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College of Dentistry

Fiber reinforced composites in dental application

A Project Submitted to
The College of Dentistry, University of Baghdad, Department of Restorative & Esthetic Dentistry in Partial Fulfillment for the Bachelor of Dental Surgery

By

Haya Basim Rasan

Supervised by:

Lec. Ammar Azeez Lateef

B.D.S,M.Sc.(conservative dentistry)

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بسم الله الرحمن الرحيم

قَالُوا سُبْحَانَكَ لا عِلْمَ لَنَا إِلاَّ مَا عَلَّمْتَنَا إِنَّكَ أَنْتَ الْعَلِيمُ الْحَكِيمُ

صدق الله العظيم

سورة البقرة الآية (32)

Certification of the Supervisor

I certify that this project entitled " **Fiber reinforced composites in dental application**" was prepared by the fifth-year student **Haya Basim Rasan** under my supervision at the College of Dentistry/University of Baghdad in partial fulfilment of the graduation requirements for the Bachelor Degree in Dentistry.

Supervisor's name:

Lec. Ammar Azeez Lateef

B.D.S., M.Sc.(conservative dentistry)

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List of Abbreviations

Abbreviation	Complete word
BISGMA	Bisphenol A-glycidyl methacrylate
FRCs	The fiber reinforcement composite stracture
UDMA	Urethane di-methacrylate
PMMA	Poly methyl methacrylate
FPD	Fixed partial dentures
PFM	Porcelain-fused-to-metal
PE	Polyethylene

Introduction

Composite resin has revolutionized our field of dentistry and composites have now become the material of choice. The use of adhesive material to reinforce weakened teeth, and undermined enamel was first given by Denehy and Torney in 1976. Traditionally, the dental composites used for direct esthetic restoration consists of mainly polymer matrix and dispersed reinforcing inorganic filler particles. The composite resin is an extensively used direct restorative system**(Quinn et al.,2003).**

Bonded composite resins are commonly used instead of amalgam by many clinicians. In fact, a growing number of practitioners have totally excluded amalgam from their practices. This is supported by declines in amalgam sales by the manufacturers and resultant increases in composite sales, indicating that a growing number of practitioners are phasing amalgam out of their material selection and replacing it with resin based materials **(Lutz et al., 1979).**

There is different varieties of composite resin restorative materials available and their potential uses in clinical practice . Microfilled composites have been available in dentistry for nearly 30 years. As their name implies, they are composites that are filled with very small particles. Filler particles in nearly all other types of composite resins are generated by grinding or milling large particles of quartz or glasses into small ones. The average size of these fillers ranges from 0.1 µm to 100 µm. In the case of the microfilled composites, however, particle size averages only 0.04 µm. These ultrasmall particles, commonly referred to as colloidal silica, are produced by heating quartz particles (ie, silicon tetrachloride) to high temperatures, thereby forming a fume. On condensation, ultrasmall silica particles (also called fumed silica) are generated. The advantage of the small particles is two fold. In addition to enhancing certain properties of the composite resin, they also render the composite resin highly polishable. Clinically, microfilled composites can be used to create restorations in anterior areas, where esthetics is a main concern. Although they do lack in strength when compared with other types of composite resins, their small particle size allows for an excellent final finish. Consequently, they have been quite successful in the restoration of class III and V cavity preparations and as a direct restorative resin for facial veneers **(Michl et al., 1979).**

Hybrid composites were created to address the issues that plagued microfilled composites (lack of strength) and macrofilled composites (excessive wear and lack of esthetics). Hybrid composites in general possess an average particle size of 1 μm. In the authors' opinion, the development of the hybrid composite was the beginning of the development of a universal material. By reducing the particle size, the wear rates of these composites began to show clinically acceptable numbers. Esthetically, these materials began to exhibit a cosmetic result that would be acceptable by most clinicians. Hybrid composites generally contain two types of filler particles. As a rule, these are ground glass particles and colloidal silica. The average size of the ground glass particles ranges between 0.5 μm and 1 μm, while the colloidal silica is much smaller. The colloidal silica takes up about 20% by weight of the total filler loading, while the larger sized filler particles represent the balance. Together, the two particles generate a filler loading that approximates nearly 75% by weight. Microhybrid was developed to improve the hybrid composites and create a more universal material. The improvements in this category were focused on enhancing wear resistance and esthetic properties, without sacrificing strength. Most composite resins in this category exhibit an average particle size of 0.5 μm.Nanoparticles represent a relatively new field of technology not only in the industrial world but also with dental resin composites and dentin adhesives. In essence, nanoparticles are the smallest particles ever used in conjunction with composite resins or dental bonding agents.Nanoparticles are generated differently than conventional particles found in composite resins. Conventional particles are ground from larger sized particles into ones that average from one to several microns **(Rodrigues et al., 2008).**

Dental composites have improved particularly in terms of mechanical and physical qualities, through the use of fiber fillers. In FRCs, the fiber reinforcement provides the composite structure with better biomechanical performance due to their superior properties in tension and flexure. Fibre reinforced composites (FRCs) were first described in the 1960s by Smith when glass fibres were used to reinforce polymethyl methacrylate**(Smith ,1962).**

In the 1970s, carbon fibres were also used to reinforce acrylic resins and, in the 1980s, similar attempts were repeated **(Manley et al .,1979).**

In the 1990s, FRCs were used to fabricate fixed prosthodontic restorations. Since then, there has been a steady increase in research into this interesting group of materials and initial efforts were made to fabricate fibre-reinforced prosthodontic frameworks for implants, fixed prosthodontic restorations, orthodontic retainers, splints, and reinforcement of fibres for post endodontic restorations (**DeBoer et al ., 1984)**.

The use of FRC technology in clinical dentistry may solve many of the problems associated with a metal alloy substructure such as corrosion, toxicity, complexity of fabrication, high cost and aesthetic limitation. **(Garoushi et al., 2009).**The development of FRC has given the practitioner the first real opportunity to create reliable composite structures with highly favourable mechanical properties, non corrosiveness, translucency, good bonding properties and repair facility. **(DeBoer et al ., 1984)** .

Aim of study

1-To evaluate the effectiveness and success rates of FRC for various restorative procedures in dentistry.

2-To determine if FRC offer advantages restorative materials
over traditional
3-Highlighting the potential benefits and limitations of using
FRC for dental restorations

Chapter One: Review of Literature

1.1 Concept of fiber rainforced composites

Fiber reinforced composites (FRCs) are composite materials with three different components: the matrix (continuous phase), the fibers (dispersed phase), and the zone in between (interphase). FRC materials present high stiffness and strength per weight when compared with other structural materials along with adequate toughness **(M. F. Sfondrini et al., 2011).**

FRCs have been used for numerous applications in various engineering and biomedical fields for a long time. The reinforcement of dental resins with either short or long fibers on the other hand has been described in literature for more than 40 years FRCs based on carbon, polyaramid, polyethylene, and glass have been largely studied and among all, glass fibers of various compositions are more commonly applied as restorative and prosthetic materials **(A. I. Karaman et al., 2002).**

With the introduction of new technologies, nanofillers, fibers, adhesion protocols, and application techniques, the design principles of FRC devices need further understanding which open new fields of research both preclinically and clinically **(M. F. Sfondrini et al., 2014).**

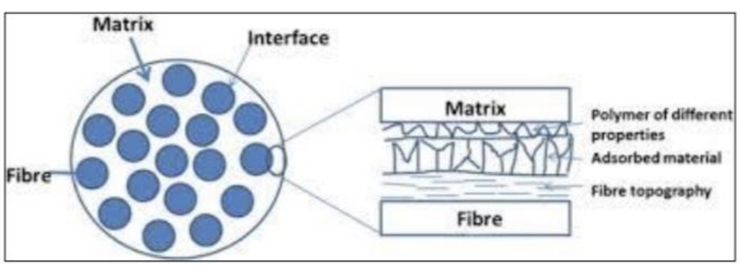

Figure (1.1) fiber reinforced compsite component

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1.2 Composition and Architecture of FRC

1.2.1 The Matrix in FRC

The polymeric plastic matrix, consisting of polymerized monomers, has the function of holding the fibers together in the composite structure. It also transfers stresses between fibers and protects the fibers from the outside environment such as chemicals, moisture and mechanical shocks. Thus the matrix may influence the compressive strength, interlaminar shear , interaction between the matrix and the fiber and defects in the composite **(Soares et al., 1999).**

Ideal requirement are that a resin material proposed for incorporation of fibres must possess mechanical properties that tolerate masticatory forces, the material should be biocompatible, be able to resist degradation, should have low water sorption and solubility and low residual monomer concentration **(Freilich et al., 1999).**

Two types of resins, the cross linked or linear, are used in FRCs. The cross linking polymer is also called a thermoset polymer, which include multifunctional or dimethacrylate resins such as epoxy resin, bisphenol A-glycidyl methacrylate (BISGMA) and urethane di-methacrylate (UDMA). The linear polymer is also called a thermoplastic polymer, referring to monofunctional methacrylate polymers. In some FRCs the matrix is IPN type, so-called interpenetrating polymer network structure that contains poly bis-GMA as the cross linked phase and poly methyl methacrylate (PMMA) as a linear phase**(Vallittu et al., 2009).**

Setting reactions in the resin matrix are polymerization reactions and cross linking reactions. A polymerization reaction is the formation of a polymer by sequential addition of monomeric units. Typical polymerization reactions are addition (including free radical addition polymerisation) and condensation polymerizations**. (J Dent Res ,1997)**

1.2.2The fibres in FRC

Fibres represent the largest volume (from 40 to 65 vol.%) and contribute to stiffness and strength of the matrix and determine the load bearing capacity of FRCs structure . Carbon, Kevlar (p-phenylene diamine), polyethylene, and glass fibres with micron scale diameter have been used in either unidirectional or woven orientation as reinforcements for dental FRCs. In dentistry, glass fibre reinforcement is frequently used for post endodontic restoration, restoration of grossly carious tooth, crowns, fixed partial dentures (FPD), implant prostheses, facial prosthesis, splinting teeth, root canal posts and orthodontic retention device applications.The reinforcing ability of the fibres depends on the diameter, orientation, quantity, compatibility, and impregnation of the fibres with the matrix resin.**(Vallittu ,1997)**

1.2.2.1 Orientation of Fibres

Mechanical and physical properties are related to the orientation of the reinforcement. Fibre orientation can influence the strength, modulus and coefficient of thermal expansion. Fibre orientation can change the properties of a fibre reinforced polymer from isotropic (isotropic: Properties of a material are identical in all directions) to anisotropic (anisotropic: Properties of a material depend on the direction)and even orthotropic(A material is orthotropic if its mechanical or thermal properties are unique and independent in three mutually perpendicular direction).

FRCs can be arranged in different directions (Fig. 2)

(i) unidirectional fiber laminates

(ii) discontinuous short and long fiber (bidirectional)

(iii) textile fabrics (woven, knitted and braided fabrics) laminates.

The unidirectional continuous fibers are anisotropic (have different properties in different direction) that can have advantages in various applications. Bidirectional are available in various textile structures, such as linen, and twill weave. They give orthotropic (same properties in two directions with different properties in the third, orthogonal direction) properties, fiber weave is an example of the bidirectional reinforcement of polymers and random (chopped) oriented fibers give isotropic properties. Hybrid fiber composites are a combination of two or more types of fibers **(A. Tezvergil et al., 2003).**

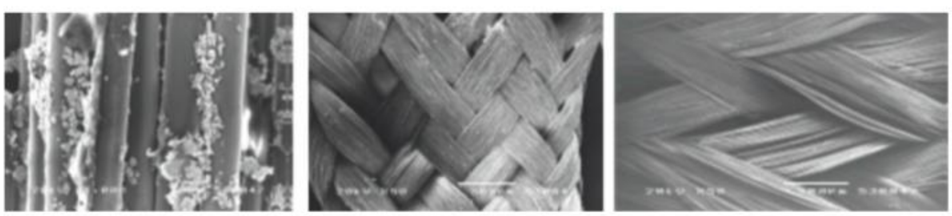


Figure (1.2) Scanning electron micrographs showing the different architecture of fibres available for dental use. (left to right): Unidirectional and pre-impregnated); Glass span (woven in rope manner); Connect (woven).

1.2.2.2Quantity of Fibres

Fibre quantity in a polymer matrix can be given in weight percent (wt. %) or in volume percent (vol. %). Due to the differences in the density of the fibres, presentation in volume percent is recommended. Generally, the volume fraction of fibre in dental FRCs range from 40 to 65 vol. %.

1.2.3 Fibre-Matrix Interface

The interfacial adhesion of the fibre/matrix depends on the interactions between the components and can either be mechanical or chemical in nature. Mechanical bonding depends on the morphology and surface texture of the fibres, while a chemical covalent bond can be achieved by using appropriate coupling agents (Fig. 3). Silanation of fibres has been shown to enhance the surface wettability and improve the adhesion by forming siloxane bridges and hydrogen bonds on the fibre surface **(Lassila et al., 2004).**

The adherence of fibres to the resin matrix is an important quality for good mechanical properties. Fibre reinforcement is effective only when a given load can be transferred from the matrix to the reinforcement, and this can be accomplished when there is complete adhesion between resin matrix and fibres. Insufficient adhesion of fibres by resin matrix results in voids and porosities in the fibre rainforced composite that is susceptible to water sorption. Voids and porosities in the fibre reinforced composite may lower flexural properties and silane coupling agents can optimize chemical and physical bonding between different components in composite materials.

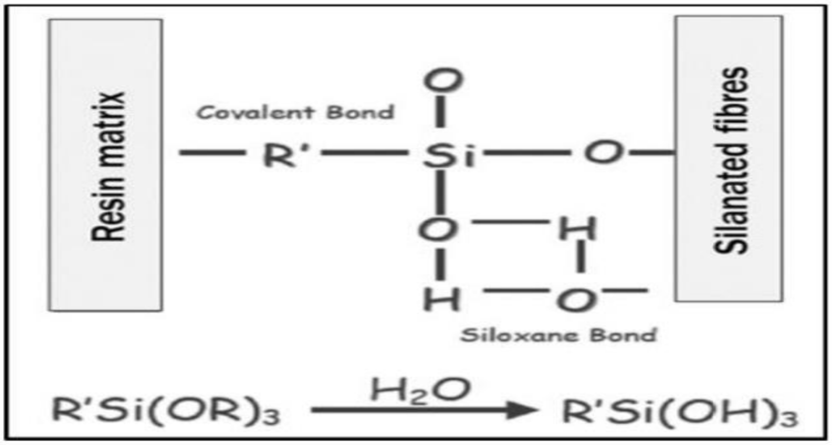


Figure (1.3) schematic of the coupling reaction at the fiber post matrix interface

(Lassila et al .,2004)

1.3 Advantages and disadvantages of FRCs

Advantages:(Freilich et al., 1999).

1- Lower treatment costs.

2- Single visit immediate tooth replacements

3- Suitable for transitional and long term provisional restorations.

4- Readily repaired.

5- Suitable for young patients (developing dentition) and elderly (time saving).

6- Metal free restoration.

7- Improved aesthetics.

8- Can be produced in a simple manner in the laboratory without the need for waxing, investing and casting.

9- Can frequently be used with minimal or no tooth preparation.

10- Wear to opposing teeth much reduced in comparison to traditional metal ceramic restorations

Disadvantages:

1. Potential wears of the overlying veneering composite especially in patients with significant parafunction.

2. May lack sufficient rigidity for long span bridges.

3. Excellent moisture control required for adhesive technique.

4. Space requirements are greater in posterior occlusal situations in comparison to metal occlusal surfaces (to allow sufficient room for fibres and adequate bulk for veneering composite overlay).

5. Uncertain longevity in comparison to traditional techniques **.**

1.4Properties of Fibre Reinforced Composite

1.4.1 Water sorption

Water sorption of a material includes both water adsorbed on the surface and water absorbed into the body of the material during preparation and while the material is in service. PMMA 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.

1.4.2 Flexure Strength

These materials are often tested in the laboratory, although the mode of failure and many other properties affect clinical performance. Investigators highlight the importance of fatigue and fracture toughness in predicting clinical performance of several classes of dental materials, including fibre reinforced composites. Flexure strength for some commercial fibre reinforced composites products may range from approximately 200 to 1,000 MPa, depending on the specimen preparation and geometry as shown in table 1.

Table 1. Flexural properties of some dental FRC products

Product	Flexural modulus (GPa)	Flexural strength (MPa)	Manufacturer
everStick® (p)	24.3	764	StickTech, Turku, Finland
FibreKor® (p)	28.3	539	Pentron, Wallingford, Connecticut, USA
Vectris® (p)	28.9	614	Ivoclar Vivadent, Germany
GlasSpan© (n)	13.9	321	Glas Span, Exton, Pennsylvania, USA
Construct (n)	8.3	222	SDS/Kerr, Orange, California, USA
Ribbond® (n)	3.9	206	Ribbond, Seattle, Washington, USA

FRC: fibre-reinforced composite; (p): machine-impregnated by manufacturer;
(n): required hand impregnation by the technician or dentist

1.4.3 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 **(Lassila et al., 2004).**

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.

1.4.4 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.

1.4.5 Solubility

Over time, components such as stabilizers, plasticizers, monomers, residuals of initiators and degradation products may be released to the oral environment. Thus, the quantity of such components should be as small as possible, ensuring that the polymer retains its characteristic properties and that no components adversely influence biocompatibility.

1.4.6 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.

1.4.7Cytotoxicity

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

1.4.8 Polymerization shrinkage

It has been reported that reinforcing the resin with glass fibres could change the polymerization kinetics of resins and to influence the degree of monomer conversion. The orientation of fibers creates an impact on linear shrinkage strain.

In case of continuous unidirectional FRC materials, the shrinkage strain along the fiber was low, whereas the main shrinkage occurred in the transverse direction to the fiber direction. Similar to the continuous unidirectional FRCs, the bidirectional FRC showed very little shrinkage strain in either direction. FRC with randomly oriented fibers showed low polymerization shrinkage, but slightly higher than the bidirectional FRC. The short fibers were also effective in restricting the shrinkage **(A. Tezvergil et al., 2006).**

1.5 Types of Fiber Reinforcements

1.5.1 Glass fiber

The mechanical behaviours of fiber reinforced composites are primarily dependent on their inherent abilities to enable stress transfer, which in turn depends on the fiber strength, matrix strength and the strength of interfacial adhesion between the fiber/matrix **(Erden et al., 2010).**

Glass fibers (GFs) have been employed in various forms such as longitudinal, woven mat, chopped fiber (distinct) and chopped mats to enhance the mechanical and tribological properties of the fiber reinforced composites**(Alam et al., 2010).**

The properties of such composites was however dependent on the nature and orientation of the fibers laid during composite preparation Glass fibers are one of the most widely used polymer reinforcements with nearly 90% of all FRCs made of glass fibers. Of which, the oldest and the most popular form is the E-glass or electrical grade glass. Other types of glass fibers include A-glass or alkali glass,

C-glass or chemical resistant glass, and the high strength R-glass and/ or S-glass. Under laboratory circumstances glass fibers can resist tensile stresses of about 7000 N/mm2, whereas commercial glass fibers reach 2800 to 4800 N/mm2 **(Rosato and Rosato ,2004)**

1.5.2 Carbon fiber

Carbon fiber is the union of many thousands of filaments. Each Filament is made of 99.9% chemically pure carbon with a 5–10 μm diameter.Since 1980's attempts have been made to use carbon fibers to construct prosthetic frameworks. Use of carbon fibers to improve the strength of denture bases .Carbon fibers were mainly used to improve fatigue behavior and impact strength of the prosthesis. They mainly offer a quality restoration with desirable properties.**(alla et al., 2013).**

Advantages of carbon fibres:(Dr.kavyashree et al.,2022).

1-High quality.

2- Light weight.

3-No special equipments required .

4- Better adhesion.

5- Economical.

6-Fracture resistant.

Disadvantages of carbon fibres:

1- Unesthetic.

2- Cannot be recycled and reused.

Properties of carbon fibres:

1- Low density.

2- Stiffness.

3- Abrasion resistance.

4- High fracture strength.

5- High fatigue and creep resistance.

6- Biocompatibility.

7- Chemically inert.

8- Dimensional stability.

9- Low coefficient of thermal expansion.

10-Cost effectiveness.

Indications of carbon fibre reinforcement in prosthesis:

1-Implant supported Overdentures.

2-Long span bridges.

3- In High strength endodontic posts.

4- Full mouth rehabilitation.

5- Metal free frameworks.

6- Light weight prosthesis.

7- Immediate loading fixed full - arch rehabilitations.

8- Screw retained prosthesis.

Contraindications of carbon fibre reinforced prosthesis:

1-High esthetic concern.

2- Bulky restoration .

1.5.3kevlar fiber

Kevlar is a strong, heat resistant synthetic fiber, related to other aramids such as Nomex and Technora. Developed by Stephanie Kwolek at DuPont in 1965. Kevlar is a manmade fibre, it is as an organic fibre in aromatic polyamide family. The unique properties and distinct chemical composition of wholly aromatic polyamides (aramids) distinguish them from other manmade fibre.Kevlar has a unique combination of high strength, high modulus, toughness and thermal stability. Aramid fibers are widely used for reinforcing composite materials, often in combination with carbon fiber and glass fiber. The matrix for high performance composites **(kadolph et al.,2002).**

1.5.4 Ribbond fiber

A ribbon reinforcement material, Ribbond has been available commercially since 1992. This material is composed of preimpregnated, silanized, plasma treated, leno woven, ultra high molecular weight (UHMW) polyethylene fibres. Leno weave is a special pattern of cross linked, locked stitched threads which increase the durability, stability and shear strength of the fabric. The open and lacelike architecture of the leno woven ribbon allows it to adapt closely to the contours of the teeth and dental arch. The dense network of locked nodal intersections of the material reduces the potential for damage to the fabric architecture by preventing the fibres from shifting during manipulation and adaptation before polymerization. The material has a three dimensional structure due to the leno weave or triaxial braid (Figure 4). These features provide mechanical interlocking of the resin and composite resin at different planes, thereby enabling a wide processing window. In addition, micro cracking is minimised during polymerization of the resin.**(Karbhari et al., 2003)**

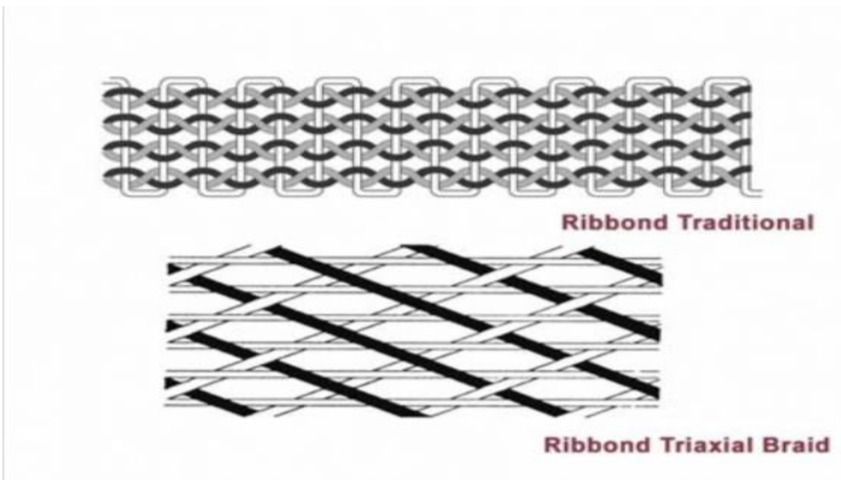


Figure (1.4) Schematic representation of Ribbond Traditional and Ribbond Triaxial. **(Sema Belli et al ., 1992)**

Sometimes is takes multiple pieces of Ribbond to cover the internal surfaces of the cavity. Remember: A small single piece of Ribbon mitigates the harmful effects of C-factor and reinforces the tooth-restoration-complex only where it is placed. To cover as much internal surfaces as possible, sometimes means using more than one piece of Ribbond.

1.6 clinical Application

1.6.1 Clinical Applications in conservative dentistery

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. the dental restorations ideally would be as minimally invasive as possible and sub stitute the missing hard dental tissues resembling mechanical features and properties of natural teeth FRCs have been reported to have superior physical properties and fracture toughness compared to Un reinforced compasite **(S. K. Garoushi et al., 2007).**

In addition, polymerization shrinkage and depth of cure of FRCs have been reported to be superior to conventional resin compasite **(S. Garoushi et al., 2013).**

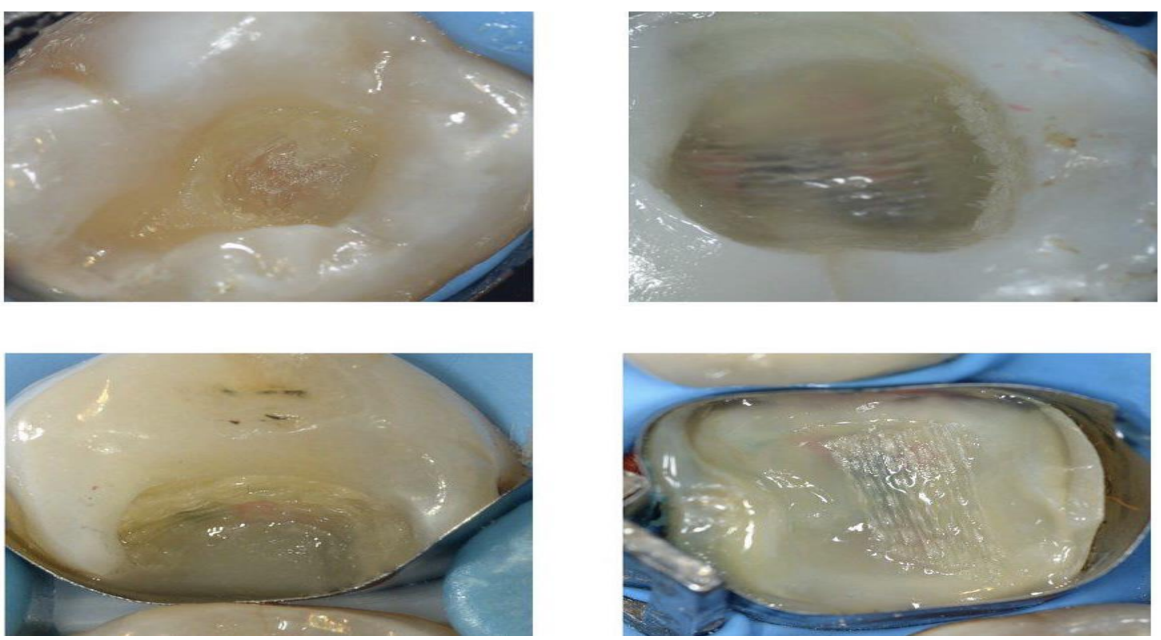


Figure (1.5) Ribbond in compasite restoration **(Singh et al.,2016).**

1.6.2 Clinical Applications in Prosthodontics

Many clinical studies recommend the use of fibre reinforcement in removable dentures. The impact strength of a maxillary complete denture can be increased by a factor greater than 2 when reinforced with bidirectional FRC (Fig. 6). However, just like in the case of any other fibre reinforcement, the positioning of fibre is of prime importance to achieve positive results. Both unidirectional and woven light polymerized FRC strips can be used effectively for chair side repairs of fractured acrylic resin prostheses. 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.

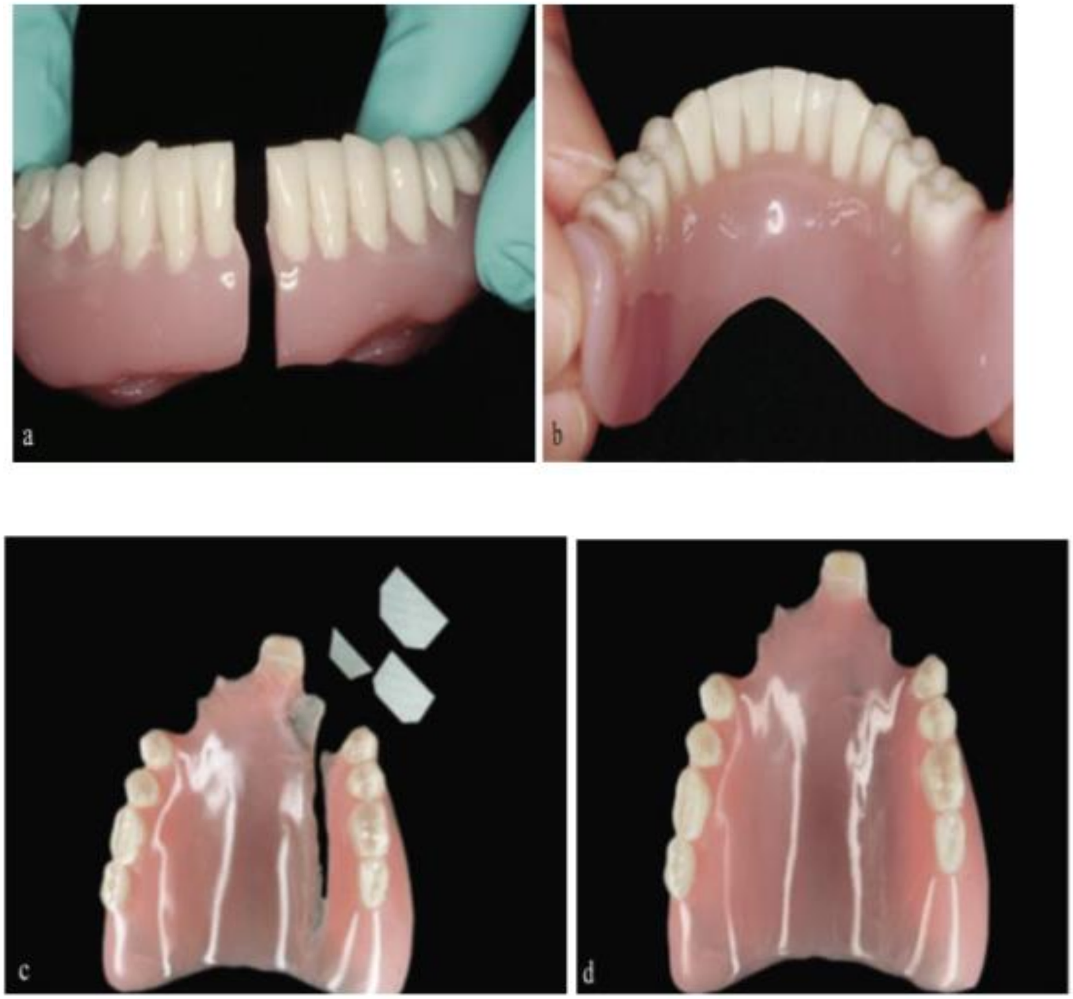


Figure (1.6) Repair and reinforcement of a removable denture: (a) fractured lower denture; (b) final form of the fibre-reinforced lower removable denture; (c) proper placement of continuous bidirectional FRC to the margin where an evaluated crack had occurred; (d) final form of the fibre-reinforced upper removable denture.**(Cacciafesta , 2009)**

Figure(1.7) A laboratory fabricated bridge in the anterior area **(Pekka K Vallittu, 2009)**

1.6.3 Clinical Applications in Endodontics

Prefabricated fibre reinforced composite posts consist of a resin matrix, in which structural reinforcing carbon fibres or quartz/glass fibres are embedded. 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 **(Farah ,2001).**

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 **(Bell et al., 2005)**.

Two categories of FRC posts are available: chair side-fabricated and prefabricated. Chair side fabricated posts are custom designs that use polyethylene non preimpregnated woven fibres (Ribbond, Connect) or glass fibres (ever Stick) to reinforce the root and hold a composite core **. (Vallittu ,1996)**

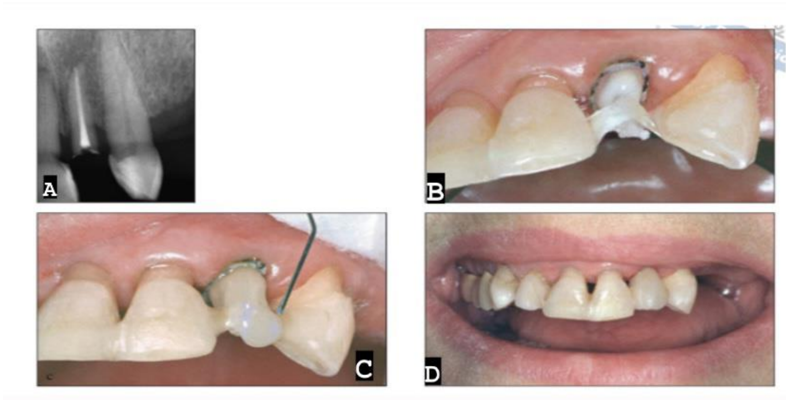
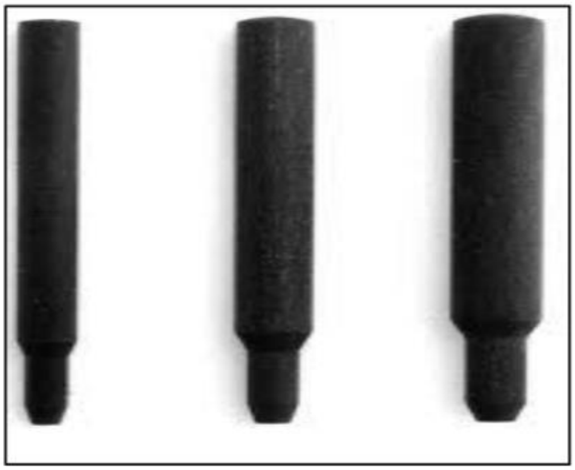


Figure (1.8) Root canal anchoring in combination with surface-retained splinting: (a) intra-oral periapical radiograph showing the remaining root of a canal treated maxillary lateral incisor with vertical bone loss; (b) additional fibres placed over the cemented fibre post in order to splint the tooth; (c) flow and hybrid composite resin used to build up the crown; (d) labial view of definitive restoration.**(Vallittu ,2009)**

1.6.3.1 Carbon fibre posts

Carbon fibre posts (Composipost, C-Post) were the first prefabricated FRC posts introduced to the market in the 1990s (Fig. 6). The posts were made of continuous unidirectional carbon fibres embedded in an epoxy matrix .One of the most important proposed advantages with carbon fibre posts was the lower elastic modulus (more flexible) compared to metal posts, which was thought that forces would be distributed more evenly in the root, resulting in fewer unfavourable tooth fractures. The lack of radiopacity and black colouration limits their use due to poor



aesthetics under all ceramic crowns**. (Karmaker et al., 1996).**

Figure (1.9) Prefabricated carbon fibre reinforced composite posts**(Alla RK et al.,2013).**

1.6.3.2 Glass fibre posts

The glass FRC posts with a translucent or white appearance has been developed as an alternative to the dark carbon fibre posts (Fig 7). The translucency would facilitate the polymerisation process of light cured luting cements with a consequent improvement of their mechanical properties **(Vallittu ,2009).**

Glass FRC posts are fabricated from different types of glasses that differ in their chemical composition. E-glass is the most commonly used glass, in which the amorphous phase is a mixture of a calcium-alumino-borosilicate with low alkali content . In addition, glass FRC posts can also be made of quartz fibres, which is pure silica in crystallised form. A potential advantage of glass FRC posts is that their modulus of elasticity is close to that of dentine therefore, post failure may occur before tooth fracture when force is applied. **(Lassila and Lappalainen ,2014).**

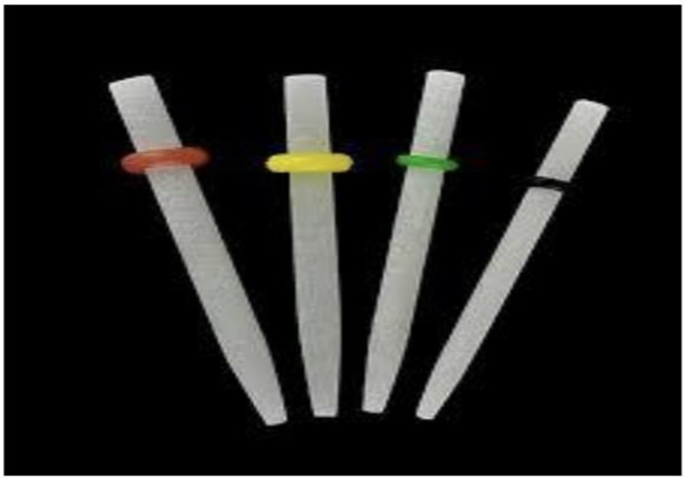


Figure (1.10) Prefabricated Glass fibre reinforced composite posts**(E. S. Elsubeihi et al ., 2020)**

1.6.4 Clinical Applications in Pediatric Dentistry

In pediatric dentistry FRCs can be used in 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 pediatric dentistry showed acceptable clinical performance, durability ,and ease of use 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**(Sawant et al., 2017).**

However, the application of FRC with a spot bonding technique has been proposed, in order to reduce framework rigidity, thus allowing physiologic tooth movement **(Sfondrini et al., 2017).**

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 **(Vallittu And Närhi et al .,2015).**

Figure (1.11) FRCs loop space maintainer **(Ramakrishna Yeluri , 2012)**

1.6.5 Clinical Applications in Orthodontics

The main use of FRCs in clinical orthodonties is as fixed retention After orthodontic treatment. the need for maintaining the teeth in correct position is crucial for long term stabilityof 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. great advantage of

FRCs splints over convencional metallic retention is esthatics. Fibers are barely invisible and do not effect translucency of teeth**(Freilich et al., 1998).** Applications of fibre reinforced composite in orthodontic practice include:

1. Fixed orthodontic retention appliance (Fig. 12)

2. Fixed space maintainer

3. Temporary esthetic retention appliance

4. Post traumatic stabilization splint.

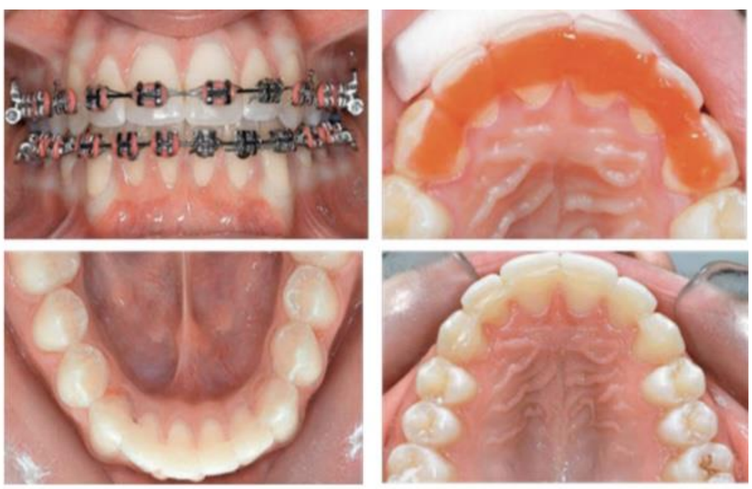


Figure (1.12) Maxillary and mandibular bonded retainers after orthodontic therapy **(Sufyan Garoushi et al., 2009)**

1.6.6 Clinical Applications in Periodontology

Periodontal or post traumatic 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.

The use of FRC in periodontal or post traumatic 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 **(Cacciafesta et al., 2007).**

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 **(Frese et al., 2014).**

Figure (1.13) Surface-retained periodontal splint: continuous unidirectional glass FRC applied on the lingual surface of the teeth.**(Sufyan Garoushi et al ., 2009).**

1.6.7 Short Fibre Reinforced Composite.

In 2013, a short fibre-reinforced composite (SFRC) (everX Posterior, GC) was introduced to the market with the goal to substitute the missing dentin with a material having a similar behaviour; additionally, the material has clinically shown to be also able to mimic the stress absorbing properties of the DEJ simultaneously. Fibre-reinforced composites have been used in dentistry for the past 30 years but their true potential and function is just being realised. The reinforcing effect of the fibre these natural tissues to withstand a lifetime of mastication. Therefore, the DEJ might be considered a specialized tissue type of its own fillers is based on stress transfer from the polymer matrix to the fibres **(Garoushi et al., 2013).**

which is influenced by the size of the fibres and the connection between the fibres and the matrix. The actual average size of the glass fibres in the SFRC material is 1-2 mm, thus exceeding the critical fibre length and making stress transfer possible.

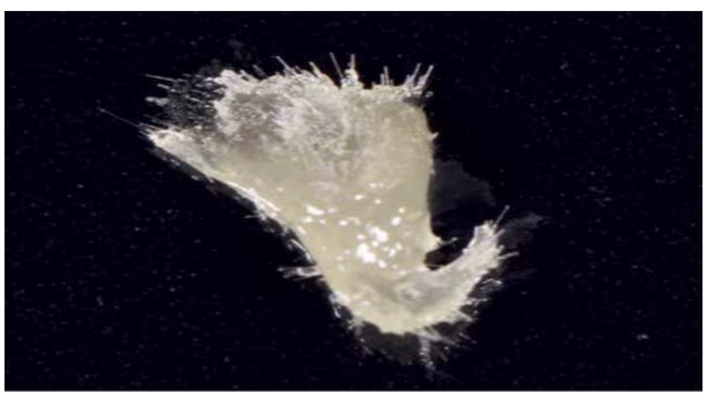


Figure (1.14) The unique size of the short fibres is visible when the SFRC material is extruded from the unitip **(Demarco et al., 2012)**

Additionally the fibres are silanised and are therefore able to chemically connect to the matrix. As a consequence of these features, the SFRC is able to reinforce the dental structures even in case of extreme loading conditions. Since these fibres show random orientation, they can reduce the polymerisation stress generated by the composite resin in all directions **(Sailynoja et al., 2013).**

This makes it possible to use the material in layers up to 4mm. However, the in vitro research carried out by the authors has shown that everX Posterior applied in 2-3mm thick layers with oblique layering gave the best results regarding the fracture resistance of posterior molar teeth among the restored groups **(Basaran et al., 2013).**

Furthermore, this technique showed the highest number of repairable fractures once fracture occurred. Thus this technique (2-3 mm thick layers with oblique layering) seems to be the most beneficial.

When following the biomimetic restorative principles, the indications for the usage of everX Posterior are dentin substitution in medium and large cavities in posterior teeth, which means that in practice the surfaces of these modern direct restorations should be made of microhybrid or nanohybrid composite covering the SFRC “dentinal core” in at least 1 mm thickness everywhere.

The other revolutionary indication of SFRC is in case of indirect restorations or repair of damaged restorations. The SFRC material contains a semi-interpenetrating polymer matrix (semi-IPN), which consists of both linear and cross- linked polymer phases. The linear phase can be dissolved if a suitable adhesive resin is added on its surface, thus enabling the reactivation of the material and also true chemical bonding to it **(Fráter et al., 2014).**

1.6.7.1 Composite and Short Fiber Reinforced Composite Combination properties

1-Fracture resistance

The in vitro restoration of Class II MOD cavities. with EverX combined with a 2mm occlusal layer of conventional composite has been reported to yield superior fracture resistance when compared to a cavity restored with consecutive 2 mm thick oblique increments of packable composite resin. This finding shows that regardless of whether EverX was applied in bulk or in 2 mm increments, it still provides superior resistance **(Frese et al., 2014).**

However, other studies following a similar application of EverX below an occlusal layer of conventional composite reported greater mean values for fracture resistance when compared to restorations with conventional composite only nonetheless, they did not find statistical differences **(Fráter et al., 2021).**

2-Preventing fracture

In addition to superior fracture resistance, EverX can withstand a greater fatigue load, and therefore, is recommended for use in high stress restorations areas such as MOD cavities **(Sáry et al., 2019).**

The improved fracture resistance may be attributed to the millimeter scale of the short fiber structure of EverX. Another observation was that an increased bond durability with universal adhesives may also account for the improved performance of EverX over particulate filled composites **(Bijelic-Donova et al., 2016) .**

When these restored cavities are subjected to high loads, these fibers can undergo a stress modifying effect in which they absorb and redistribute the forces applied to the tooth, which is made possible by the bond formed between the dentine and the composite resin restorative material **(Tsujimoto et al .,2016)**

3-Fracture patterns

After comparing various combinations of restorative materials, including conventional particulate filled composite (specifically G-aenial Posterior), short fiber reinforced composite (specifically EverX Posterior), and fiberglass net, the authors report that bulk-fill restorations with EverX posteior occlusally layered with 2 mm of conventional composite produced the greatest rate of favourable fractures than other combinations **(Garlapati et al .,2017).**

These findings are similar with those of another study reporting that application of EverX via an oblique layering technique occlusally layered with 1 mm of coventional composite produces more favourable fracture patterns than EverX applied in a horizontal incremental technique in which composite was placed in was placed in two consecutive maximum 2 mm thick horizontal layers. Taken together, these findings suggest that when restorations do fracture, short fiber reinforced composites, specifically EverX with composite resin, produces more favourable fracture patterns than conventional particulate filled composites**(Lassila et al .,2004).**

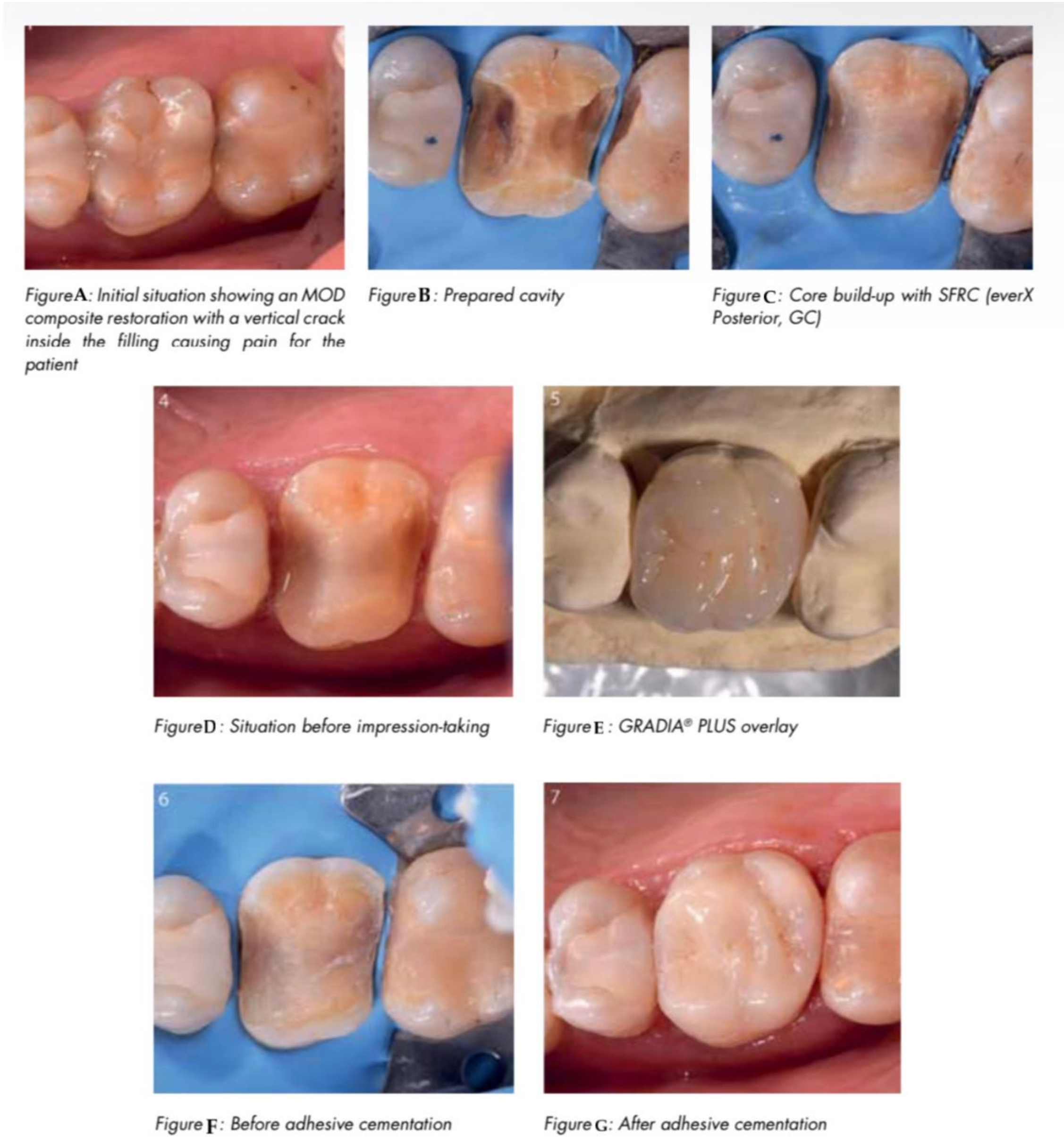


Figure (1.15) Clinical application of ever x **(Márk Fráter and András Forster ,2020)**

Chapter Two: Discussion

Some studied show that In Ever X Posterior there is no additional cement was used between Ever X Posterior material and dentin, Long, narrow, and deep cavities have high C-factor causiing shrinkage stress during polymerization, which might exceed the bond strength.Additionally, the curing light loses too much intensity due to attenuation before reaching the bottom of the cavity, and inadequate polymerization can occur in the deep sections of the cavity(**Van ende et al., 2013).**

In addition, the light conducts and scatters over the fibers for longer distances and results in relatively deep and wide polymerization. Since the root canal has high C-factor design, Ever X Posterior was selected in the present study instead of fiber post. Ever X Posterior results in a degree of toughness that is equivalent to dentin and provides anisotropic reinforcing effect**(Bell et al., 2005).**

A previous study indicated that the FRC had been claimed to control polymerization shrinkage stress more favorably within the restoration. On this note, the similar bond strength results obtained with Ever X Posterior (instead of post) could be related to its well adaptation and thereby good bonding to the root canal wall**(Vallittu ,2014) .**

Other study show short-fiber reinforcement composite has adequate fracture resistance and flexural strength which promote it to be a suitable material for the restoration of endodontically treated teeth with a large cavities**(Wael Gamal et al .,2022).**

And auther suggest From the results of there study, it can be concluded that the increase in SFRC thickness as intermediate layer increases the fracture resistance on class II restoratio**(Calvina Hartanto et al ,2020).**

Other auther show SFRCs can be beneficial in large stress bearing restorations as a dentine replacing materials, resulting into less fracture related failures and improving overall longevity of direct and indirect resin composite restorations. If only comparing facets of physical properties, the use of the short fiber reinforced composite product (everX Flow) as viable alternative with comparable flexural strength and physical properties to that of prefabricated fiber posts (RelyX) may not have been established. The data clearly shows the superior strength of RelyX versus everX Flow in the comparative analysis. Continued advancements in the field of dental materials may eventually develop products that could perform at the same level, or even better, than present pre-fabricated fiber post systems. More research and development of innovative materials in this specific field could lead to the next restorative dentistry breakthrough**.(COL Joseph Lowe,2022).**

Everstick post is a glass FRC post and performed significantly better than Ribbond which is a polyethylene fiber. Mangoush et al.observed a similar finding that glass FRCs have superior characteristics and provide significantly better reinforcement than polyethylene FRCs. This is due to the difficulty in silanization and impregnation of polyethylene fibers leading to weak adhesion of the resin to polyethylene FRC whereas, in glass FRC materials, adhesion is promoted by silane coupling agents **(Mangoush et al.,2003).**

Everstick post showed significantly high resistance to fracture when compared with the other FRC post (Ribbond) and thus can be a promising alternative to the conventional post-core systems and other FRC pos**(Deeksha Khurana et al., 2021).**

Chapter Three: Conclusion

FRC materials offer a combination of strength and modulus that is either comparable to dental tissues. The specific mechanical and physical strength and specific modulus of these fiber reinforced composite materials may be markedly superior to those of existing resin-based composites and metallic materials. In the short term, reasonable success for glass fiber-based restorations including endodontic posts, fixed partial denture, and posterior restorations. For these reasons, FRC have emerged as a major class of structural material and are either used or being considered as substitutes for traditional materials in dental applications.

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