Fiber Reinforced Composites in Pediatric Dentistry

Frc in Pediatric Dentistry

Dr. Sunita Agarwalla, et al.

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*I owe a deep sense of gratitude to all my teachers **Dr. Pratik Kumar Lahiri MDS, Dr. Sudipta Kar MDS, Dr. Rajib Saha MDS, Dr. Piyali Datta MDS** for their valuable guidance and constructive criticism.*

*I am extremely grateful to **my parents** for their love, prayers, care and sacrifices for educating and preparing me for my future. I am very much thankful to **my husband and my daughter** for their love, understanding, prayers and continuing support to complete this work. Also I express my thanks to my sisters, brother, and brother in law for their support and valuable prayers.*

Foreword

Let me start this writeup with a famous quote of C.S.Lewis

"You are never to old to set another goal or to dream a New Dream"

Its my privilege to say few words on this book.

Use of composite in restorative dentistry is constantly evolving. Reinforcement of Composite with fibre has come up with variety of additional clinical applications.In this book Sunita has left no stone unturned to update readers on different clinical possibilities which will help not only the academicians but also the clinicians.

I wish all success of this endeavor though I believe in the famous quote of Winston Churchill Success is not final,failure is not fatal: it is the" courage to continue " that counts.

Maintain this "Courage to continue".

Gautam

Prof.(Dr)Gautam Kumar Kundu
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Dedicated to…

Gopal and Khanak who always inspire me and make me so proud…

Without whom this work would not have been possible.

CONTENTS

INTRODUCTION

The dental restorative materials are considered as a unique class of biomaterials with some restrictions in physical, mechanical and biological properties like biocompatibility, aesthetics, and material properties. Examples include Amalgam, composite resin, glass ionomer cement, resin modified glass ionomer cement (RMGIC), compomers which fall under the direct restorative materials. The indirect restorative materials include porcelain (ceramic), composite resin, ceramic-resin hybrids, gold, other historical fillings such as platinum, aluminium, tin and iron, thorium, lead and tungsten etc. In recent years the dental restorative materials are the main target of an excellent deal of research with the goal of improving restoration performances by changing the initiation systems (composite), fillers (GIC) and by developing novel polymerization strategies (composites) etc.[1]

Despite better understanding of the materials and recent improvements in physical properties, no material has been found that is ideal for any dental application. Silver amalgam has been used for dental restoration for more than a century; however, there has been a serious concern about mercury toxicity from the amalgam restorations for several years. Another major concern is the color of amalgam for aesthetic considerations and alternative materials are being sought to replace. The composite restorative materials have promising esthetics however these materials are very technique sensitive and mechanical properties are not as good as of amalgam. Restorative dentistry is constantly evolving as a result of innovative treatment procedures based on new materials, treatment techniques and technologies, with composite materials being a key example.[1]

As popular and successful as these materials are, they exhibit shortcomings that frequently cause clinical problems:[2]

1. The metal alloys used to make substructures that reinforce crowns and fixed prostheses are strong and rigid, but they are not esthetic as given in figure below. Furthermore, the base metal alloys commonly utilized in clinical practice may corrode and a few patients

have an allergy to them. Certain components of some base metal alloys may even cause acute and chronic health hazards to laboratory personnel.

Metal ceramic prosthesis prior to try in appointment

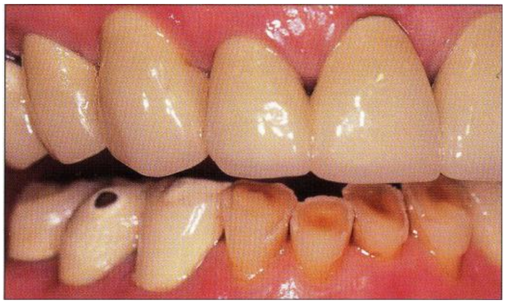
Unesthetic appearance due to metal exposure at base of the crown

Source: James Fondriest 2019

2. Ceramic materials such as porcelain may exhibit good optical qualities, but they are also brittle and hard, they have the potential to lose structural integrity, and they sometimes abrade or fracture the opposing teeth.[2]

Metal-ceramic FPD with a fractured porcelain veneer and abrasion of opposing teeth

3. The porcelains used to mask the metal substructure are opaque, unesthetic and require a minimum thickness of coverage to obtain an acceptable result. Use of hard, brittle porcelain veneer results in severely abraded mandibular anterior teeth opposing the porcelain and porcelain-metal junction of metal-ceramic crowns.



4. The acrylic polymer materials such as methyl methacrylate that are used to make removable and provisional fixed prostheses offer desirable handling qualities and physical properties, but they are susceptible to fracture in many clinical circumstances.[2]

Failure of PMMA polymer, with fractured maxillary complete.

The development of fibre reinforcement has further increased the potential uses of composite resins in restorative dentistry. Fiber-reinforced composites (FRCs) are composite materials with three main constituents: the matrix (continuous phase), the fibers (dispersed phase), and the zone in between (interphase). FRC materials have high stiffness, strength and adequate toughness per weight in comparision with other structural materials. The development of the fiber-reinforced composite technology has brought a new material into the realm of metal-free adhesive esthetic dentistry.[3]

FRCs have been used for various applications in various other fields like engineering and biomedical for a long time. For more than 40 years, the reinforcement of dental resins with either short or long fibers has been described in literature. Fiber-reinforced composites (FRC) are resin based materials containing fibers aimed at enhancing their physical properties.

It has been suggested recently that resin bonded, glass fibre-reinforced fixed partial dentures (FPDs) may be an alternative to resin-bonded FPDs with a cast metal framework. FRCs consists of reinforcing component provides stiffness and strength surrounding matrix supports the reinforcement and provides workability. The fibers routinely used in dental applications for reinforcement are polyethylene, glass, polypropylene, carbon or aramid. The matrix comprises of epoxy resin which maintains the position and orientation of the reinforcement and provides strength and rigidity to a prostheses.

Different fiber types such as glass fibers, carbon fibers, Vectran fibers, Kevlar fibers, and polyethylene fibers have been added to composite materials. Glass fibers, consisting of glass interlaced filaments, improve the impact strength of composite materials. They have excellent esthetic properties, but they do not easily stick to the resinous matrix.

- Carbon fibers prevent fatigue fracture and strengthen composite materials, but they have a dark color that is esthetically undesirable. Kevlar fibers, made from an aromatic polyamide, increase the impact strength of composites, but are not esthetic, hence their use is restricted. Vectran fibers are synthetic fibers which comprises of aromatic polyesters. They show acceptable resistance to abrasion and impact strength, but are expensive.

- However, polyethylene fibers improve the impact strength, modulus of elasticity and flexural strength of composite materials. When compared to other fibers, these fibers almost invisible in the resinous matrix.

- Due to these reasons, they are the most appropriate and the best esthetic strengtheners of composite materials.

- The use of this fiber is based on the clinical reports of tooth replacement by Bradenstein and Sperber, Marcus, and Millerand Portilla, among others.[4]

- This fiber has been described as being used for perio splints,strengthening removable prosthesis, post and core fabrication, and provisional use.

- Fiber-reinforced materials have highly favorable mechanical properties, and their strength-to-weight ratios are superior to those of most alloys.

- When compared to metals they offer many other advantages as well, including non corrosiveness, translucency, good bonding properties, and ease of repair.

- Since they also offer the potential for chairside and laboratory fabrication, it is not surprising that fiber-reinforced composites have potential for use in many applications in dentistry.[3]

Because of the ability to manipulate the properties of composites to match with structural aspects, fiber reinforced composites (FRCs) have many clinical applications in dentistry. In Additionally, the mechanical properties of FRC are often optimized to equal that of bone or dentin. This unique property has been tailored for dental needs by designing frameworks for crowns, anterior or posterior fixed prostheses, chair side tooth replacements, posts and appliances like space maintainers, periodontal splints and orthodontic retainers.[4]

- Dental caries is the most common chronic disease in childhood despite the fact that it is largely preventable. The caries may take a toll and may result in total destruction of the dental elements in cases like early childhood caries.

- The oral rehabilitation of these teeth is a great challenge for pediatric dentistry. Until very recently, for early childhood caries the only treatment option was extraction of the affected primary anterior tooth, which resulted in severe coronal destruction .

- The early loss of primary anterior teeth may result in reduced masticatory efficiency, loss of vertical dimension, development of parafunctional habits (tongue thrusting, speech problems), esthetic functional problems such as malocclusion and space loss, and psychological problems which might subsequently lead to personality and behavioral problems in children at a later stage.

- Various restorative treatment options are pre-fabricated crown and biological and resin composite restoration either by means of direct or indirect techniques mentioned in the literature.

- Reinforcement fibers (polyethylene fibers) were recently introduced and can be used as an intra-canal retainer associated with the resin composite as an alternative option for reconstruction of primary incisors greatly damaged by an extensive carious lesion.

- A more recent approach has used composite alone or in combination with other reinforcement material, and the use of fiber set in composite resin resulted in an increase in the strength of restoration.[5]

HISTORY

- Fiber reinforced composite (FRC) group of materials have been in use and tested since 1960s but for dental use developed and clinically approved materials are available more extensively during the last 30 years and for the medical implant use during the 15 years.

- The initial attempts for using fiber reinforcement in clinical dentistry began more than 35 years ago. In the 1960s and 1970s, investigators sought to reinforce standard polymethyl methacrylate dentures with glass or carbon fibers.

- In the 1980s, similar attempts were repeated, and initial efforts were made to fabricate fiber-reinforced prosthodontic frameworks for implants, fixed prosthodontics restorations, orthodontic retainers, and splints.[2]

- While these materials and techniques demonstrated improved mechanical properties, they failed to achieve general clinical acceptance because of insufficient enhancement of properties and awkward clinical manipulating procedures.

- Almost all the procedures advocated involved automatic manual placement of fibers into dental resins that were otherwise processed with routine methods.

- But this approach was inconvenient because free fibers are difficult to handle and utmost care must be taken to avoid either damaging or contaminating them.

- Even though the addition of fibers increased mechanical properties, the degree of improvement achieved was far below other commercial applications.

- There were two main reasons for the lower-than-expected mechanical results.

- First, the actual amount of fiber incorporated into the dental resins was low, typically less than 15% by volume. (Industrial products may contain 50% or even as much as 70% fiber by volume.)

- Second, as stated in theory the fiber reinforcement was not very effective due to the poor wetting of the fiber bundles by the resin which led to insufficient coupling and gaps between the fibers and resin.

- During testing, it was found that effective coupling usually results in failure within the matrix not at the fiber-matrix interface.

- Clinical uses and whether the fiber bundles are pre-impregnated with resin by the manufacturer or resination is required by the dentist or laboratory technician. [2]

- Though there is wide variation between products in fiber surface treatments, dental manufacturers use only standard industrial fibers; methods for incorporating the fibers into the polymeric resin, and chairside and laboratory processing methods.

- Towards the end of 1980s, dental researchers found the importance of effective coupling and complete impregnation of the fiber bundles by the resin and started developing techniques applicable for dentistry.

- Since then two approaches have evolved. In the first technique, manual application of a low viscosity resin to the fiber bundles is done by the dentist or laboratory technician. It provides complete wetting, Though it provides versatility in the selection of fibers and resin, this approach can be cumbersome and requires an additional step in the procedure.

- The other approach is to use pre-impregnated fiber bundles during a controlled manufacturing process.

- There are numerous manufacturing parameters which regulate the final fiber dimensions and content, the viscosity of the resin, speed of the process, tension on the fiber bundles etc.

- These complex process parameters allow for high fiber content, complete wetting, minimum void content, and control of the cross-sectional dimensions in pre-impregnated FRCs.[2]

- Some of the earliest of these experimental pre-impregnated FRCs designed for dental applications were based on glass-reinforced thermoplastics.

- Clinical trials were conducted using glass-reinforced polycarbonate as orthodontic retainers. The function of esthetic retainers is satisfactory and the mean service life of 20.4 months.

- Most importantly, only 6% of those that failed were due to frank mechanical breakage of the fiber composites, confirming that the physical properties of these materials are adequate for this clinical application. The cause of most of the clinical failures was debonding of the retainers from the tooth surface.

- A successive clinical trial evaluated the application of pre-impregnated glass-reinforced polycarbonate as the framework for acid-etched fixed partial dentures (FPDs).

- 14 three unit restorations were placed both in anterior and posterior region using adhesive techniques and without any tooth preparation.

- After 9 years, three restorations were still in place. Eleven failures were caused by separation in the region of the tooth restoration interface and none was due to frank mechanical breakage of the fiber-reinforced framework.

- The clinical failures mainly occurred at the adhesive-tooth interface, the adhesive–fiber composite interface, or within the outer matrix of the fiber-reinforced composite.

- This study established the acceptable mechanical properties of FRCs for use in prosthodontics and it also confirmed that it is difficult to manipulate the thermoplastic resin matrix and offers poor bonding to tooth structures.[2]

- These problems were overcome by switching to a bisphenol glycidyl methacrylate (bis-GMA) based resin as the matrix for the FRCs.

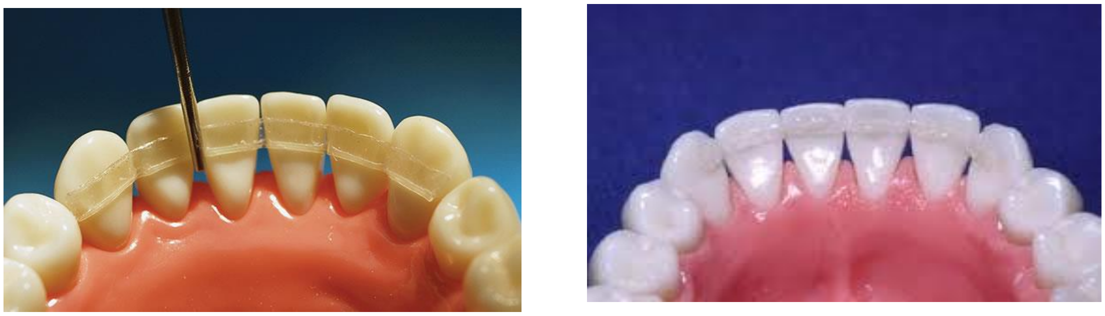
- 4 year clinical trials of carbon fiber–reinforced polymethyl methacrylate implant-supported prostheses also demonstrated the potential for prosthodontic applications. After 4 years, only 5 (19%) of 27 original prostheses had fractured; however, these experimental materials had less than half the strength of the commercial materials currently used.

- Recent laboratory studies of provisional restorations have demonstrated that proper reinforcement with woven polyethylene fiber or glass fiber improves fracture resistance.

- Continued research on glass-reinforced bis-GMA systems, combined with important manufacturer-designed fiber impregnation and packaging systems, has led to the commercial pre-impregnated systems available today: Sculpture/FibreKor, Splint-It (Jeneric/Pentron); and Targis/Vectris (Ivoclar).

- The fiber-reinforced strips in both systems measured several millimeters in cross section and several centimeters in length and packaged in separately sealed, light-tight containers.

- Using either pre-impregnated or hand-impregnated strips, a dentist or technician forms and fabricates the desired restoration, splint, or appliance, which is then cured.[2]



Glass fiber-reinforced polycarbonate orthodontic retainer

- For most of the FRC procedures, a direct or indirect method can be used. Splints are commonly fabricated with a direct approach and light-cured, while to minimize chair time and to allow for optimum esthetic and mechanical results fixed prostheses are typically fabricated by dental laboratories.

  - Both hand-impregnated and pre-impregnated systems are commercially available to the laboratory, although the latter are more widely used.

  - Two commercial pre-impregnated systems are available for dental laboratories. Both use fiber composites to fabricate the framework, and the final tooth shape is then built with particulate reinforced restorative composite.

  - One system, Sculpture/FibreKor (Jeneric/Pentron), uses hand fabrication to form the framework and con-dense the strips .[2]

  - The other system, Targis/Vectris (Ivoclar), uses custom-made matrices and special equipment to apply pressure to the fiber strips during fabrication.

  - The primary aim in the fabrication of the framework are to incorporate adequate amount of fiber reinforcement, reduce voids and confirm strong bonding between both the layers of pre-impregnated fiber strips and restorative composite and the fiber framework in both systems,.

  - Clinical trials of the commercial systems, now in their third year, demonstrate satisfactory performance when appropriate designs, fiber volume, and manipulative procedures are followed, although a loss of surface luster was often observed soon after placement.

  - The initial designs of fiber-reinforced FPDs required substitution of the facings, however repair techniques have been described to minimize or eliminate the need to replace the complete restoration.

APPLICATIONS FOR FIBER REINFORCED COMPOSITES OUTSIDE DENTISTRY:

- Fiber-reinforced composites (FRCs) have the potential to remedy many of the structural andesthetic problems described above.

- Though the use of these materials is new to dentistry, but they have found application in a number of industries outside dentistry because of their many advantageous properties.

- Recreational boat hulls (Fig:2A) as well as many other components used in the boatingindustry, such as masts and rudders, are now routinely made with FRCs.

- High-quality buses and large modern windmills (Fig:2B&C) are also made with fiber-reinforced materials. [2]

- Fiber-reinforced materials have good overall mechanical properties, and their strength to weight ratios are superior to those of most alloys.

- The additional features that make these materials advantageous compared to metals are-noncorrosive properties, potential translucency, radiolucency, good bonding properties, and ease of repair.

- Given that they also offer the potential for chair side and laboratory fabrication, it is not surprising that FRCs have many applications in dentistry.[2]

Fig 2A: High-quality sailboat made with glass fiber–reinforced hull

Fig 2B: Glass fiber reinforced bus

Fig 2C: Modern windmill with fiber reinforced blades

DEFINITION AND CLASSIFICATION OF FIBER REINFORCED COMPOSITES:

- Fibre-reinforced composite restorations are resin-based restorations containing fibres aimed at enhancing their physical properties.
- The nature of the fibre, the geometrical arrangement of the fibres and the overlying resin used makes this group of materials is very heterogeneous
- An adhesive interface allows the fibres within the composite matrix to bond to the resin.

The main factors that influence the physical properties of FRC structures are listed as follows:

- Fibre loading (volumetric fraction) within the restoration;
- The fibre-resin interface bond efficacy;
- Fibre orientation relative to load;
- Fibre position in restoration[3]

CLASSIFICATION:[2] Fiber reinforced composites can be classified as follows:

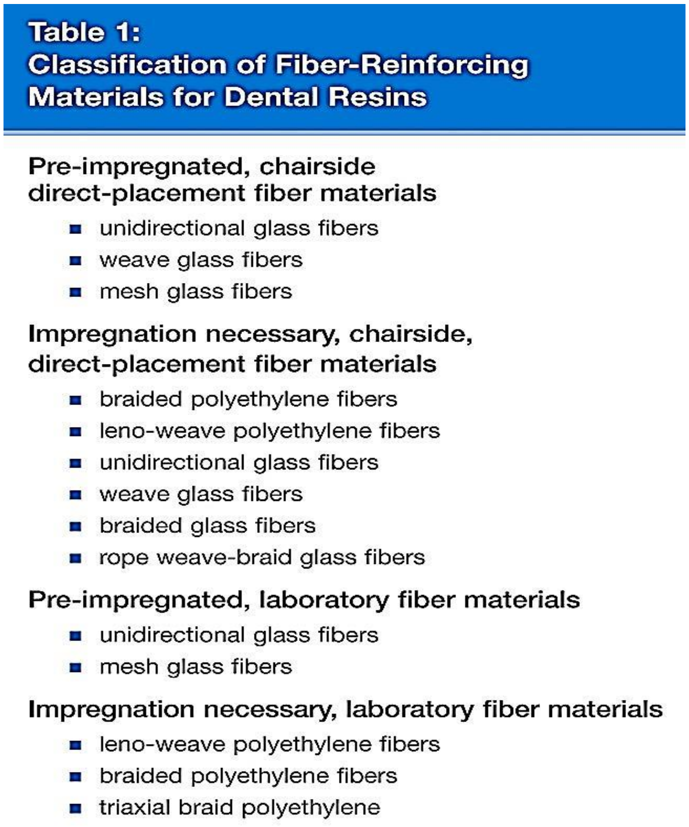


Table 1:
Classification of Fiber-Reinforcing Materials for Dental Resins

Pre-impregnated, chairside direct-placement fiber materials
- unidirectional glass fibers
- weave glass fibers
- mesh glass fibers

Impregnation necessary, chairside, direct-placement fiber materials
- braided polyethylene fibers
- leno-weave polyethylene fibers
- unidirectional glass fibers
- weave glass fibers
- braided glass fibers
- rope weave-braid glass fibers

Pre-impregnated, laboratory fiber materials
- unidirectional glass fibers
- mesh glass fibers

Impregnation necessary, laboratory fiber materials
- leno-weave polyethylene fibers
- braided polyethylene fibers
- triaxial braid polyethylene

ADVANTAGES AND DISADVANTAGES OF FRCs:

ADVANTAGES

- Lower treatment costs.
- Single visit immediate tooth replacements.
- Appropriate for long-term and transitional provisional restorations.
- Readily repaired.
- Suitable for young patients (developing dentition) and elderly (time saving).
- Metal free restoration.
- Improved aesthetics.
- Can be produced in a simple manner in the laboratory without the need for waxing, investing and casting.

- Can be routinely used with minimal or no tooth preparation.
- Minimize abrasion of the opposing teeth in comparison to conventional metal-ceramic restorations.

DISADVANTAGES

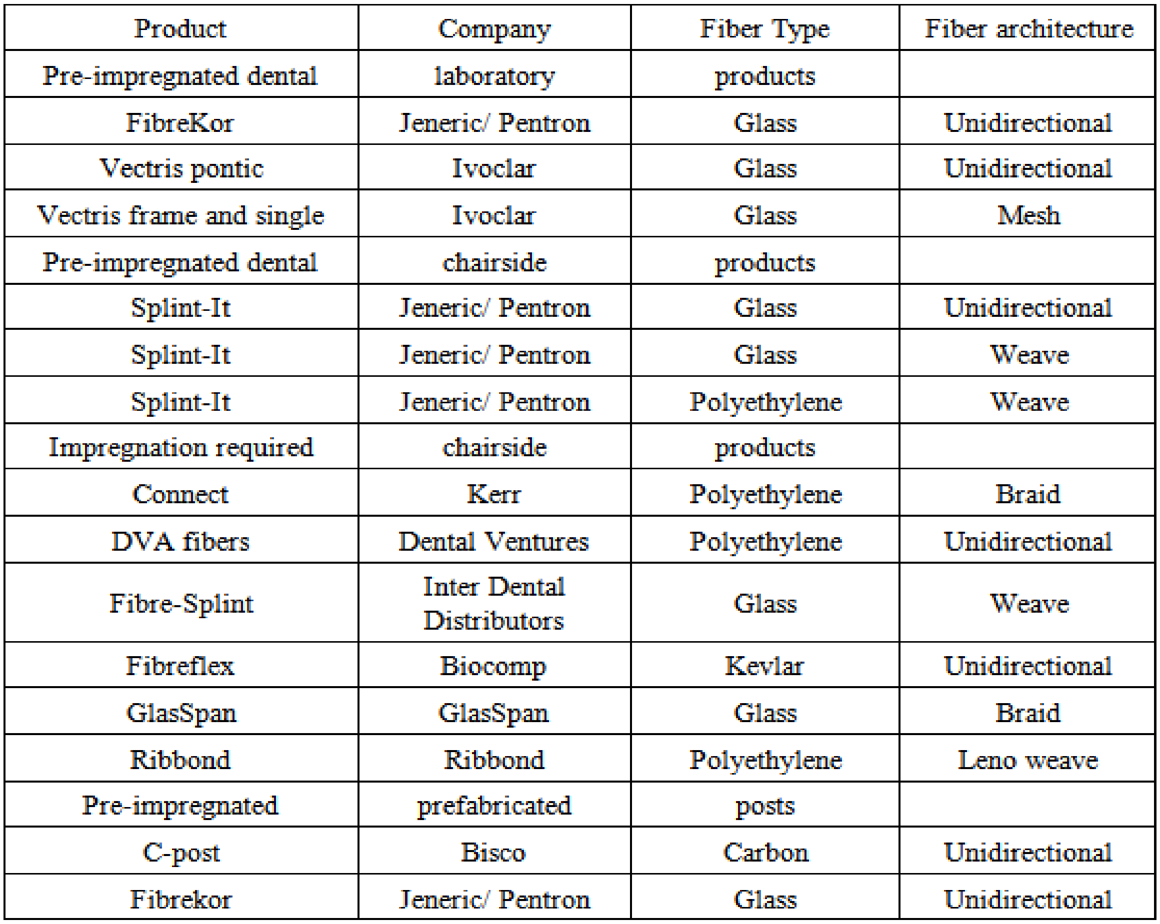
- Potential wear of the overlying veneering composite especially in patients with significant parafunction.
- May lack sufficient rigidity for long span bridges.
- Excellent moisture control required for adhesive technique.
- To allow sufficient room for fibres and adequate bulk for veneering composite overlay, space requirements are greater in posterior occlusal situations in comparison to metal occlusal surfaces.
- Uncertain longevity in comparison to traditional techniques.[3]

COMPOSITION, ARCHITECTURE, AND MECHANICAL PROPERTIES OF FIBER-REINFORCED COMPOSITES[4]

- Fiber-reinforced composites (FRCs) are structural materials that have at least two distinct constituents.
- The reinforcing component imparts stiffness and strength, whereas the encompassing matrix supports the reinforcement and provides workability.
- In dental applications, one of the constituents may be metal, ceramic, or polymer, polymeric or resin matrices reinforced with glass, polyethylene, or carbon fiber are most common.
- Usually, fibers are 7 to 10 pm in diameter and span the length of the prosthesis or appliance. The particle size used in standard restorative dental composites are 1 to 5 pm in diameter, or submicron. The fibers may be arranged in various configurations: unidirectional fibers —continuous, long and parallel—are the most popular, followed by braided and woven fibers.

- The type of fiber used to make an FRC depends on how it is intended to be used and the characteristics that are needed for that purpose.
- Glass fibers of various kinds are commonly used in dental laboratory products, while polymeric reinforcements, such as polyethylene, are often used for chairside applications. Posts are made of carbon or glass fibers.
- Table below (table:2) lists different types of fiber and the important mechanical and physical characteristics of each. The types of fiber and architecture found in various products products are classified according to their clinical uses and whether the fiber bundles are pre-impregnated with resin by the manufacturer or resination is required by the dentist or laboratory technician.[4]

DIFFERENT TYPES OF FRC PRODUCTS ACCORDING TO FIBER TYPE AND ARCHITECTURE: Table:2



Product	Company	Fiber Type	Fiber architecture
Pre-impregnated dental	laboratory	products	
FibreKor	Jeneric/ Pentron	Glass	Unidirectional
Vectris pontic	Ivoclar	Glass	Unidirectional
Vectris frame and single	Ivoclar	Glass	Mesh
Pre-impregnated dental	chairside	products	
Splint-It	Jeneric/ Pentron	Glass	Unidirectional
Splint-It	Jeneric/ Pentron	Glass	Weave
Splint-It	Jeneric/ Pentron	Polyethylene	Weave
Impregnation required	chairside	products	
Connect	Kerr	Polyethylene	Braid
DVA fibers	Dental Ventures	Polyethylene	Unidirectional
Fibre-Splint	Inter Dental Distributors	Glass	Weave
Fibreflex	Biocomp	Kevlar	Unidirectional
GlasSpan	GlasSpan	Glass	Braid
Ribbond	Ribbond	Polyethylene	Leno weave
Pre-impregnated	prefabricated	posts	
C-post	Bisco	Carbon	Unidirectional
Fibrekor	Jeneric/ Pentron	Glass	Unidirectional

Scanning electron micrographs of glass-reinforced thermoplastics showing the degree of wetting of the fibers by the matrix:[2]

MECHANICAL PROPERTIES OF FRCs:

- Mechanical properties in the matter of strength, toughness, stiffness and fatigue resistance rely upon the geometry of the reinforcement. The provision of strong fiber resin interfaces contributes to greater static and fatigue properties.
- Increased hardness and tensile strength are influenced by the incorporation of silanated filler particles of fiber (Debnath *et al*., 2004).

- The effectiveness of the fiber reinforcement, as described on theKrenchel's factor, differs according to the length and fiber orientation.
- The reinforcing efficiency factor for the fiber reinforcement goes against the known direction of stress (Krenchel 1963).
- Many other parameters contribute to the reinforcing efficiency offibers, between them interfacial adhesion, fiber volume fraction and elongation of fibers (Murphy, 1998).
- Fiber-reinforced composites are classified as short discontinuous and long continuous FRCs. They show differences in their mechanical properties even when their fiber volume fraction is similar (Kardos 1993).
- For instance, if continuous unidirectional fibers are replaced by longitudinally oriented discontinuous short fibers of lower aspect ratio, a reduction of the ultimate tensile strength of the composite will be the result (Vallittu, 2015).[4]
- The isotropicity-anisotropicity of the material plays a role. Continuous and discontinuous FRCs are anisotropic and they become isotropic when the orientation of short fibers is random, with the outcome of reducing the tensile strength.
- In a polymeric structure the provision of fiber reinforcement increase its modulus of elasticity or stiffness and toughness (Wright *et al*., 1997).
- The modulus of elasticity (*E*) is a measure of the stiffness, defined by the slope of the stress-strain curve linear segment before plastic deformation.
- According to that, a direct influence exists between the *E* and the stiffness, providing that the higher the *E,* the stiffer the material will be.
- The greater the *E*, the less the elastic deformation will be as a resultant of the stress application.
- Toughness is the ability of a material to absorb energy and have the capacity to plastically deform without fracturing (Callister, 1991). Some investigations have been focused on the effects of fracture toughness and *E* on FRCs.
- One of them found that the *E* of particulate reinforced composites increases when cross-sectional designs included 1 or more fiber reinforcements located at the compression side (Dyer et al 2005).[4]

ADHESIVE INTERFACE:

- The adhesive interface transfers the load from the polymer matrix to the reinforcing fibers, which positions this interface as a key aspect for the durability of FRCs (Bouillaguet *et al*., 2006).
- A chemical bond is achieved between the polymer matrix and the exposed glass fibers due to the use of silane coupling agents.
- The abilities of silanes to enhance the surface wettability of the glass fibers, resulting in chemical bridges formation and an increased physical attachment of the resin to the surface of glass have been reported in some studies. (Goracci *et al*., 2005).
- Some other aspects have an effect on the durability of FRC restorations, for instance, the properties of the fibers; resin matrix; the quantity of fibers; the direction, orientation, distribution, construction and position of the fibers and the impregnation of the fibers with the resin (Pensler *etal*., 1997).
- Two types of resins are used in FRCs, forming a cross-linked (thermoset) Polymer matrix, or a linear (thermoplastic) polymer matrix. Multifunctional or dimethacrylate resins are involved in the formation of the cross-linked matrix, contrary to the non-crosslinked polymer matrix where monofunctional methacrylates are included (Väkipartaet *al*., 2007).
- A combination of thermoset and thermoplastic resins has been used as impregnation methods. In this case, the polymer matrix is a semi-interpenetrating polymer network (semi-IPN), where a cross-linked polymer and a linear polymer are merged(Kallio *et al*., 2001). [6]
- Cross-linked polymer matrix results in FRCs with higher modulus of elasticity than the achieved by thermoplastic or semi-IPN polymers (Lassila *et al*.,2002).
- Additionally, higher toughness is one of the advantages that thermoplastic and semi-IPN polymer matrices contribute over FRCs manufactured from highly cross-linked thermosets.
- The semi-IPN polymer matrix of FRC provides some benefits over crosslinked dimethacrylate regarding its handling properties and the adhesion of indirectly made restorations to resin luting cements and veneering composites (Kallio *et al*., 2001).Polyethylene (PE), polyetheretherketone (PEEK), polyacetal (PA), and polyurethane (PU) are examples of thermoplastics that are used in medical applications of thermosets are epoxy polymer, bis-GMA, and TEGDMA copolymer (Tuusa *et al*.,2007).

Rule of Mixtures

- In prosthodontic applications, the two most important mechanical properties for FRCs are strength and stiffness. The modulus of elasticity refers to stiffness or rigidity of the material.
- For fiber-reinforced FPD frameworks a high modulus is necessary because they must support the more brittle overlying restorative composite. This situation is comparable to metal frameworks supporting porcelain in a metal-ceramic prosthesis.
- In an ideal unidirectional FRC, the modulus as well as the strength in the fiber direction is proportional to the volume and individual properties of the fiber and the matrix. This relationship is known as the rule of mixtures.[2]
- The rigidity and strength of a unidirectional fiber composite are significantly dependent on the properties and volume of the fiber as the properties of the fiber are generally much greater than those of the matrix,
- Large volumes of high-strength unidirectional fibers are desirable when the highest mechanical properties are desired in a single direction, as in a post or in the pontic region of an FPD framework,
- Areas where esthetics may not be of concern, carbon fibers may be used. Glass fibers are generally preferred where translucency is required along with good mechanical properties.
- Fiber volumes are generally limited to less than 50% because of the necessity of having all fibers fully wetted by the resin. Classic pre-impregnated unidirectional dental fiber composites incorporating approximately 45% glass fibers have a flexure modulus in the range of 28 to 34 GPa and flexure strengths of about 600 to 1,000 MPa.

- These values are about 10 times greater than those for dental resin alone, and they represent the primary mechanical benefit of using fiber reinforcement in dentistry.

How FRC Materials Work

- Several parameters influence the mechanical performance of FRC. Increasing fiber volume leads to a greater increase in mechanical strength. The fiber architecture: unidirectional fibers long, continuous, and parallel followed by braided and woven fibers also increase flexural strength b van Hueman.[4]
- Typically, fibers are 7 to 10 µm in diameter and span the length of the prosthesis or appliance whereas the size of the particles used in standard restorative dental composites are 1 to 5 µm in diameter, or submicron in size.
- Glass fibers of various kinds are commonly used in dental laboratory products, while polymeric reinforcements, such as ultra high molecular weight polyethylene, are often used for chair-side applications. Posts are made of carbon or glass fibers.

• Woven fiber has lesser flexural strength and is less technique-sensitive, and easy to manipulate thus conforming to the desired shape and maintains its adaptation during placement and is the ideal choice while making an appliance for rotated or malpositioned teeth.

• Unidirectional fiber has greater flexure strength and rigidity and is the better choice for high stress situations as in prosthodontic frameworks.[4]

The Two Approaches have Evolved Namely Non-Impregnated and Pre-Impregnated

Non Impregnated :

Non-impregnated are the fibers that needs to be wetted with an unfilled fourth or fifth generation bonding resin at chairside. A partially filled bonding resin is not recommended to wet the Ribbond as they are more viscous and hence are not self wetting. While it provides complete wetting, this approach can be cumbersome, requires an additional step in the procedure and displays limited service as splints. However, this method can be considered versatile.

Pre-Impregnated Fibers :

- Clinical longevity of non-impregnated fibers is compromised as it lack good adhesion between the fiber and resin matrix compromising and freshly drawn glass fibers exhibit higher strength than ordinary glass fibers but are rapidly degraded on exposure to moisture and humidity.[4]
- As these fibers with resin maintains the high strength values if coated immediately, the concept of pre-impregnation of glass fibers evolved (Splint-it). This procedure is accomplished by pre-impregnating the fiber bundles with resin during the manufacturing process.
- Pretreatment of glass fibers are done with organo-silanes and polyethylene fibers are subjected to cold gas plasma treatment to increase their wettability and chemical bond. E-glass and S-glass are two types of glass fibers of which E-glass is employed in dental materials. Another type used is C-glass mainly used in chemical applications that requires greater corrosion resistance to acids than is provided by E-glass.

IMPREGNATION OF FIBERS:

- Resin impregnation allows an optimal reinforcement and transfer of stresses from the polymer matrix to the reinforcing fibers (Vallittu, 1998b).
- Effective impregnation is a requirement to achieve a good contact between the matrix and each fiber, which isoften performed using various monomers. Some of these monomers are bis-GMA,UDMA, urethane tetramethacrylate (UTMA), poly(methylmethacrylate) (PMMA) ortriethylene glycol dimethacrylate (TEGDMA) (Lastumäki *et al*., 2003).
- The use of only monomers for the impregnation of fibers brings as a consequence a high polymerization shrinkage, which may affect the mechanical properties of the FRC (Vallittu, 1996).
- Then, pre-impregnated FRC systems have been developed, which facilitates the handling properties.
- Deficiencies in the impregnation of fibers increase the water sorption in FRC, reducing their strength and modulus of elasticity (Miettinen *et al*., 1999).
- The use of high viscosity resin systems and the polymerization shrinkage of the resin can have as consequence an inadequate degree of impregnation of fibers (Vallittu 1995a; Vallittu 1995b).
- This enhances water sorption through voids leading to decreased mechanical properties of FRC (Miettinen & Vallittu, 1997). In addition, voids originated due to poorly impregnated fibers serve as oxygen reservoirs that inhibit the radical polymerization of the polymer matrix (Vallittu, 1999).
- Pre-impregnated FRCs also show good mechanical properties due to the reduction in voids and cracks in its composition, which can limit water sorption. Water sorption due to poor impregnation can have detrimental consequences in the bond strength and lead to hydrolytic degradation of polysiloxane network of FRC (Miettinen & Vallittu, 1997).[5]

PROPERTIES OF FIBRE REINFORCED COMPOSITE

Water sorption:

- Water sorption of a material includes water absorbed into the body and water adsorbed on the surface of the material during preparation and while the material is in service.
- Poly (methyl methacrylate) absorbs water because of the polarity of the water molecule and because it is smaller than the inter chain distance in the polymer.
- The volume of water uptake by a polymeric material is determined by polymer structure, content of various polar and hydrophilic groups in the polymer structure, temperature, concentration of various additives, presence of voids within the matrix, Physicochemical and mechanical properties can be affected by absorbed water.[5]

Flexure Strength:

- These materials are often tested in the laboratory, although the mode of failure and many other properties affect clinical performance.
- Investigators accentuate the importance of fatigue and fracture toughness in predicting clinical performance of several classes of dental materials, including fibre composites.
- It is important to note that test methods, procedures for preparing the samples, and, in particular, the geometry of the test specimens all affect the calculated flexure strength.
- Flexure strength for commercial laboratory–processed fibre-reinforced composites may range from approximately 300 to 1,000 MPa, depending on the specimen preparation and geometry.

Fracture toughness:

- The fracture toughness of a material reflects the resistance of a material to fracture and represents the energy required to propagate a crack through the material to complete fracture.

- Fracture toughness of polymer composites depends on the type of polymer and reinforcement. Fracture toughness of a monomethacrylate-based material is lower than in a dimethacrylate-based material.
- Generally, “intrinsic” physical aging and/or storage in a humid environment at elevated temperatures can decrease fracture toughness, as well as other mechanical properties. However, an increase in fracture toughness can be achieved by adding reinforcing fibres to a polymer to prevent or slow down crack growth.[5]

Linear coefficient of thermal expansion:

- The variation of the coefficient of thermal expansion between different materials is important because a mismatch can lead to strains, resulting in stress formation and adverse effects on the interface.
- Therefore, thermally induced strains and stresses adversely affect long-term stability of intraoral multiphase materials. By adding fibres to a polymer, the coefficient of thermal expansion decreases.
- Usually, the thermal coefficient varies with the direction of the fibres. The matrix is forced to expand in the transverse direction as in a composite rigid fibres appear to prevent expansion of the matrix in the longitudinal direction.
- One of the major concerns in the development of dental materials is physical and chemical durability.

BIOCOMPATIBILITY

Solubility:

- Stabilizers, plasticizers, monomers, residuals of initiators and degradation products are the components that may be released into the oral environment over time.
- Therefore, the amount of such components should be as small as possible to ensure that no components adversely influence biocompatibility and the polymer retains its characteristic properties.

Residual monomer:

- Biological features, as well as mechanical properties, of polymeric materials are highly influenced by the monomer-polymer conversion.
- Residual monomer will alter the property and may leach out to pulp if a protective layer of base is not given.[5]

Cytotoxicity:

- Some substances released from materials are cytotoxic and residual monomers leached out into the oral environment may induce toxic and allergic reactions.

Polymerization shrinkage:

- The increased awareness among clinicians to protect and reinforce the remaining sound tooth structure and gradual improvement in adhesive systems resulted in the increased use of particulate filler composite resin materials (PRFC) both at the anterior and posterior regions.
- Despite the continuous improvement through modifications in formulation, polymerization shrinkage seems to be a problem for the PRFC.

Various steps have been undertaken to evaluate and improve restorative composite resin against wear and lower the polymerization shrinkage. Attempts have been made to change type and size of filler and their silanization. Also attempts to change the polymerization kinetics of resins and to influence to degree of monomer conversion. Reinforcing the resin with glass fibres with fibre-reinforced composite (FRC) substructure and optimization of filler content are among the methods that have been studied.

THE MATRIX IN FRCS

- The fibers in the composite structure are held together by the polymeric plastic matrix composed of polymerised monomers. It protects the fibers from the external environment such as moisture, chemicals and mechanical shocks and transfers stresses between fibers.
- Therefore the matrix may have an impact on the compressive strength, interlaminar shear and in-plate shear properties, interaction between the matrix and the fiber and defects in the composite. [6]
- Two types of resins namely the cross-linked or linear, are used in FRCs. The cross-linking polymer referring to multifunctional or dimethacrylate resins is also called a thermoset polymer. The linear polymer referring to monofunctional methacrylate polymers is also called a thermoplastic polymer.
- The matrix consists of a cross-linking polymer, a linear polymer and a photo-initiator with an interpenetrating polymer network (IPN) structure in FRCs. Polymerization reactions and cross-linking reactions are the setting reactions in the resin matrix. Sequential addition of monomeric units leading to the formation of a polymer by is a polymerization reaction.
- Addition (including free-radical addition polymerisation) and condensation polymerizations are the main polymerization reactions. The cross-linking reaction in a polymer is the formation of a cross-link where chains are bonded together either through direct connection or an intermediary atom, ion, molecule or chain. This produces a 3D strongly cross-linked system.

FIBER:

- A fiber may be described as an elongated uniform material with a more or less equiaxed and uniform transverse cross sectional diameter or thickness less than 250 μm, and with an aspect ratio, i.e. length to cross-sectional diameter or thickness ratio, which is usually greater than about 100.
- However, in some cases, such as short fibers, chopped fibers, or staple fibers, the fibers’ aspect ratio can be smaller than 100.

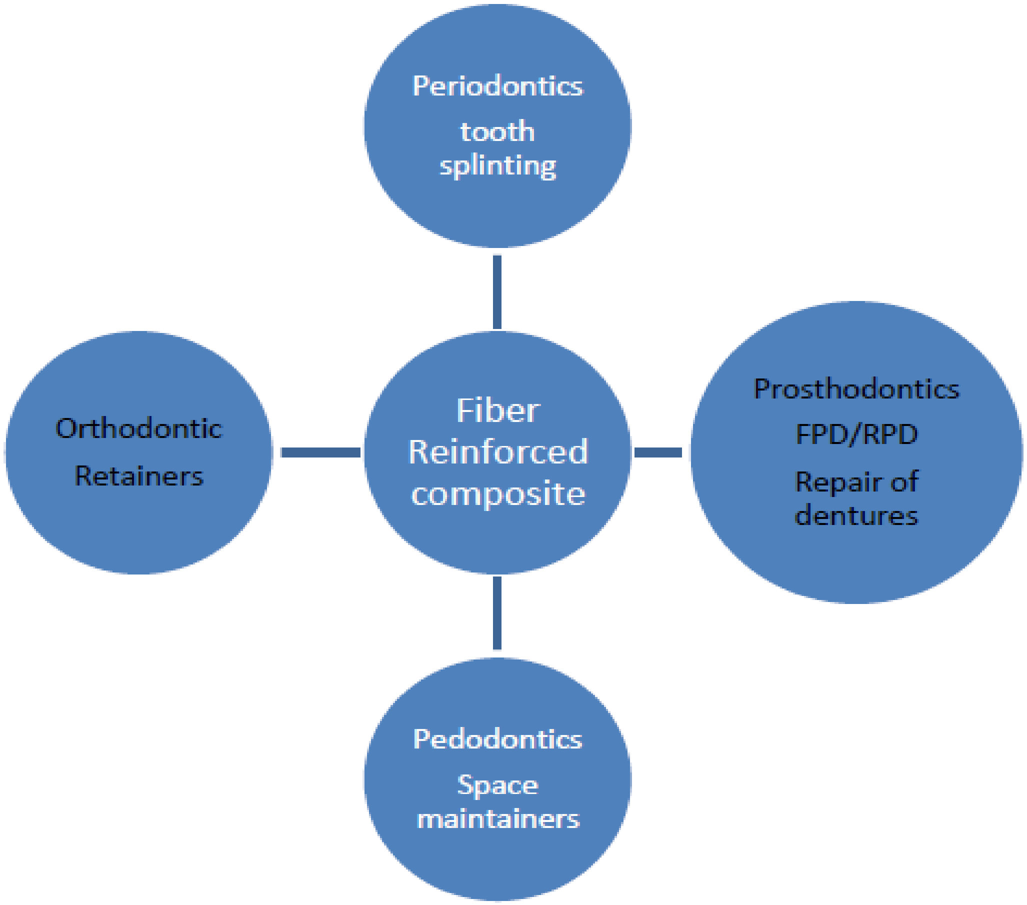
- For the reinforcement and clinical success the fiber orientation, content, distribution and the ability to maintain these parameters are significant.
- The type, length, orientation and volume fraction of the fiber influence the following properties of the FRC: their tensile strength and modulus, compressive strength and modulus, fatigue strength and fatigue failure mechanism, density, electrical and thermal conductivity, and finally their cost. [6]
- Glass, polyester, polyethylene, carbon/graphite, aramid, quartz and ceramic fibers are the commonly used fibers.

ADHESION BETWEEN FIBER AND MATRIX

- Silanes are hybrid inorganic-organic chemical compound in which a carbon is directly attached to silicon, eg. ≡Si–C≡. These silicon esters are used as coupling agents in silanization treatment, often called as silanation. This refers to bonding of dissimilar matrices together with surface treatment.
- Preimpregnation means that the fibers are impregnated with the matrix resin before further steps in the fabrication of the final restoration in dentistry. Highly porous linear polymers are used to preimpregnate the fibers as described in of the current preimpregnation based fiber reinforcement system.
- This is why the high-viscous denture base resin is subjected to further impregnation.
- The use of natural rubber and thereafter synthetic polymers as denture base polymers had already started in the 1860s.
- With the introduction of crosslinking thermoset monomers in dentistry by Bowen, crosslinking dimethacrylate monomers became available also for monomer liquids of denture base resins and, thus, in multiphase denture base polymers—the start of the use of interpenetrating polymer network (IPN)-like structures in dentistry.
- As a concept, an IPN is a combination of two or more polymers in network form that are synthesized injuxta position. IPNs are composed of finely divided phaseswith a thickness of approximately 5–10 nm.[6]
- They differ from polymer blends which are rougher in structure, and also differ from copolymers which are based on chemical reactions of monomer units and polymer backbones.
- Several adhesive interfaces between natural and synthetic biomaterials and adhesive resins by means of primers or coupling agents can also be considered as IPNs.

- Some other interfaces are a dentine bonding hybrid layer, silane promoted adhesive interphases between metal and ceramics and adhesive resins.
- On the other hand, the so-called semi-IPN refers to the impregnation methods based on using a combination of thermoset and thermoplastic types of resins. Here, the polymer matrix is a multiphase material.
- The semi-IPN is formed during the polymerization of the dimethacrylate monomers with a swelled linear polymer, PMMA.
- In addition to the above methods, plasma-etching has also been applied to enhance polyalkanefiber's adhesion to the matrix.
- It is also noteworthy that durable adhesion between fiber and matrix provides good load transfer between the two, which ensures that the load is transferred to the stronger fiber and this is how the fiber works as a reinforcement.
- Hardness is a surface phenomenon influenced by yield strength, true tensile strength, work hardening, elastic modulus and so on.
- Brinell, Vickers, Knoop, Rockwell, Rockwell superficial and Shore scleroscope are various standard testing methods for hardness.
- Flexural strength refers to the maximum stress and strain at the surface of the specimen and a measure of the stiffness during the first or initial step of bending a body (material) is flexural modulus.
- It is calculated according to an ASTM D-790 standard: mathematically it is the slope of the initial straight line portion on the stress–strain curve.
- In laboratory experiments, several factors have effects on the flexural properties. Previous research shows that thermo-cycling, the brand of the FRC material and diameter of the specimen may have a significant effect ($p<0.001$) on flexural strength of FRC root canal posts. Furthermore, fatigue strength refers to the stress that causes failure after some specified number of loading cycles.
- In the aspect of fatigue strength, FRCs are considerably stronger than typical cast metal alloys used in dentistry.
- In clinical use, biomechanical properties of dental materials vary depending on which application the material is utilized. For instance, in a direct fibre-reinforced resin-bonded dental bridge, the weakest region exists across the pontic–abutment interface.

THE CLINICAL APPLICATIONS OF FIBER REINFORCED COMPOSITES IN ALL SPECIALTIES OF DENTISTRY[5]



VERSATILITY OF FRC IN VARIOUS DENTAL SPECIALITIES

- The properties of fibre-reinforced composites (FRCs) that make them well suited for various clinical applications include strength; desirable aesthetic characteristics; ease of adaptability to various shapes; and potential for direct bonding to tooth structure.

Restoration:

- Modern adhesives successfully bond to tooth tissue in the short as shown in laboratory reports. Adhesives that provide strong and durable bonding to the remaining sound enamel and dentin ensures restoring teeth with minimal loss of sound tooth structure.

- Marginal deterioration of composite restorations remains major disadvantage in the long term and still is the major reason to replace adhesive restorations clinically.

- The initial and residual polymerization stresses that are present along the cavity walls may result in gap formation, leakage, recurrent caries and pulp irritation when resin composite is bonded to tooth structure.

- Along with aesthetics, the physical properties of restorative material should also be considered for long-lasting restoration. Fibre reinforcement has been introduced as a newer technique with the aim of improving the physical properties of composite materials.

- High fracture resistance of the restorative material is required in the clinical situations where the high impact stresses are experienced and incisal angle restoration is one such demand.

- Attempts have been made to improve the fracture resistance of restoration by using different bonding agents, adhesive resins and different restorative techniques using fibre reinforced technique.[7]

CLINICAL APPLICATIONS IN CONSERVATIVE DENTISTRY

- The applications of FRCs in conservative dentistry mainly consist of direct composite restorations. The advantages of the use of FRCs over conventional filling materials are related to their biomimetic properties.

- In fact, the dental restorations ideally would be as minimally invasive as possible and substitute the missing hard dental tissues resembling mechanical features and properties of natural teeth.

- Research has shown that the FRC substructure supports the composite restoration and acts as a crack-prevention layer when a bilayered approach has been proposed in which lost dentin is replaced by though short FRCs and enamel by surface layer of particulate filler composite resin in dental restorations.

- In addition, FRCs have been reported to have superior physical properties and fracture toughness compared to unreinforced composites and depth of cure and polymerization shrinkage of FRCs have been reported to be superior to conventional resin composites.

- On the other hand, bilayered biomimetic technique is recommended for direct coronal restorations of teeth with large cavities in high stress-bearing areas.[7]

CLINICAL APPLICATIONS IN ENDODONTICS

- The use of FRCs in endodontics is mainly reported as root canal anchoring system. Research on both prefabricated and individualized FRC posts demonstrated that root canal walls restored with individually formed FRC posts displayed higher fracture resistance than those restored with only resin composite.

- FRC posts both used in combination with self-adhesive and glass ionomer cements showed promising bond strength to flared root canal dentin and FRCs achieved better performances, even in combination with bulk fill resin composite.

- Mechanical properties of posts significantly decreased when compared with values at baseline after aging as shown in various studies.

- Special considerations should be taken while bonding of luting cement and core-built-up composite to FRC post: only FRC post with interpenetrating polymer network containing polymer matrix can provide reliable bonding to resin luting cements and resin based materials in general.

- Generally, FRCs present limited radio-opacity due to the low concentration of radio-opaque elements. This shortcoming of E-glass fiber would limit its application in dentistry as sufficient radio opacity is highly desirable for dental materials.

- The addition of synthesized iodine containing a new methacrylate monomer HMTIB has been tested to increase the radio opacity of FRCs with the results showing that FRCs present higher radiopacity than natural tooth enamel.

- Finally, in the field of endodontics, FRCs showed excellent integration with other new technologies such as laser applications and CAD/CAM.[7]

Endodontic Fibre Reinforced Composite Posts:

- FRC posts are a recent addition to the systems traditionally used to retain a core in severely broken down, endodontically treated teeth: custom-made metal or cast posts and cores and prefabricated metal and zirconium posts.

- The FRC posts offer greater flexure and fatigue strength, a modulus of elasticity close to that of dentin, the ability to form a single bonded complex within the root canal for a unified root post complex, and improved aesthetics when used with all-ceramic or FRC crowns as compared to custom-made cast or metal-prefabricated posts.

- The properties of this post design have the potential to reinforce a compromised root and to distribute stress more uniformly on loading to prevent root fracture moreover, the FRC post will yield prior to catastrophic root failure better than will custom- made cast metal or prefabricated metal post systems.

- Two categories of FRC posts are available: chair side-fabricated and prefabricated. Chair side fabricated posts are custom designs that use polyethylene non pre-impregnated woven fibres (Ribbond, Connect) or glass fibres (Glass Span) to reinforce the root and hold a composite core.

- Prefabricated posts are constructed of two kinds of fibre: carbon fibres embedded in an epoxy matrix (C-Post, U-M CPost, and Aestheti-Post) and S-type glass fibres embedded in a filled resin matrix (FibreKor Post).

- Fibre-reinforced composite posts consist of a resin matrix, in which structural reinforcing carbon fibres or quartz/glass fibres are embedded.

- Black carbon fibre-reinforced composite posts are, on the one hand, poorly suited for combination with translucent full ceramic restorations due to their unfavourable optical properties. On the other hand, carbon fibre posts also have unfavourable biomechanical properties.[7]

CLINICAL APPLICATIONS IN PROSTHODONTICS

- The main application of FRCs in dentistry is related to provisional or definitive prosthodontics. By using FRCs, FDPs and veneers can be realized in a minimal invasive fashion, utilizing combinations of various kinds of adhering and retentive elements.
- A resin bonded FRC prosthesis may contain inlays/onlays, surface bonding wings, and crowns. Direct and indirect frameworks can be made also immediately after extraction of tooth [Cramer et al., 2011].
- FRC FDPs could be fabricated as surface-retained, inlay-retained, or full coverage crown retained prostheses.
- The fabrication could be realized directly in the mouth or can include prefabricated pontics, simplifying the fabrication technique and providing more predictable outcomes.

The results of mechanical and adhesion properties of FRC frameworks appear to be encouraging. In addition, FRCs can be used in the repair of existing conventional prosthetic devices. Repairs of veneers of porcelain-fused-to-metal restorations with resin composite veneers can be made using woven glass fiber reinforcement, thus increasing the strength of the repair. In addition, removable devices could be reinforced using FRCs. Finally, FRCs can be used in indirect pontic fabrication, also in combination with CAD/CAM based technologies.[7]

Conservative treatment of missing tooth replacement:

- Chair side tooth replacement is an excellent application for fibre reinforcement composite technology. [2]
- Previous attempts at chair side tooth replacement involved the use of pontics derived from extracted teeth, acrylic resin denture teeth with or without lingual wire reinforcement, and resin composite.
- These were attached to abutment teeth with acid-etched bonded particulate composite. The abutment teeth used for these approaches were usually not prepared; most often, tooth replacement was only for the anterior region and the procedure was considered a short-term solution.

- The chair side fibre reinforced composite prosthesis offers a fast, minimally invasive approach for tooth replacement that combines all of the benefits of the fibre reinforced composite material for an esthetic, functional, and potentially durable result.
- A denture tooth or a natural tooth (in the case of an extraction of a periodontally involved incisor) can be used as the pontic.

Selection criteria for this tooth replacement approach include:

1. A patient who desires an immediate, minimally invasive approach
2. A patient who requires an extraction in an esthetic area and desires an immediate replacement
3. Abutment teeth with a questionable long term prognosis
4. Anterior disarticulation during mandibular protrusive movements
5. A non-bruxing patient
6. Cost considerations [2]

Repair of Acrylic Resin Prosthesis

- Both unidirectional and woven light-polymerized FRC strips can be used effectively for chair side repairs of fractured acrylic resin prostheses. As mentioned earlier, FibreKor (Jeneric/ Pentron) and Vectris (Ivoclar/ Williams) are unidirectional materials available for laboratory use.
- Splint-It (Jeneric/Pentron), another chairside material, is available either as a unidirectional or a woven fibre. All of these materials have significantly greater flexural properties than unreinforced resin.
- Woven FRC has a shorter memory than unidirectional FRC, which makes it easier to handle; however, unidirectional FRC has superior flexural properties and will likely provide a stronger repair.

Indications for Chair side Repairs with Light-polymerized FRC

Virtually any acrylic resin prosthesis or appliance can be repaired with light-polymerized FRC:

1. Complete dentures
2. Acrylic bases of partial dentures
3. Provisional removable partial dentures
4. Provisional FPDs
5. Obturators
6. Palatal lift appliances
7. Orthodontic retainers
8. Occlusal splints and night guards[4]

CLINICAL APPLICATIONS IN PERIODONTOLOGY

- Periodontal or posttraumatic FRC splints have been reported in clinical periodontology. Splints are used to stabilize teeth, which have become loose as a result of supporting bone loss as a consequence of periodontal disease.
- The main advantage of stabilization splints is the reduction of tooth mobility. FRC periodontal or posttraumatic splints have been reported to have reliable long term stability.
- In fact, fiber reinforced frameworks showed higher flexural forces when compared with conventional metallic wires.
- Moreover, FRC splints showed high flexural resistance also when polymerized directly with polymerization lamp without laboratory oven post polymerization, thus reducing the number of clinical steps and number of appointments for the patients.
- The common failure types are debonding and fractures. In fact, the splinting with FRC materials of periodontally compromised teeth that have different mobility grade is prone to debonding, with the mobility grade as main causative factor.
- However, FRC splints can be easily repaired, so in many cases it is not necessary to completely debond the framework with the substitution with a new one.[7]

Tooth Stabilization and Splints:

- Fibre reinforced composite materials are an excellent choice for the stabilization of mobile teeth due to periodontal reason or due to any trauma.
- Chair side-fabricated fixed splints have previously been made from material combinations that have included resin composites, wire, wire mesh, wire embedded in amalgam and resin and fibre mesh embedded in composite.
- All of these materials suffered from various problems like Poor handling characteristics, Over bulking ,Insufficient bonding of the internal structural materials to the dental resins, Poor esthetic outcome, Fibre splints overcome these drawbacks and provide ease in tooth splinting. Splinting can be done on palatal/lingual surfaces, labial surface or both the surfaces.[4]

CLINICAL APPLICATIONS IN ORTHODONTICS

- The main use of FRCs in clinical orthodontics is as fixed retention. After orthodontic treatment, the need for maintaining the teeth in correct position is crucial for long term stability of clinical results.
- These bonded retainers appear to be both relatively independent of patient cooperation and well accepted by patients.
- Bond strength is reported to be sufficient both on enamel and on dentin. Clinical reliability is also reported to be successful for moderate time.
- A great advantage of FRC splints over conventional metallic retention is aesthetics. Fibers are barely invisible and do not affect the translucency of teeth [Karaman et al., 2002]. This aspect is important, considering the higher number of adult patients who request an orthodontic therapy.
- Finally, FRCs are metal-free and are indicated for adult and young patients screened by Nuclear Magnetic Resonance or in subjects allergic to metals. On the other hand, FRC splints are more rigid than conventional metallic splints, thus leading to a higher ankyloses risk of teeth involved.

- However, the application of FRC with a spot-bonding technique has been proposed, in order to reduce framework rigidity, thus allowing physiologic tooth movement.
- Clinical success of FRC resins has been reported also for space maintainer purpose. The early loss of deciduous molars is a frequently encountered problem in dentistry and, if untreated, it could evolve in various orthodontic problems. Space maintainers are developed to prevent the loss of the space.
- FRC space maintainers can be prepared on plaster models of patients and fixed directly to the adjacent teeth. In addition to stabilization uses, in orthodontics, FRCs have been proposed also for active tooth movement. [4]
- Groups of two or more teeth can be splinted with FRCs and moved "en masse" with sectional mechanics. One other application of FRCs has been proposed as innovative materials for fabrication of brackets and wires; yet only a few research papers have been conducted on the topic.

Applications of fibre reinforced composite in orthodontic practice

1. Fixed orthodontic retention appliance
2. Fixed space maintainer
3. Temporary esthetic retention appliance
4. Posttraumatic stabilization splint [7]

CLINICAL APPLICATIONS IN ORAL AND MAXILLOFACIAL SURGERY

- The use of FRCs has been recently reported also in oral and maxillofacial surgery. These materials can be applied in oral implantology for bone replacing and bone anchoring implants.

- The rationale for this application is that, although metal implants have successfully been used for decades, devices made out of metals do not meet all clinical requirements.

- Metal objects may interfere with some medical imaging systems, while their stiffness also differs from natural bone and may cause stress shielding and overloading of bone.

- Glass fibers are responsible for the load-bearing capacity of the implant, while the dissolution of bioactive glass particles supports bone bonding and provides antimicrobial properties for the implant.

- Moreover, FRCs materials can be used in maxillofacial discipline for orbital floor implants, cranioplasty implants, and craniofacial bone reconstruction.[7]

CLINICAL APPLICATIONS IN PAEDIATRIC DENTISTRY

- In paediatric dentistry FRCs can be used in almost all the fields as described above: restorations, space maintainers, splints, or other frameworks. The main difference is that the enamel of primary teeth is significantly different compared to permanent enamel.

- The differences have been mainly detected in composition, mechanical characteristics, bond strength, and clinical performance. However, the FRC devices used in paediatric dentistry showed acceptable clinical performance, durability, and ease of use.[7]

CLINICAL USE OF DENTAL FRCS AS FILLING RESIN COMPOSITES (POSTERIOR BULK FILLING MATERIAL)

- Although amalgam has shown its many benefits as dental restorative material its use is ending due to environmental reasons. Direct resin composite restorations are used used for the treatment of damaged tooth structure allowing high cost-effect ratio for the treatment outcome.

- Particulate filler resin composites have fulfilled direct application requirements in terms of material cost but often failed in terms of longevity of restorations made by general practitioners.

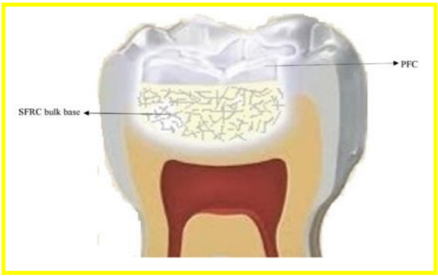
- One reason for the limited longevity of restorations is low mechanical strength of the particulate filler resin composite as material and inadequately adjusted occlusion, which can cause high local stress concentrations and damage the restoration.

- Resin composite restorations and ceramic restorations do not become adjusted to the occlusion like amalgam restorations did during long lasting setting reaction. Occlusal adjustments of the resin composite and ceramic restorations must be made by the dentist with high precision.

- Utilization of reinforcing fibers in filling composites to toughen the material has been tested for years but not until recently, the reinforcing effect by fibers has been proved.
- Reasons for the poor success of previous FRC filling materials have been of selecting of too short discontinuous fibers, which were not even in theory able to increase strength and toughness of the resin composite.
- The current concept of using FRC in fillings is based on the bilayered composite system in which FRC base is made of discontinous fibers with length of the fibers exceeding the critical fiber length in the dimethacrylate polymer matrix.
- Fibers in the FRC increase toughness and other physical properties of the material compared to regular filling composites.

The function of the FRC base for filling composites is to provide a crack propagation prevention layer for the restoration. The occlusal surface of the FRC is covered with more polishable and wear resistant particulate filler resin composite. The bilayered resin composite structure is considered as a biomimetic restoration system by mimicking the fibrous structure of dentin-enamel complex.[8]

ever ***X Posterior***



Schematic representation of biomimetic (bilayered) posterior composite restoration.

Garoushi et al. J Invest Clin Dent. 2018.

- The failures of composite resins are due are typically due to secondary caries and bulk fractures of the composite. These relate to the material's properties; particulate filler composites are prone to crack propagation and therefore have low damage tolerance, causing bulk fractures to occur. On the other hand, particulate fillers keep the composite isotropic in terms of its many properties, including polymerisation shrinkage.

- Shrinkage causes gaps between the filling and the tooth and creates a predisposition to secondary caries. Research studies using FRCs in tooth filling applications have shown how the structure of a restored tooth can be more biomimetic. everX Posterior is a short fibre-reinforced composite which is used to replace tissue in damaged teeth, especially dentine.

- The fibres of the everX Posterior material simulate the collagen in the dentine and provide enhanced toughness for the restored tooth, while at the same time, the fibres also control and minimise polymerisation shrinkage.

- everX Posterior is used as a bilayered filling material, i.e. the outermost part of the filling, which simulates enamel, is made of high quality hybrid composite resin.[9]

A cross section of everStick glass fibers

Fibers in everX posterior stop crack propagation

(Vallittu PK. Flexural properties of acrylic polymers reinforced with unidirectional and woven glass fibres. J Prosthet Dent 1999;81:318-326.)

FIBER-REINFORCED COMPOSITE AS A POST AND CORE MATERIAL IN A PEDIATRIC DENTISTRY

- Management of fractured teeth have always presented a challenge to the dentists. Today, the predictability of root canal therapy states that it can retain almost indefinitely, even very badly broken teeth.

- One of the widely accepted techniques involving restoration of extensively carious or badly fractured teeth is the fabrication of a post and core, utilizing the root canal space for anchorage.

- Thus far, the only materials that have been available to the dentists for thisprocedure have been a variety of metallic alloys. Hard and unyielding, these metals haveto be cast in the precise shape of the prepared canals and cemented into place.[10]

- Today, materials are available, which eliminate all the intermediate steps, and control is rendered in the hands of the dentists, to fabricate on the chair, a resilient, esthetic and bonded post and core. One such material is fiber reinforced composites (FRCs).

- A recently developed bondable reinforcement fiber, Ribbond, (Ribbond THM, Ribbond Inc., Seattle, WA) is reported to be an alternative to conventional post materialsbecause of its aesthetic qualities, mechanical properties, and the neutral color of the reinforcing material.

- First introduced to the market in 1992, Ribbond consists of bondable, reinforced ultra-high-strength polyethylene fibers.

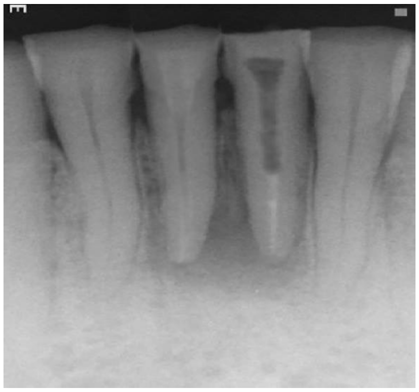
- The open and lace like architecture of Ribbond allows it to adapt closely to the teeth and dental arch. This is an advantage over prefabricated fiber posts where adaptability to root canals is difficult.

- Apart from this feature the Ribbond can be condensed properly in the canals with little microleakage. The application of a fiber layer increases the load bearing capacity of the restoration and prevents crack propagation from the restoration to the tooth.

- When prefabricated fiber post is placed in flexure, cracks appear on the tensile face and due to brittleness of the material rapidly propagates causing failure.[10]

STEPS INVOLVED IN THIS PROCEDURE ARE:

- The tooth should be adequately obturated and the canal space should be prepared.
- The use of Ribbond does not require additional tooth preparation as is required for metal posts.
- Isolation of the tooth using rubber dam, high suction evacuation with cotton rolls.
- Gutta percha to be removed using gutta percha solvent until the desired length for the post was achieved.



Radiograph showing post space

Source: Pic courtesy Acharya S. and Tandon S. srmjrds 2015

- The post hole shaped using gates glidden drills,cleaned with 5% sodium hypochlorite and dried.

- The width of Ribbond (Ribbond THM, 2, 3 or 4 mm, Ribbond Inc., Seattle WA) is decided on the root canal space available.

- The depth of the post space measured using a periodontal probe, and a 3mm wide Ribbond cut using special scissors provided with the kit (Ribbond starter kit, Ribbond THM, Seattle), measuring twice the depth of the post space and 3-4 times the height of the core build-up and placed in dual cure adhesive resin and set aside in light protected container.

- The root canal wall etched for 15 s, washed for 30 s and then gently air-dried.

- Excess water removed from the post space using paper points (Spident, SPI Dental Mfg. Inc., Korea).

- The dual cure adhesive resin (Ed Primer II A and B) applied using a microbrush in 2 consecutive coats and gently air-driedto evaporate the solvent.[10]

- Dual cure resin cement (Panavia F,Kuraray, Japan) is injected in the canal space.

- The Ribbond removed from the resin and the excess resin was removed using a hand instrument, folded in a V-shape and coated with dual-curing resin cement (Panavia, Kuraray MedicalInc., Japan).

- The piece of ribbon then placed in the postspace in a facial-lingual direction with an endodontic plugger.

- Excess resin cement removed, and the cement cured for 20s.

- The two protruding ends of the Ribbond strips formed the reinforcement for the core build-up to replace the lost coronal portion of the tooth.

- The remaining resin mix from the syringe extruded onto this framework to create a core resembling almost like the shape of a lower central incisor.
- The space between the protruding ribbon ends was filled with resin so as not to leave any voids.

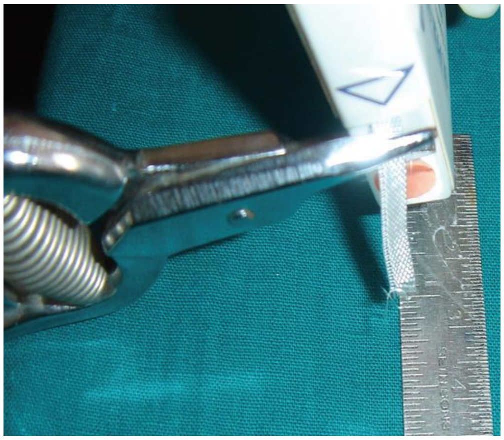
- Composite resin should also be placed so as to cover the ribbond ends completely and leave none of them exposed on the outer surface of the core.
- All the material thoroughly light cured to create a set surface.
- The material left in the mouth for a couple of hours to ensure complete set of the self curing component of the resin mix.
- The result of this procedure came out to be a single piece post and core, which was bonded onto the root, creating a solid structure without any wedging effect on the root. There were no voids and resin conforming to the inside shape of the canal space ensured that the fitting problems normally associated with cast posts were eliminated.**[10]**
- The bands of Ribbond reinforced the resin material and made it extremely strong and durable.
- The restorative procedure completed by building up the tooth using dual cure hybrid composite resin following technique of small progressive build up.
- If the development of occlusion is not completed a crown should be advised at a later stage when occlusion development is complete.

In recent times the number of endodontic procedures have increased with extremely good results and restoration of teeth after endodontic treatment is becoming an integral part of the restorative practice in dentistry even when the teeth have gross lesion. Fibre-reinforced composites emerges as a boon to the esthetic dentistry.

Fibre-reinforced composites have been used in pediatric dentistry in deciduous teeth for restoring grossly decayed tooth structure in patients with early childhood caries where restoring function and esthetics presents as a challenge. There are very few cases reported for permanent anterior teeth in pediatric patients but it has been used as a post and core material in a permanent tooth for a pediatric patient with satisfying esthetic results and improved mechanical properties.

Postspace preparation

Source: Pic courtesy Acharya S. and Tandon S. srmjrds 2015



Measured amount of Ribbond prepared

Ribbond prepared to be inserted in the canal

DIRECT FIBER-REINFORCED COMPOSITE RESTORATION IN AN ENDODONTICALLY-TREATED MOLAR

- The reconstruction of structurally compromised non-vital posterior teeth may represent one of the most challenging adhesive-based restorative procedures.

- Several factors may influence the longevity of direct fiber-reinforced resin composite restorations: endodontic procedures prior to post cementation, dentin and/or post surface treatments, selection of the appropriate post design and architecture, resin composite polymerization and layering techniques.

- Thus, different specialties, such as endodontics and restorative dentistry, should work as a team to improve the longevity of restorations.

- Endodontically, treated teeth are weakened because of a decrease in water content and loss of dentin. The decay process and/or tooth fracture may be responsible for the structural weakening of non-vital teeth; the tooth preparation required for adequate endodontic treatment may also contribute to the increased fragility.[11]

- After endodontic therapy, selecting the appropriate reconstruction for each non-vital tooth should be based on the remaining hard tooth structure, the number and thickness of the residual cavity walls, the position of the tooth in the arch and the load implied.

- Resin bonded composite (RBC) restorations showed a strengthening effect on the tooth structure, with fracture resistance similar to that of unaltered teeth. For many years, direct adhesive restorations have been used for anterior teeth with conservative endodontic access and intact marginal ridges.

- Posterior non-vital teeth with an intracoronal conservative access only have also been restored with direct RBC.

- Conversely, for many years, full coverage restorations have been indicated when the teeth are weakened by additional cavities on both the anterior and posterior area.

- With the use of improved adhesive systems in the last decade, clinicians started proposing alternative techniques to reconstruct severely damaged teeth; the main goal of the new build-up protocol is preservation and reinforcement of the remaining sound tooth structure.

- Although most of the coronal portion of the tooth is compromised, RBC restorations may serve to properly build-up anterior non-vital teeth by using adequate layering and curing techniques.

- RBC restorations are indicated in posterior teeth as long as sufficient tooth structure is preserved; more compromised teeth with missing marginal ridges and/or cusps may require placement of a post to gain additional retention of the core.

- Lately, prefabricated tooth-colored fiber posts have been introduced and have demonstrated advantages over conventional metal posts.[11]

- Though they are esthetic, bond to tooth structure and have a modulus of elasticity similar to dentin but prefabricated tooth-colored fiber posts require the dentin preparation to fit the canal space, thus further weakening the remaining tooth structure.

- Prefabricated posts are indicated for round post space; whereas, custom posts are required to closely adapt to the contours of wide root canals or oval-shaped canals.

- Lately, increasing interest has also been devoted to the use of direct ***Ultra High Molecular Weight Polyethylene (UHMWPE)*** custom fiber reinforced post systems.

- Being that they are bondable reinforcement fibers, ***UHMWPE posts*** adapt to the shape of the root canal; they are indicated for both round- and oval shaped canals. The risk of root perforation is eliminated as enlargement of the root canal space is not required.

- The following steps are from a article which reports on the three-year longevity of direct fiber-reinforced RBC restorations in a severely damaged, non-vital molar and discusses the benefits of UHMWPE posts. Procedure as described in the case report has been enumerated below with reference to the material used.[11]

STEPS INVOLVED IN THIS PROCEDURE ARE AS FOLLOWS:

- A rubber dam was placed and the existing temporary filling removed. A #12 and #14 coarse ball-shaped bur was used to rounden sharp angles. No bevels were placed on the occlusal, proximal or gingival surfaces.**[11]**

(***Source:*** Pic courtesy Delperi S. Operative dentistry2008;33:209-214.)

(***Source:*** Pic courtesy Delperi S. Operative dentistry2008;33:209-214.)

- Three to four millimetres of gutta-percha were removed from the mesio-buccal root canal. A sectional matrix was placed on the tooth and interproximal adaptation was secured using wooden wedges.

(***Source:*** Pic courtesy Delperi S. Operative dentistry2008;33:209-214.)

- Enamel and dentin were etched for 30 seconds using 35% phosphoric acid; etchant was removed, and the cavity was washed for 30 seconds with water spray, being careful to maintain a moist surface.

(***Source:*** Pic courtesy Delperi S. Operative dentistry2008;33:209-214.)

- A fifth generation 40% filled ethanol based adhesive system was placed in the preparation, gently air-thinned to evaporate solvent and light cured for 20 seconds at 800 mW/cm2 from the occlusal surface using an LED curing light.

- A particular composite placement technique was selected to build-up the restoration.**[11]** The combination of RBC wedge-shaped increments and the UHMWPE fiber-reinforcement system was considered to be of paramount importance to further reduce polymerization shrinkage, better support the RBC, reinforce the remaining tooth structure and reduce total composite volume mass An UHMWPE triaxial fiber (Ribbond) was selected, and the dental assistant started to manipulate it according to the manufacturer’s instructions.

- Triaxial fibers were wetted with an unfilled resin, excess resin was removed andthe fibers were completely covered with a B1 light cured flowable resin composite and placed in the central area of the restoration.

- UHMWPE triaxial fibers were folded and each end wasplaced into the root canal using a thin composite spatula.

- The fiber-resin complex and flowable resin composite were light cured at 800 mW/cm2 for 120seconds to assure complete polymerization of the fiber resin composite complex down into the canal.

A piece of Ribbond fiber was wetted with unfilled resin, covered with flowable composite and inserted into the mesial buccal canal

The enamel contour of the tooth was built-up using wedge shaped increments of PA and PS shades

(Source: Pic courtesy Delperi S. Operative dentistry2008; 33:209-214.)

- Vit-l-escence microhybrid RBC was considered the material of choice for restoring the non-vital teeth, because of its variety of enamel shades and excellent mechanical properties.

- In order to avoid microcrack formation on the remaining facial/palatal wall, the authors used a previously described technique, based on a combination of pulse and a progressive curing technique.

- The sectional matrix was burnished against the adjacent tooth. Tooth build-up was started using 2 mm triangular-shaped (wedge-shaped) gingivo-occlusal placed layers of amber (PA) and smoke (PS) enamel shades to reconstruct the proximal and facial surfaces.

- This uncured composite was condensed and sculptured against the cavosurface margins and sectional matrix; each increment was pulse cured for three seconds at 800 mW/cm2 to avoid micro-crack formation.

- Final polymerization of the PA and PS composite proximal and palatal/facial walls was then completed at 800mW/cm2 for 20 seconds.

Dentin stratification was performed placing A4 to A1 shades

The restoration was completed with the application of PF/PN shade to the final contour of the occlusal surface

(***Source:*** Pic courtesy Delperi S. Operative dentistry2008;33:209-214.)

- The enamel contour of the restoration was built-up, offering more reference to creating the correct occlusal anatomy.**[11]**
- Dentin stratification of the facial, palatal and proximal walls was initiated, placing 2 mm wedge-shaped increments of A3 RBC into each enamel wall, avoiding contact with fresh increments.

- Successive A4 and A3.5 increments were placed in the central area of the restoration surrounding the resin impregnated fiber composite system to increase the chroma, unnaturally reduced by previously using B1 flowable composite.

- Each dentin increment was cured using a progressive “curing through” technique(40 seconds at 800mW/cm2 through the facial and lingual walls instead of a conventional continuous irradiation mode of 20 seconds at 800mW/cm2 from the occlusal surface).

- At this point, the middle third of the dentin restoration was built-up using a combination of A2 and A1 resin composite. Enamel layers of PF or PN were applied to the final contour of the occlusal surface according to a successive cusp buildup technique.

- This final layer was pulse-cured for one second at 800 mW/cm2. A waiting period of three minutes was observed to allow for stress relief; the wedges and matrix were removed, along with the rubber dam; occlusion was checked and the restoration was finished using the Ultradent Composite Finishing Kit.

- The final polymerization cycle was completed by irradiating the restored tooth through the facial, palatal and occlusal surface, respectively, for 20 seconds at 800mW/cm2.

- Final polishing was performed using Jiffy polishing cups and points (Finale, Ultradent).[11]

The reconstruction of severely damaged non-vital teeth requires knowledge of both curing and adhesive techniques. Fiber-reinforced resin composite restorations allow for the utilization of conservative tooth preparation, preservation and reinforcement of sound tooth structure. Selection of the appropriate fiber-post design and architecture is paramount to achieving this goal.

The rigidity of traditional metal posts and novel ceramic posts is a major concern, because the rigidity may pose a risk of root fracture (Torbjörner et al 1996, Schmitter et al. 2007). A stiff post transmits the occlusal forces to the surrounding dentin. Tension stress at the apical regions of the post cause microscopic fatigue fractures, which, with time, may lead to macroscopic fractures of the root.

- There are two ways of reducing the tension stress that causes fatigue fracture of the root.

- The traditional approach is prolonging the post preparation of a stiff post. This principle, which is called the moment compensation principle, is in practice, very difficult and not always possible to carry out.

- Another current approach, called the modulus compensation principle, is to use a post material which is biomechanically more suitable, e.g. a post material which is strong enough but also flexible so that it can behave like tooth structure inside the root under the occlusal forces.

- The flexibility or stiffness of a material may be described by the so-called modulus of elasticity or elastic modulus (Young's modulus, E-modulus).

- The E-modulus is the constant that relates the stress and the strain in the linear elastic region where elastic deformation of a material occurs (Gutmann 1992, Van Noort 2002). A group of materials which offers stiffness equal to that of dentin, as well as high durability is the group of fibre-reinforced composites (FRC).**[11]**

FIBER REINFORCED COMPOSITE- FIXED FUNCTIONAL SPACE MAINTAINERS

- Premature loss of the primary teeth is a common occurrence in children. A space maintainer is the safest and effective method in preventing malocclusions pertaining to early loss of a primary tooth and is durable and economical.

- Among the various space maintainers used in pediatric dentistry, band and loop is the most commonly used fixed space maintainer.

- However, the construction of band and loop requires three steps, it involves a clinician as well as a laboratory technician, and therefore it is expensive.

- With the advances in the technology and materials, there is a need to search for an alternative to overcome various disadvantages of the band and loop space maintainer.

- Fiber-reinforced composite resin (FRCR) provides new opportunities to us in this regard. In addition to their mechanical properties, FRCR materials are now being used in many areas of dentistry due to their advantages, such as the possibility to be prepared by the dentist chairside, the number of visits are decreased, adherence to teeth structures by way of adhesive applications along with improved aesthetic properties.

- Fabrication of SMs with fiber reinforced composite (FRC) possesses the advantages of being easily manipulated and directly chair-side applied. Moreover, they are fixed, minimally invasive, aesthetic, readily repaired, reversible, biocompatible, and of relatively lower treatment costs. However, their longevity is still a controversial issue.

- Polyethylene fiber-reinforced composite used as a fixed space maintainer offers many advantages. FRC has an aesthetic appearance, is easily manipulated, can be quickly inserted in a single-visit procedure that requires no laboratory services, poses no risk of damage to abutment teeth and is easy to clean.

There are various designs and methods by which a space maintainer can be fabricated. They are as follows:

DESIGN 1: (CHAIR SIDE FABRICATION)

STEPS INVOLVED IN THE FABRICATION OF FRC SPACE MAINTAINER ARE AS FOLLOWS:

- Fabrication of a space maintainer resting on the buccal surfaces of the neighboring teeth.
- Maxillary and mandibular impressions are obtained with alginate and models have been obtained.
- Space spans on the models measured and recorded.
- Glass fiber material has been cut in required size and has been shaped on the model of each patient in accordance with the directions of the manufacturing company.

The following procedures to be carried out on abutment teeth:

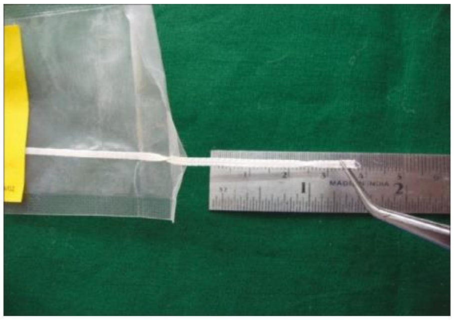
- Abutment teeth cleaned with non fluoride polishing paste.
- Isolation precautions are taken.
- Etching done with 37% phosphoric acid for 30 seconds (15 seconds for permanent teeth).
- Bonding agent (Prime & Bond NT; Dentsply International Inc., Milford, DE, USA) applied and scrubbed for 20 seconds and 10 seconds light applied for polymerization.
- Flowable composite (Flow Line; Heraeus Kulzer, Dormagen, Germany) applied to enamel surfaces.[12]
- Space maintainers that previously prepared are placed and then polymerized by applying light for 20 seconds. Here a halogen light device (Blue Swan; Dentanet, Ankara/Turkey) with light power of 800 mW/cm2 is used during the polymerization of both the bonding agent and the composite resin material.
- Polishing and final occlusion controls made.[12]

(***Source:*** Pic courtesy Tayab T and Srinivasan I.Dental Traumatology2011;27:159-162.)

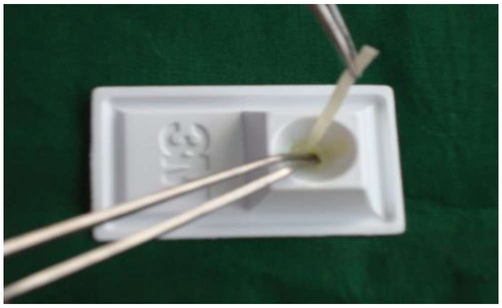
STEPS IN THE FABRICATION:

- The initial framework of FRC loop is constructed using a commercially available polyethylene fiber system (Ribbond, Inc., Seattle, WA, USA).

- Ribbond fiber of 40 mm length and 2 mm in breadth is wetted with unfilled adhesive resin (Adper™, Single Bond, 3M-ESPE, St. Paul, MN, USA) to formulate the loop, leaving 5 mm of fiber on each end for attachment to the abutment tooth[13]



2mm Ribbond fiber being utilized

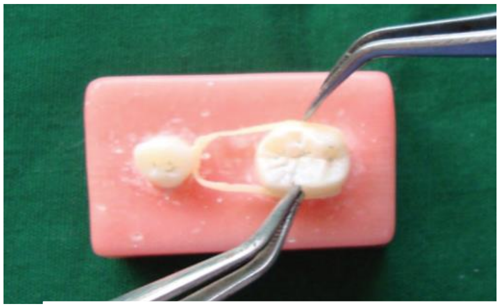


Ribbond being wetted with adhesive resin

(***Source:*** Pic courtesy Yeluri R and Munshi AK. Contemp Clin Dent 2012;3:S1:26-8.)

- A thin layer of restorative composite resin is added to the outer portion of the fiber, leaving 5 mm of the fiber on each end to provide initial rigidity, handling and adaptability to the unetched middle third of the buccal and lingual surface of the mounted molar tooth in acrylic as shown in the figure below.

Mounted teeth in acrylic to simulate the space



Wetted ribbond fiber being manipulated to form a loop

(***Source:*** Pic courtesy Yeluri R and Munshi AK. Contemp Clin Dent 2012;3:S1:26-8.)

- The assembly is then light cured for 40 seconds through its entire length. The loop is then detached from the tooth; restorative composite resin is added to the inner portion of the loop except the 5 mm of the fiber on each end and light cured for 40 seconds. The loop is then finished and polished with finishing burs and soflex discs.[13]

FRC LOOP AFTER FINISHING AND POLISHING

(***Source:*** Pic courtesy Yeluri R and Munshi AK. Contemp Clin Dent 2012;3:S1:26-8.)

- The buccal and lingual surfaces of the tooth are etched with phosphoric acid for 15 s, rinsed with water, dried, and bonding agent is applied and cured for 40 seconds.

- The loop is finally attached to the tooth using restorative composite resin followed by finishing and polishing.[13]

FRC LOOP AFTER FINISHING AND POLISHING

(***Source:*** Pic courtesy Yeluri R and Munshi AK. Contemp Clin Dent 2012;3:S1:26-8.)

Causes of failure of Fiber reinforced composite space maintainer:

- ➢ Debonding of fiber-composite interface
- ➢ Debonding of enamel-composite interface
- ➢ Fiber frame fracture
- ➢ Caries or gingival inflammation

CLINICAL SUCCESS OF FRC AS A SPACE MAINTAINER:

- Space maintainers made from FRCR material which are adhered to the surfaces of teeth have various advantages, such as biocompatibility, esthetics, ease of application, and fast preparation by the dentist or assistant in one appointment.
- The stabilization of abutment teeth via space maintainers in developing jaws is seen as one of the disadvantages of the method; however, the flexible nature of the fiber material decreases this effect.

- The FRCR space maintainers were fixed on primary teeth–primary teeth or primary teeth–permanent teeth.

- When such space maintainers are fixed on primary teeth, the prismless enamel surface structure of primary teeth may have negative effects on the retention of resin material.

- It has been stated in previous studies that space maintainers prepared similarly using fiber material are more stable when fixed on permanent teeth.

- Swaine and Wright have carried out a study during which they determined the failure rate as 18% in cases when primary teeth are used as abutment and as 60% in cases when application is made between primary and permanent teeth.

- Researchers think this is due to isolation problems in addition to the fact that polymerization light cannot reach the back region sufficiently.

- Researchers have suggested etching at the area to where space maintainers will be applied to decrease the external prismless layer of the enamel.**[14]**

- The failure rate of wire-composite space maintainers during the first 6 months varies between 4 and 30%, whereas the failure rate at the end of the first 6 months in our study is 2.3%, which is quite low.

- Studies during which the retention of FRCR space maintainers was compared for 12 months with those of band-loop space maintainers have indicated the success ratios as 53 and 33% respectively.

- ***Baroni et al.*** emphasize that occlusal stresses are more important for the long-term use of space maintainers instead of their design. Furthermore, in another study made by ***Kara et al.*** to compare the biomechanics of space maintainers, it is found that load distributions of band-loop, direct bonded, and fiber-reinforced space maintainers seem comparable.

- It has also been put forth that children mostly use the right side of the jaw when chewing and hence, space maintainers fixed to the right side of the jaw experience more occlusal stress and are thereby lost earlier.

- ***Kirzioğlu and Ertürkhave*** stated that the FRC space maintainers they placed to the right side of the arc are less successful in comparison with those placed to the left side.

- It has been determined during the study carried out by ***Subramaniam et al.*** that 46% of the space maintainers applied to the right side of the jaws are unsuccessful.

- On the contrary, ***Santos et al.*** have determined a high failure rate in the left maxilla region, whereas ***Kirzioğlu and Yilmaz,Baroni et al.*** have determined no statistically significant difference during their studies in which they compared wire-composite space maintainers placed to the right and left sides of the jaw.**[14]**

- Studies in the literature carried out in this topic are generally in the form of either a case report or the evaluation of a method. The number of studies examining the long-term success of such space maintainers is rare.

ANTERIOR FIBER-REINFORCED RIBBON COMPOSITE RESIN BRIDGE:

- Different therapeutic options can be considered for the replacement of a congenitally or traumatically missing permanent incisor in young children and adolescents. One of the greatest challenges that the dentist faces is the esthetic and functional rehabilitation of a missing anterior tooth.
- The procedure becomes difficult when the missing tooth cannot be replaced by an implant-supported prosthesis or a conventional fixed dental prosthesis due to a local bony defect, inadequate volume of bone in the edentulous area, occlusal function, systemic disorders, or the socioeconomic status or unwillingness of the patient to experience invasive implant surgery or the preparation of natural teeth for retainers.
- The fiber reinforced composite resin FPD (FRC FPD) can be considered a viable alternative in such situations or in those in which conservative preparation is needed.

CLINICAL PROCEDURE:

- After oral prophylaxis and restoration of cervical caries of the maxillary left central incisor with light cure composite resin, a preliminary maxillary impression is made with polyvinyl siloxane elastomer of putty consistency.
- The composite resin pontic is fabricated using an incremental buildup technique on the impression of the maxillary left central incisor) followed by light curing.
- The pontic obtained by this technique replicates the maxillary left central incisor which is made to resemble the maxillary right incisor with minor modifications using composite resin.[15]
- A properly finished and polished modified ridge lap pontic design is made.
- After fabrication of the pontic,the same impression is poured with die stone to obtain a cast.
- The pontic is then placed on the cast in accurate buccolingual, mesiodistal, and cervicoincisal position as per the esthetics and stabilized with wax from the palatal side.
- A putty matrix/index is then made with polyvinyl siloxane elastomeric putty on the cast with the pontic in position.
- This matrix is used for accurate positioning of the pontic in the patient's mouth and it helps to minimize the pressure exerted by the pontic on the edentulous area.

Putty index fabricated on cast after stabilization of pontic, Fiber reinforced composite resin placed on cast with wax slots after stabilization of pontic with putty

(***Source:*** Pic courtesy Singh K et al. Case reports in dentistry.2014.)

- Palatal grooves, approximately 3mm wide and 1.5mm deep, involving at least three-quarters of the mesiodistal width of the abutments, were prepared with round and inverted cone diamond rotary burs, in the patient's mouth.[15]

Slots prepared at palatal surface of abutments

(***Source:*** Pic courtesy Singh K et al. Case reports in dentistry.2014.)

- A similar size groove involving the whole of mesiodistal width of the pontic was prepared on the pontic.
- The grooves prepared on abutments and pontic should be at the same level.The distance between the grooves was measured and a piece of the fiber ribbon (Perfect Splint, Hager Werken, Germany) is cut with the same dimensions as the space between two grooves.
- The bonding agent is applied on the cut piece of fiber ribbon and kept aside.
- The fiber impregnated with bonding agent should be kept out of the dental light until used.
- One should avoid touching the fiber ribbon after it is wetted with bonding agent via the fingers, because any contact can contaminate its reactive surface layer.
- The prepared slots and mesioproximal surfaces of both the abutments were then etched with 37% phosphoric acid for 15 seconds.
- After thoroughly rinsing and drying, a bonding agent was applied with amicrobrush applicator on both the prepared abutment areas and on the groove on the pontic.
- Excess bonding agent was removed with the brush tip and by gently blowing with air. The bonding agent was light cured for 15 seconds.[15]
- The pontic was then placed in the patient's mouth and held in accurate position with the putty index.

Fiber reinforced composite resin placed in slots after stabilization of pontic with putty index.

(***Source:*** Pic courtesy Singh K et al. Case reports in dentistry.2014.)

- Composite of the selected shade is first placed properly in the grooves on the abutments and on the pontic followed by placement of the cut piece of fiber ribbon along the grooves using composite placement instruments.
- The excess composite which flows into the proximal embrasures should be removed carefully before starting polymerization.
- The composite with fiber ribbon is carefully polymerized with a Quartz tungsten halogen light curing unit for 40 seconds each from the buccal and palatal surfaces of both abutments and from the lingual surfaces of pontic.
- Finally a flowable composite is placed over polyethylene fibers, giving a smooth, glossy appearance on palatal surfaces. Occlusion is evaluated and premature contact eliminated. Figures below show incisal and labial views of definitive prosthesis, respectively.[15]

INCISAL VIEW OF DEFINITIVE PROSTHESIS

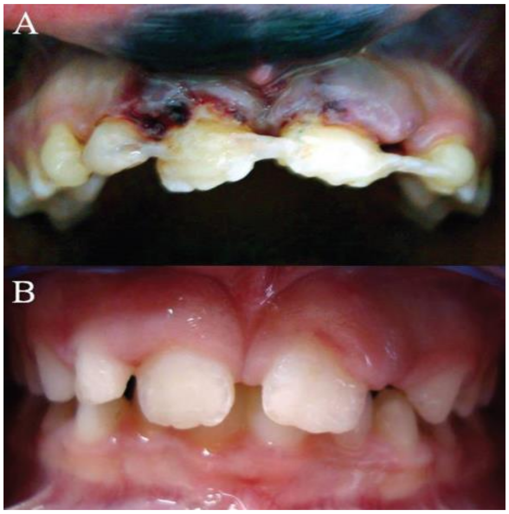
LABIAL VIEW OF DEFINITIVE PROSTHESIS

(***Source:*** Pic courtesy Singh K et al. Case reports in dentistry.2014.)

- Fiber reinforced composite resin FPD and resin bonded FPD can be considered conservative approaches for replacing missing anterior tooth in certain favorable clinical conditions.
- A common problem with metal ceramic resin bonded FPD has been the grayish discoloration of the incisal third of the abutment teeth and debonding of metal retainers from tooth.
- The fiber reinforced composite resin FPD require only preparation of palatal slots on the middle of the palatal/lingual surface.
- The retention of these FPD depends on the proper placement of fiber framework in the grooves and careful bonding procedure.
- The incidences of debonding are less when fiber framework is properly placed in the grooves and bonding procedure is carefully executed.
- In addition to above-mentioned advantages, other advantages include completion of procedure in single appointment, low cost, and less invasiveness, and repairs can be carried out directly without the need for any complicated techniques or materials.
- Adjustments to the design, esthetic details and occlusal relationships may be preparation, advancement in bonding systems, and reported success suggest that this prosthesis can be used as a long term definitive treatment alternative as in the case report described above.
- Long term success depends on proper abutment selection, slot preparation, careful bonding technique, and type of occlusion.[15]
- There should be no contact on the pontic, sufficient horizontal overlap, and minimum vertical overlap.
- This technique is simple, easy, and less time consuming than other approaches.
- It is an affordable and quick solution for the patients who reject more invasive treatments.[15]

USE OF FRC IN DENTAL TRAUMA:

- FRCs can be used for splinting in case of trauma to primary or permanent teeth.
- Clinical steps in splinting are as follows:
- The labial surfaces of the teeth to be etched, rinsed and dried, and Single Bond applied.
- To insure semi-rigidity, the interproximal region is not etched or bonded.
- After applying a flowable composite to the enamel surfaces, the Ribbond is pressed through thecomposite against the teeth and cured.
- The Ribbond is then coated with additional flowablecomposite and cured again for 20 s.[17]



(A). Frontal view after stabilization with a Ribbond-composite splint.

(B). Frontal view after healing.

(***Source:*** Pic courtesy Tuloglu N, Bayeak S and Tunc E. European journal of dentistry2009;3.)

- Two weeks later, the Ribbond splint at the interproximals is cut with a diamond bur. Then, the splint is removed from the abutment by sliding a scalpel blade between the Ribbond and the teeth on the most distal end.
- The remaining adhesive is then removed with a tungsten carbide bur (KometH284; Brasseler Co., Lemgo, Germany) in a lowspeedhandpiece under coolant water and surfaces are polished with disks.[17]

FABRICATION OF CHAIRSIDE FIBER-REINFORCEDCOMPOSITE RESIN PROVISIONAL FIXED PARTIAL DENTURES:

INDICATIONS FOR FRC FPD:

1. Optimal esthetic result
2. Metal free prosthesis is required
3. Decrease wear to opposing tooth
4. Use of an adhesive luting technique

CONTRAINDICATIONS OF FRC FPD:

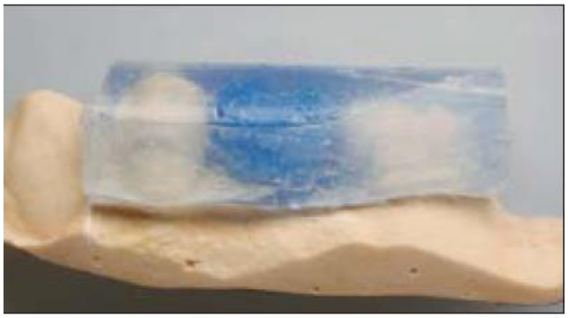
1.Inability to maintain fluid control
2.Long span needed
3.Patients with parafunctional habits
4.Opposing unglazed porcelain

- First, an accurate impression of the edentulous region is made with alginate. It is usually unnecessary to make a full-arch impression because the opposing cast is not needed.
- A stone master cast is made from the impression and used to establish the tooth contours and tooth position according to the clinical situation.
- The stone cast is also used for the fabrication of a wax crown substitute for the edentulous space.
- A template is constructed by loading polyvinyl siloxane into a syringe and applying it around the wax tooth substitute on the master cast.
- A transparent template is essential because the clear matrix allows the light to reach the resin to initiate polymerization.[16]
- After polymerization is completed, the template is separated from the cast by carefully excising the occlusal aspect with a surgical knife and removing the wax crown.
- Then, the template is ready for transfer to the patient’s mouth.[16]

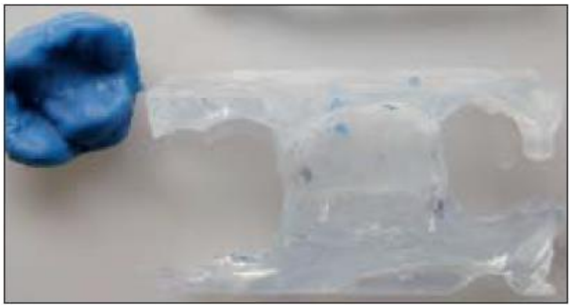
A stone master cast *(beige)* was prepared from an alginate impression, and a wax crown *(blue)* was prepared to fill the edentulous space in the stone cast.

Transparent polyvinyl siloxane was applied with syringe

(***Source:*** Pic courtesy Ballo A and Vallittu PK. The International journal of prosthodontics 2011;24.)



The polyvinyl siloxane template reached its final hardnessalong the occlusal aspect, and the wax crown was remove within 5 minutes of initial mixing.



The hardened template was separated from the stonecast by cutting

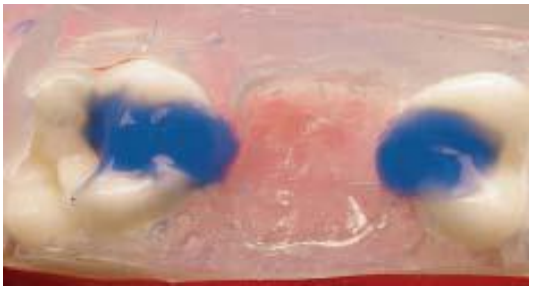
(***Source:*** Pic courtesy Ballo A and Vallittu PK. The International journal of prosthodontics 2011;24.)

- Next, the necessary cavities were prepared by either removing old fillings or preparing new cavities.
- The template is transferred to the patient’s mouth and positioned correctly.
- Glass ever- Stick fibers (Stick Tech) should extend from one end of the cavity to the other.
- This length can be determined by directly measuring the span with a metal foil cord. Next, the prepared cavities are etched, and dentin adhesive is spread throughout the bonding area.

- A thin layer of flowable composite resin is applied, and the fiber bundle is pressed into place and light cured for 10 seconds.
- The pontic construction was initiated by laying down a thin layer of enamel for the underlying wall. Then, a deposition area of the template was built up.
- Next, a reinforced dentin core was constructed between the fibers. The pontic was then coated with enamel and the template was removed.
- Finally, the pontic was finished and polished.[16]

Template positioned in the patient's mouth

The enamel was etched and me foil was used to measure the length of the fiber sticks of the sticks



A bonding agent and flowable composite resin was applied

Fiber pressed into place with hand instruments

(***Source:*** Pic courtesy Ballo A and Vallittu PK. The International journal of pro sthodontics 2011;24.)

The fibers were light cured

Occlusal framework in place view showing the FRC

(***Source:*** Pic courtesy Ballo A and Vallittu PK. The International journal of prosthodontics 2011;24.)

FIXED PARTIAL DENTURE WITH A NATURAL TOOTH PONTIC:

- Following clinical and radiographic examinations, a fixed partial denture reinforced with Ribbond using the natural tooth as a pontic is fabricated.

- The root of the tooth is removed below the cemento-enamel junction, and the coronal pulp chamber is cleaned and filled with a light-cured composite resin.
- The lingual surface of the crown is trimmed and polished.[17] Following completion of etching and bonding procedures, a thin layer of flowable composite resin is applied (without curing) to the lingual and interproximal surfaces of the abutment teeth, a length of 2-mm-wide.
- Ribbond is placed on the lingual surface of the teeth, and slight pressure is applied with a hand instrument to create close contact at the interproximal area.(Figure:B)
- The excess resin composite is removed, and the Ribbond is light-cured for 20s. The lingual surface of the pontic was then prepared for bonding.
- A thin layer of flowable composite was applied to the natural tooth pontic, which was placed in the desired position on the Ribbond and cured for 20s.
- The patient's occlusion is checked for premature contacts, and the resin composite is polished using a polishing disc.[17]

Preoperative View

Palatal View Of Polyethylenefiber-Reinforced Composite Fixed Partial Denture

Polyethylene fiber-reinforced Composite fixed partial denture constructed with a natural tooth following anterior tooth trauma

(***Source:*** Pic courtesy Tuloglu N, Bayeak S and Tunc E. European journal of dentistry2009;3.)

- From clinical point of view, there is a lack of long term clinical research of FRC prostheses. However, the longitudinal studies reported general failure rates between 5% and 16% over periods up to 4-5 years.
- These finding were demonstrated for prostheses with both extracoronal and intracoronal retainer designs, but only for patients who did not exhibit severe parafunctional habits. ***Van Heumen et al.*** showed a survival rate of 64% after 5 years follow-up of 3-unit anterior FRC prostheses made with the materials and techniques used in late 1990s.
- One study reported a much higher failure rate of 40% over a 3-year period. The recent clinical data, on the semi-IPN resin matrix FRC FPDs made directly in patients mouth, suggest high survival percentages (>96% at five years), which reflects material development and learning of fabricating FRC FPDs.**[17]**

TOOTH STABILIZATION AND SPLINTS

- For the stabilization of hypermobile teethFRC materials are an excellent choice.
- Chairside-fabricated fixed splints have previously been made from material combinations that have included resin composites, wire, wire mesh, wire embedded in amalgam and resin and fiber mesh embedded in composite.
- All of these materials suffered from various problems: poor handling characteristics, overbulking, insufficient bonding of the internal structural materials to the dental resins, and poor esthetic outcome.

- FRC stabilization can be either intracoronal or extracoronal, depending on the clinical situation.
- The intracoronal technique requires a prepared horizontal channel that will accommodate the width and thickness of the FRC reinforcement material.
- The dimensions of this channel usually range from 2.0 to 3.0mm wide and from 1.0 to 2.0mm deep. This channel is prepared in the middle to incisal third of the teeth.
- Mandibular splints are usually placed on the lingual surfaces, while a maxillary splint can be placed on either the lingual or facial surface, depending on the occlusal relationships between the teeth.
- The facial approach has the advantage of maintaining the occlusal stops on sound tooth structure, preventing the restorative (particulate) composite from interfering with function.
- Intracoronal splints for posterior teeth require channels that are usually placed on the occlusal surface; the channel can be prepared into an existing restoration and then inserted into particulate composite, which is placed within the channel preparation.[2]
- FRC materials are available with different fiber architectures.
- Fiber architecture has a significant impact on both mechanical properties and handling characteristics.
- Woven fiber is less technique-sensitive and easier to manipulate because it has less memory than unidirectional fiber and is thebest choice for rotated or malpositioned teeth. Unidirectional fiber has greater flexure strength and rigidity and is the better choice for high stress situations.
- Currently, two categories of fiber reinforcement material can be used for intraoral use: pre-impregnated and non–pre-impregnated.

Resin Pre-impregnated FRC Splinting Technique

- Pre-impregnated material (Splint-It, Jeneric/Pentron) has two fiber designs: a 2-mm woven fiber and a 3-mm unidirectional fiber.[2]

Materials required for the intraoral(chairside) fabrication of a periodontal splint are as follows:

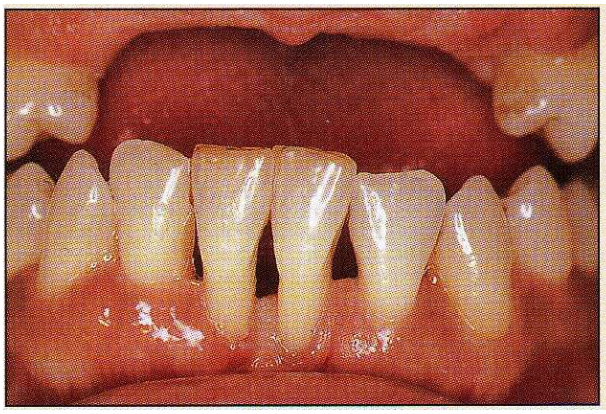
- Diagnostic cast
- Rubber dam
- Wedges, Stimudents, high-viscosity polyvinyl siloxane impression material
- High-speed handpiece and burs
- Phosphoric acid gel etchant
- Fourth-generation (multiple bottle) or fifth generation (single bottle) enamel-dentin bonding agent
- Intraoral FRC material (Splint-It, Jeneric/Pentron)
- Visible light–curing flowable particulate composite resin
- Visible light–curing unit[2]

EXTRACORONAL SPLINTING TECHNIQUE USING PRE-IMPREGNATED FRC MATERIAL

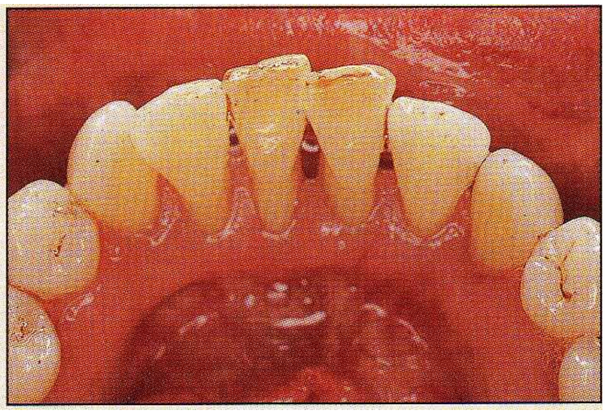
NON-PRE-IMPREGNATED FRC SPLINTING TECHNIQUE

- Non—pre-impregnated materials include plasma-treated, woven, polyethylene ribbons (Ribbond Reinforcement Ribbon, Ribbond; Connect, Kerr) and flexible white continuous filament glass ceramic fiber that has been etched and silanated (GlasSpan, GlasSpan) Plasma treatment of the polyethylene ribbon permits a chemical union to take place between the resin and the polyethylene fibers.
- Etching and silanation of the glass allow for both a mechanical and a chemical union of the fibers.
- The Ribbond Reinforcement Ribbon is available in a 1.0-mm width for orthodontic stabilization and 2.0-, 3.0-, and 4.0-mm widths for tooth stabilization and tooth replacement.
- Connect is available in 2.0- and 3.0-mm widths. GlasSpan is available in 1.0-, 1.5 and 2.0-mm-wide braided ropes and a 2.0-mm-wide woven tape.
- The materials used for this chairside procedure are the same as for the pre-impregnated FRC splinting technique with the exception of the type of FRC material that is used.

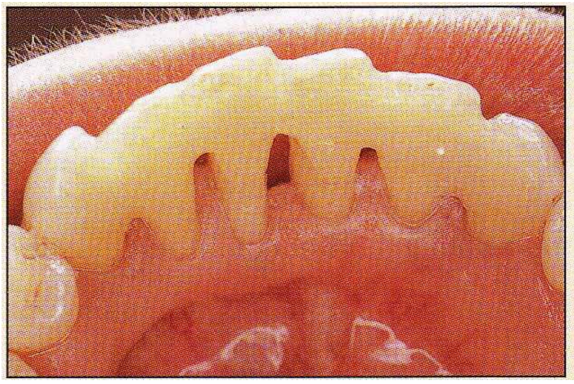
Fabrication of a periodontal splint with non–pre-impregnated FRC material



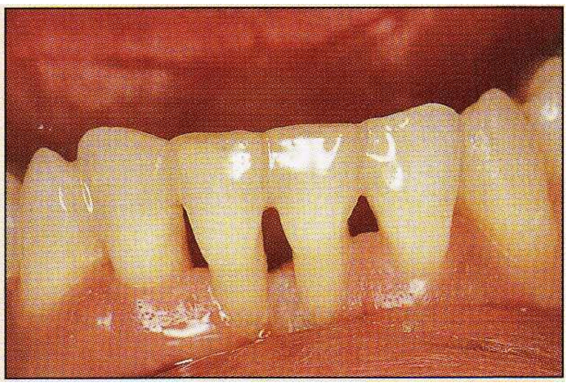
Preoperative facial view of mandibular anterior teeth requiring stabilization



Preoperative lingual view of mandibular anterior teeth.



Lingual view of completed leno-weave polyethylene ribbon intracoronal splint



Facial view of completed leno-weave polyethylene ribbon intra- splint giving a very esthetic and imperceptible result

(Source: Martin A. Freilich, Jonathan C.Meiers, Jacqueline P.Duncan, A.JonGoldberg. Fiber Reinforced Composites In Clinical Dentistry.U.S.A:Quintessence Publishing Co,Inc;2000.)

CHAIRSIDE CONSERVATIVE TOOTH REPLACEMENT:

- Chairside tooth replacement is an excellent application for FRC technology. Previous attempts at chairside tooth replacement involved the use of pontics derived from extracted teeth, acrylic resin denture teeth with or without lingual wire reinforcement and resin composite.
- These were attached to abutment teeth with acid-etched bonded particulate composite, acid-etched particulate composite, and either wire designs or plasma-treated, polyethylene fiber ribbon.
- The abutment teeth used for these approaches were usually not prepared; most often, tooth replacement was only for the anterior region and the procedure was considered a short-term solution.[2]
- The chairside FRC prosthesis offers a fast, minimally invasive approach for tooth replacement that combines all of the benefits of the FRC material for an esthetic, functional, and potentially durable result.
- A denture tooth or a natural tooth (in the case of an extraction of a periodontally involved incisor) can be used as the pontic.

Selection criteria for this tooth replacement approach include:

A patient who desires an immediate, minimally invasive approach

- A patient who requires an extraction in an esthetic area and desires an immediate replacement
- Abutment teeth with a questionable long term prognosis
- Anterior disarticulation during mandibular protrusive movements
    - A nonbruxing patient
    - Cost considerations

Materials required for the chairside FRCprosthesis procedure are as follows:

- Diagnostic casts
- Denture or natural tooth
- Intraoral putty occlusal-incisal pontic index
- Phosphoric acid gel etchant

- Fourth-generation (multiple bottle) or fifthgeneration (single bottle) enamel-dentin bonding system
- Visible light—curing flowable particulate composite
- Unidirectional pre-impregnated FRC
- Finishing and polishing burs and points

Chairside Fixed Partial Denture:

Initial Visit

- During the initial visit, a shade is selected for the denture tooth, and an alginate impression of the arch in which the FPD will be placed is taken to create a diagnostic cast.[2]
- This diagnostic cast is used for selecting and modifying the denture tooth pontic.

Denture Tooth Modification

- A denture tooth of appropriate shade that best fits the shape of the edentulous space and that matches the anatomic shape of the adjacent teeth is selected. It is modified so as to lightly contact the proximal surfaces of the abutment teeth and to conform to the ridge of the edentulous space.
- The denture tooth is then tacked to the cast in an optimal position and a line is inscribed on its occlusal/lingual surface to indicate where the slots are to be placed in the abutment teeth at the time of insertion.
- The adjusted denture tooth is modified as follows (1) Proximal Class III preparations are placed on the mesial and distal facial surfaces.
- These will be used to tack the denture tooth interproximally to the abutment teeth when first positioned in the mouth. (2) An occlusal/lingual groove, at least 2 mm wide and 2 mm deep, is prepared, with the base undercut following the occlusal/lingual line drawn earlier. This groove will receive the FRC.

Alternative Technique Using Extracted Tooth

- If the natural tooth is unsalvagable and must be extracted, it can be used as the pontic.
- The length of the tooth is determined by measuring from the extraction site to the incisal edge of the adjacent teeth; the root is then cut from the tooth crown at this determined length.
- The root canal opening at the apical end is restored by preparing the root canal with a 330 bur to a depth of 1.5 mm. The preparation is restored with particulate composite using an adhesive technique.The technique for placing the natural tooth crown is similar to that for a denture tooth.[2]

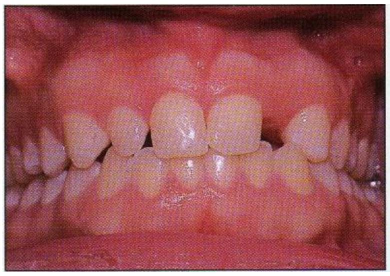
Fabrication of an Intraoral, Occlusal-Incisal Pontic Index

- The denture tooth is positioned on the diagnostic cast and a positioning index is fabricated to aid in the accurate alignment of the denture tooth pontic in the mouth.
- Fabricated from vinyl siloxane putty, the positioning index encompasses the occlusal-incisal portion of the pontic and the adjacent abutment teeth and fills the occlusal/lingual groove for the FRC.
- The gingival extension should not block facial access to the Class III proximal retentive forms of the pontic.[2]

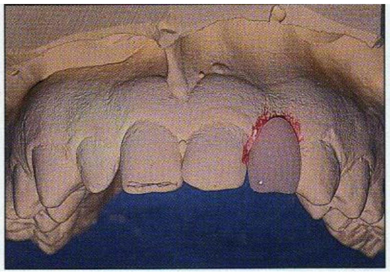
Chairside Insertion Technique

- The abutment teeth are anesthetized; the denture tooth is tried in to verify fit, shade, and contour; and a rubber dam is placed.
- Grooves are prepared in the abutment teeth to align with the groove in the denture tooth these are to be at least 2 mm wide and2 mm deep so as to duplicate the groove in the pontic.
- The occlusal/lingual groove in the denture tooth pontic is sandblasted with 50 pm aluminum oxide.
- The occlusal/lingual grooves and the interproximal areas of the abutment teeth adjacent to the edentulous space are etched and treated with a dentin bonding agent.
- The denture tooth is placed in the putty index and positioned in the mouth.[2]
- A flowable composite is placed and light cured into the Class III interproximal preparations and onto the proximal surfaces of the abutment teeth.

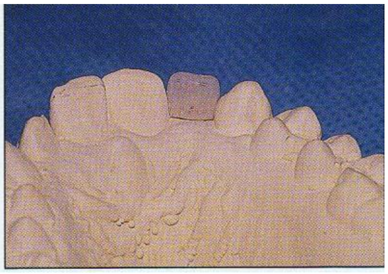
- This will tack the pontic in place and allow for the removal of the putty index with-out dislodging or moving the denture tooth.
- A small amount of high viscosity flowable particulate composite resin is syringed into the occlusal/lingual grooves, and the proper length of FRC is added into the particulate composite–based groove.
- Three or more pieces of FRC should be placed and condensed into the groove,below the occlusal/lingual surface of the abutment teeth or pontic, and then light cured.
- A less viscous flowable particulate composite resin is used to completely fill the remaining portion of the groove and light cured.
- The rubber dam is removed and occlusal adjustments are made using a high-speed handpiece with a composite finishing bur.[2]



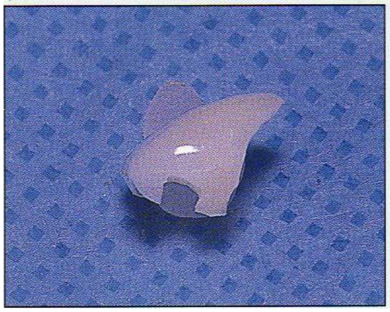
Patient presenting with incisor and peg- right lateral incisor



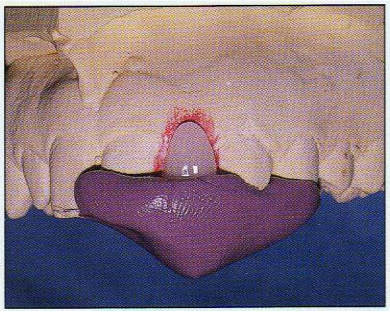
Facial view of modified denture tooth on maxillary cast.



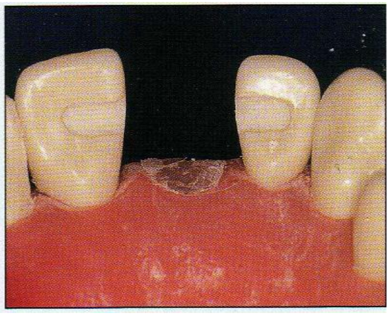
Lingual view of modified missing left lateral denture tooth on maxillary cast.



Proximal view of the lingualFRC slot prepared on the modified denture tooth

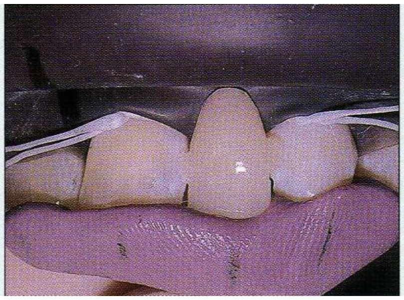


Intraoral incisalpontic positioning index with denture tooth on the maxillary cast. Note that the index allowsaccess to the interproximal surfaces ofthe denture tooth and abutments

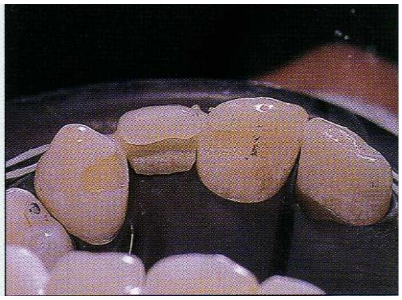


Cast with lingual slot preparations.Slots must be at least 2 mm wide,2mm long, and 2 mm deep to receive atleast 3 to 4 strips of FRC material.

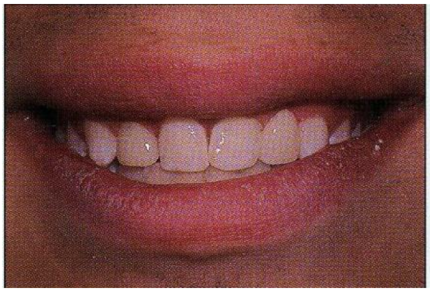
Rubber dam isolation withthe lingual slots prepared on the centralincisor and the canine.



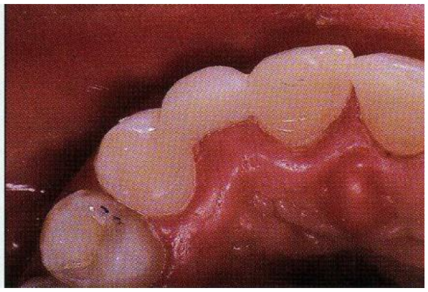
Intraoral incisalpontic positioning index in place, aligning the denture tooth pontic in the correct position Particulate composite resin has been added interproximally to tack the ponticprior to removal of the index. This willhold the pontic for the placement of the FRC.



Lingual view of the tacked pontic, ready for FRC placement. Notethe alignment of the pontic groove withthe slots on the canine and the centralincisor.



Facial view of the finished chairside FRC FPD and recontouredpegshaped right lateral incisor.



Lingual view of the completed chairside FRC fixed prosthesis. The lingual contour has not been altered by the FRC placement.

(Source: Martin A. Freilich, Jonathan C.Meiers, Jacqueline P.Duncan, A.JonGoldberg. Fiber Reinforced Composites In Clinical Dentistry.U.S.A:Quintessence Publishing Co,Inc;2000.)

SURGICAL APPLICATIONS FOR FIBER REINFORCED COMPOSITES:

- FRC in combination of bioactive modifiers like bioactive glass eliminates several shortcomings of bulk material made implants of metals, ceramics and polymers. FRC materials are durable and tough and have proven their suitability to surgical applications of implantology.
- Particles of bioactive glass (BG) have been added to the surface or inner space of FRC implants to improve osteoconductivity and osteoinductivity of the FRC material.
- The need for skull reconstructions is increasing mainly due to an increase in decompressive craniectomies, a life-saving maneuver to relieve intracranial pressure resulting from swelling of the brain due to e.g. trauma or cerebrovascular accidents. Radiation therapy can also be given in the presence of FRC implant.
- The most commonly used fibers in medical FRC are made of glass of specific composition but carbon/graphite fibers have also been tested as spinal fusion cages.[8]
- Surgically used glass fibers are referred as S glass and they are basically free of leaching ions in physiologically moist environment like in living tissues with presence of extracellular liquid.
- Use of carbon/ graphite fibers has been limited due to risk of release of micro and nanometer scale carbon wear debris to tissues.
- Glass fibers of diameter micrometers are used in implants as continuous fibers which have been woven to textile form before impregnating and coupling with resin, and this method inhibits the release of wear debris.
- In the presently used designs of FRC implants, both woven textile form of fibers and unidirectional continuous fibers are used in the implant construction.
- The role of continuous unidirectional fibers is to connect the outer and inner surface laminates together for providing high strength to the implant.
- Special features of the FRC cranial implant construction are mesh-like surface laminates and presence of free space between the outer and inner laminates, which is loaded with particles of bioactive glass.

- Long-term durability of the cranioplasty implant is important because according to the present best knowledge, the cranial defects need years of time to be closed by new forming bone even the presence of osteoinductive implant materials.
- This is the reason why any of the biodegradable polymers or composites cannot be used for repairs of large bone defects in the cranium.[8]
- Biodegradable polymer based materials degrade and loose the mechanical strength too fast in relation to the bone regeneration.
- With regard to degradable metal alloys of magnesium, there are problems in tissue healing due to release of hydrogen gas during degradation process.
- Thermoset copolymer and the silanized glass fibers form a durable composite for fabrication of patient specific and standard shaped implants.
- Biocompatibility of FRC implants is the biocompatibility of its components.
- Presence of BG on the implant surface or inside the implant enhance cell maturation of differentiated bone forming cells. In many of the FRC implant studies, there have been BG (S53P4) particles in the FRC implant.
- BGs are synthetic dissolving biocompatible osteoconductive- osteoinductive bone substitutes. Some compositions (S53P4) of BGs have clinically been used because of antibacterial and angiogenesis-promoting properties.
- Antimicrobial efficiency has been shown for more than 20 microbe species, including Staphylococcus aureus and Staphylococcus epidermis, which are the most common pathogens in periprosthetic infections.
- Clinical studies with cranial FRC-BG implants have been for improving osteogenesis, angiogenesis and antimicrobial properties and long term protection of brain tissues.
- In the biological environment ions of calcium and phosphorus are released from the BG and they biomineralize on the material surface, like the surface of glass FRC-BG implant.[8]
- For cells, at the early stage of osteogenesis, released ions from the BG and slightly increased pH due to ion exchange reactions are inducing differentiation of mesenchymal stem cells to cell lines for bone formation.
- This, in conjunction with biomineralization promotes bone growth. A series of reactions starting at the glass surface followed by a series of biological reactions are occurring with regard to osseointegration, i.e. bonding between the BG of the implant and bone tissue.

- The different reaction steps taking place at the glass surface depend not only on the glass composition but also on the surface topography, surface area of glass, and interstistial fluid flow in the microenvironment around the glass surfaces.
- In the subsequent steps, calcium and phosphate from the solution, and migrating from the bulk glass, form first amorphous hydroxyapatite and then crystallize at carbonate substituted hydroxyapatite layer (HA) at the glass surface.
- This HA layer is compatible with the biological apatite and provides an interfacial bonding between the material and tissue.
- The present design of FRC-BG cranial implant was approved for clinical use as patient-specific implant and standard shaped implant in Europe in 2014.

FUTURE ASPECTS FOR THE RESEARCH OF FRCS:

- Use of FRCs in dentistry and medicine has now taken the first steps and the use is increasing rapidly.
- New applications are tested due to versatile properties of FRC in terms of biomechanics, possibility to add biologically active compounds to the medical device structure and into the polymer matrix.[8]
- The limitations of biodegradable implants and stem cell based tissue engineering approaches in cranial bone repair can be overcome by using glass FRC-BG implants. New applications for FRC will be found from orthopaedic and trauma surgery and spine surgery and in more specific dental fields including dental implantology.

NEW FEATURES AND FUTURE APPLICATIONS

- Future research on FRCs needs to focus on many aspects such as optimization of the design of the frameworks in FRC devices, incorporation of bioactive minerals into the reinforced resin composites, and the change to fiber binding matrix from resin base to inorganic type.
- Another improvement is related to nanotechnology, with the production of functional structures in the range of 0.1-100 nm by various physical or chemical methods. Dental nanocomposites provided a cosmetically acceptable result with excellent mechanical properties.

- The addition of nanofillers particles to resin-based dental materials is the main point involved with this new trend. The utilization of continuous and discontinuous nanofillers has been proposed in conjunction with FRCs.
- FRC utilization has been proposed also in combination with Computer-Aided-Design/Computer-Aided-Machining (CAD/CAM) technologies.
- The interaction between the two technologies seems to be promising based on limited information.
- One other field where FRCs are starting to be utilized is implantology. Implant applications could benefit from certain biomechanical properties of FRCs, and the possibility of incorporating additional bioactive components into the implant structure may open new research fields.[7]

- FRCs have been suggested for tissue engineering for orthopaedic scaffolds. As biocompatibility results are promising, FRC biomaterials developed may constitute an optimized alternative to the other materials used for the reconstruction of craniofacial bone defects.
- The research options with FRC materials are open and future reports about the topic are expected to widen FRC utilization in both dental and medical fields.[7]

BIBLIOGRAPHY

1. Kandilaya V and Raj J.Recent advances and modifications of dental restorative materials-A review. International Journal Of Recent Advances In Multidisciplinary Research 2016;03:1609-1616.
2. Martin A. Freilich, Jonathan C.Meiers, Jacqueline P.Duncan, A.JonGoldberg. Fiber Reinforced Composites In Clinical Dentistry.U.S.A:Quintessence Publishing Co,Inc;2000.
3. Butterworth C, Ellakwa A and Shortall A. Fiber reinforced composites in restorative dentistry.Dental Update 2003;30:300-306.
4. Tayab T, Shetty A and Kayalvizhi G. The clinical applications of fiber reinforced composites in all specialities of dentistry an overview. International Journal of composite materials 2015;5:18-24.
5. Kumar A, Tekriwal S, Rajkumar B,Gupta V and Rastogi R.A review on fiber reinforced composite resins. Annals of prosthodontics and restorative dentistry2016;2:11-16.
6. Zhang M and Matinlinna J. E-Glass fiber reinforced composites in dental applications.Silicon2012;4:73-78.
7. Scribnate A, Vallittu PK, Ozcan M,Lippo V, Lassila,Gandini P and SfondriniM.Travel beyond clinical uses of fiber reinforced composites(FRCs) in dentistry: A review of past employments, present applications and future perspectives.Biomed research international2018.
8. Vallittu PK. An overview of development and status of fiber reinforced composites as dental and medical biomaterials. Acta Biomaterialia Scandinavica2018;4:44-45.

9. Vallittu PK. Flexural properties of acrylic polymers reinforced with unidirectional and woven glass fibres. J Prosthet Dent 1999;81:318-326.

10. Acharya S and Tandon S. Fiber-reinforced composite: Post and core material in pediatric patient: An alternative to usual.SRM Journal of Research in Dental Sciences2015;6.

11. Delperi S. Direct Fiber-reinforced Composite Restoration in an Endodontically-treated Molar:A Three-year Case Report. Operative dentistry2008;33:209-214.

12. Tayab T and Srinivasan I.Space maintainer using fiber-reinforced composite and natural tooth-a non –invasive technique.Dental Traumatology2011;27:159-162.

13. Yeluri R and Munshi AK.Fiber reinforced composite loop space maintainer:An alternative to the conventional band and loop. Contemp Clin Dent 2012;3:S1:26-8.

14. Kirzioglu Z, Zahit Z and Ceylan C.Clinical success of FRC space maintainer.The journal of contemporary dental practice2017;18:188-193.

15. Singh K et al. A conservative treatment approach to replacing a missing anterior tooth.Case reports in dentistry2014.

16. Ballo A and Vallittu PK. Alternative fabrication method for chairside fiber-reinforced composite resin provisional fixed partial dentures.The International journal of prosthodontics2011;24.

17. Tuloglu N, Bayeak S and Tunc E. Different clinical applications of bondable reinforcement of Ribbond in pediatric dentistry. European journal of dentistry2009;3.