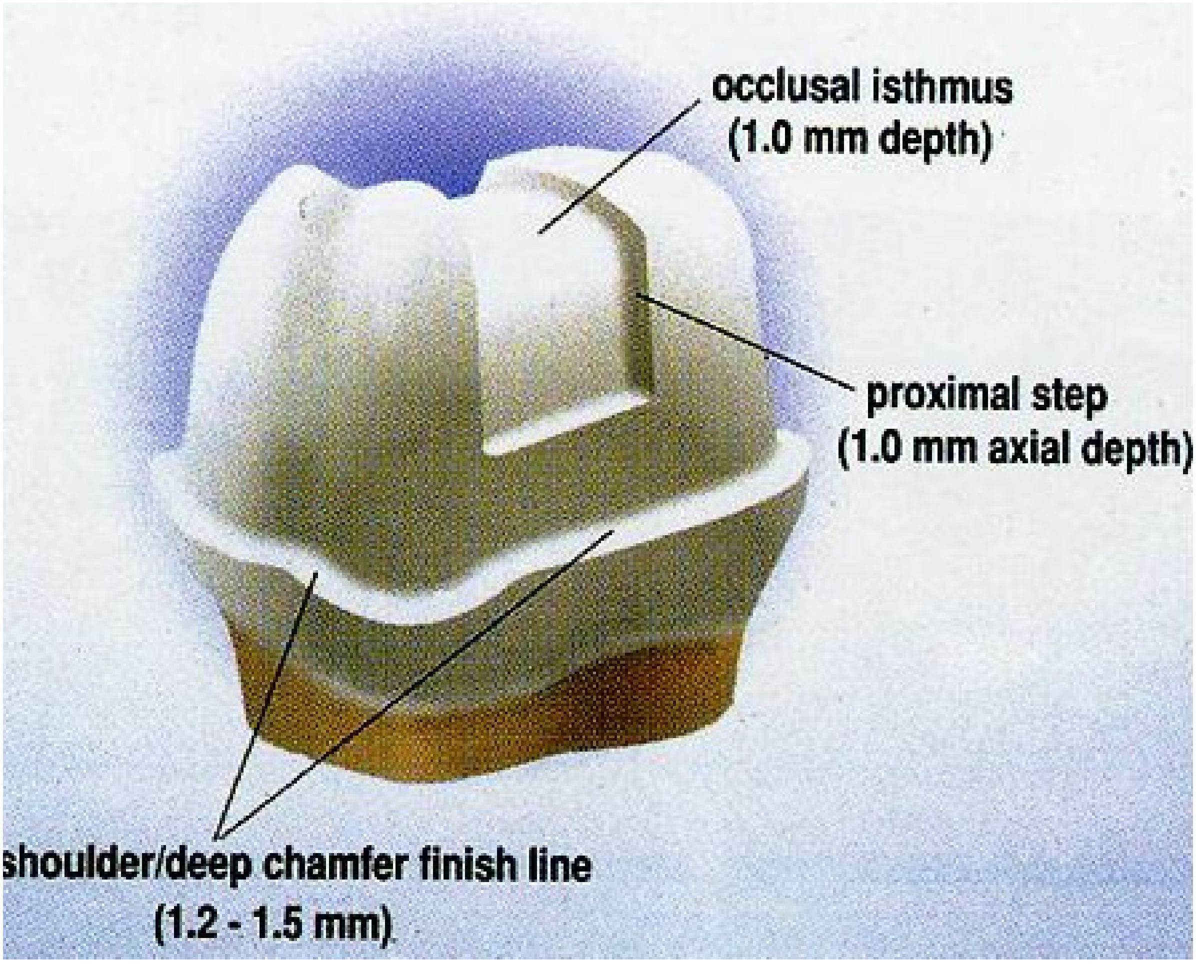

Figure 3. Schematic drawing of posterior abutment tooth preparation for the extracoronal full coverage FRC-prostheses. (From Fiber-reinforced composite in clinical dentistry, Chicago: Quintessence; 2000).

Data have shown that FRC framework design is a key point for the

neer material. Successful chemical bonding of the veneer composite to the FRC framework is another critical element for clinical success. An example of FRC framework is shown in Figure 4. Clinical studies of FRC prostheses made with pre-impregnated fibers have demonstrated greater than 90% survival of partial and full coverage prostheses for up to 5 years.7, 11

Chairside Prostheses:

The properties of FRCs that make them suitable for various chairside applications include high flexural strength, desirable aesthetic results, ease in use, adaptability to various shapes, and capability for direct bonding to tooth structure. Among the many direct intraoral applications of this technique are splinting of mobile teeth, replacement of missing teeth, and fabrication of endodontic posts.

One of the most exciting and potentially useful applications of pre-impregnated FRC technology is its use in replacing missing teeth in a timely and cost-effective manner. This ability to deliver a functional, aesthetic tooth replacement with or without minimal tooth preparation of the adjacent abutment teeth in a single visit is a realistic treatment option with current adhesive technologies and reinforced composites.

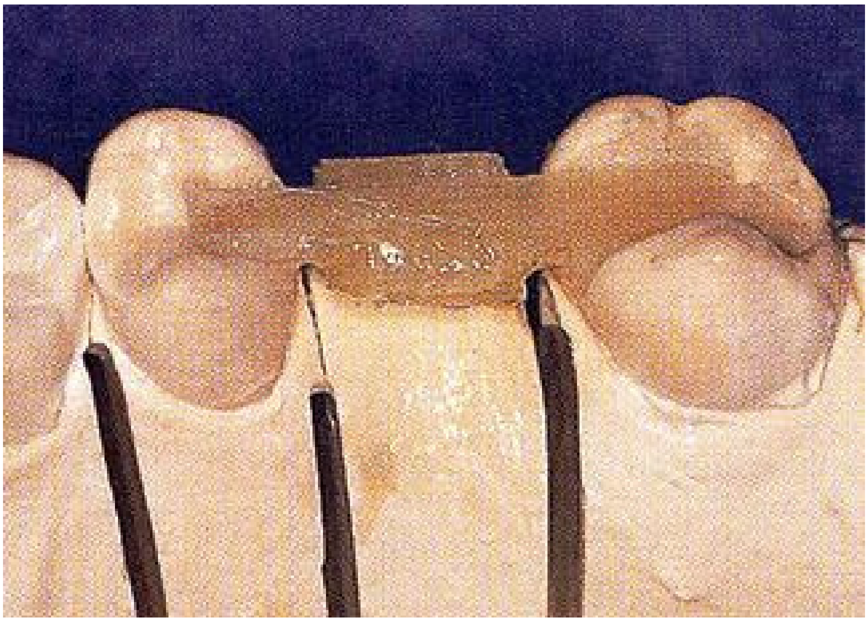

Figure 4. Partial-coverage retainer (intracoronal) using unidirectional glass framework with high-volume design placed in the edentulous region. (From Fiber-reinforced composite in clinical dentistry, Chicago: Quintessence; 2000).

The increased physical properties that fiber reinforcement provides to particulate composites resin allow for an improved approach over earlier methods in using denture teeth as pontics.12 This new approach eliminates the disadvantages caused by the incompatibility of the different chemistry between the particulate luting composite and the acrylic pontic and results in a much stronger connector between the pontic and the FRC framework. This provides the potential for long-term clinical service.13 Consequently, what was once thought of as a purely short-term or temporary solution can sometimes be considered as a more definite solution for those patients who cannot afford a conventional fixed-tooth replacement. Potential clinical applications for chairside-fabricated FRC prostheses include situations where the abutment teeth may be of questionable stability or in place of a provisional removable prosthesis immediately after anterior implant placement but before loading. Additionally, this technology can be used for immediate fixed-tooth replacement after extraction, after traumatic loss of a tooth, or for space maintenance in pediatric or adolescent patients.

FRCs is currently commonly used in several fields of dentistry. In addition to prosthodontics, applications of FRCs extend to periodontal, orthodontic, and surgical fields in the form of various splints. The recurrent fractures of removable dentures can be eliminated by the use of FRC as reinforcement.14 The impact strength of maxillary complete denture can be increased by a factor greater than two times when reinforced with bidirectional-FRC.15 However, as in the cases of any other application for fiber reinforcement, the positioning of fiber is of importance in order to achieve an efficient reinforcing effect.14 FRCs can also be used as framework in overdenture or implant-supported prosthesis and in root canal posts as prefabricated posts or individually formed (custom-made) posts.16

Clinical Problems with FRC-prostheses:

Problems associated with FRC-prostheses can be grouped under the following categories: gray/metal shadow due to metal posts and cores or amalgam cores on abutment teeth; loss of surface shining on the particulate veneering composite; excessive translucency in pontic areas; fracture or chipping of the particulate composite veneer and debonding of the retainer.

The correct design of the FRC framework and the use of high quality preimpregnated glass fibers in optimum quantity reduce the possibility of framework fractures. Veneering composite chipping can be avoided by using thicker layer (1-2 mm) of composite resin on the surface of FRC framework.17 Although there are some failures that have been associated to FRC bridges made earlier, these failures are in the majority of cases repaired by composite technology in the patient's mouth. When a failure is observed, the dentist needs to analyze its reason and repair the device accordingly. An example of this would be through adding more fibers to the restoration.

The amount of plaque accumulation on the surface of FRC materials depends on the type of fibers used. Polyethylene FRC has the roughest material with promoted plaque accumulation significantly more than the other smoother materials. Glass FRC and restorative composite showed very similar plaque accumulation properties. They are both composite materials composed of inorganic filler components and an organic polymer matrix.18

Finally, it must be emphasized that the fiber reinforcement technology offers new prospects and approaches to the profession. Instead of discussing whether fiber FPDs will replace metal-ceramic or full ceramic FPDs, attention should be paid to the added new treatment options resulting from the use of fibers.

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