Republic of Iraq
Ministry of Higher Education and Scientific Research
University of Baghdad
Department of Dentistry

Fiber-reinforced composite

A project Submitted to
The college of dentistry, university of Baghdad, Department of Restorative and Aesthetic Dentistry in partial fulfilment for the bachelor degree of dental surgery

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2022-2023

Certification of the supervisor

l certify that this project entitled "Endodontic Retreatment System" was prepared by the fifth-year student "**Noor Baher Shilage**" under my supervision at the college of dentistry / University of Baghdad in partial fulfillment of the graduation requirements for the bachelor degree in dentistry.

Dr.Abeer Ghalib AbdulKhaliq

Date:

Dedication

To my hero, Dad I am sure you see this

To my mother ‹the strongest woman I have ever seen thanks for everything

To my sister ‹zainab for your continued support

Finally, to my soul sister ‹Maryam to be in my life

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INTRODUCTION

Composite resins have 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. There was the stress development within the tooth structure, due to polymerization shrinkage and mastication. Fiber-reinforced composite (FRC) promises to overcome these problems **(Krishnamachari,2020)**
Fiber-reinforced composites (FRCs) were first described in the 1960s by Smith when glass fibers were used to reinforce polymethyl methacrylate **(Smith DC,2000)**. In the 1970s, carbon fibers were also used to reinforce acrylic resins and, in the 1980s, similar attempts were repeated **(Manley TR et al,2003).** 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 fiber-reinforced prosthodontic frameworks for implants, fixed prosthodontic restorations, orthodontic retainers, splints, and reinforcement of fibers for post endodontic restorations **(DeBoer J et al ,2003).** 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 SK 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

CHAPTER ONE:

REVIEW OF LITERATURE

1.1` Definition of Fiber-reinforced composite :

Fiber reinforced composites (FRCs) are typical composite materials made of a polymer matrix that is reinforced by fine thin fibers aimed at enhancing their physical properties **(R. Seemann et al,2015).** These composite materials consist of three different components (Figure 1): the matrix (continuous phase), the fibers (dispersed phase), and the zone in between (interphase). FRC materials are very heterogeneous depending on the nature of the fiber, the geometrical arrangement of the fibers and the overlying resin used **(J. Tanner et ,2018).** The fibers within the composite matrix are ideally bonded to the resin via an adhesive interface. The role of the fibers is to provide strength and stiffness increasing the structural properties of the material by acting as crack stoppers **(Vallittu PK et al ,2000).** The resin matrix consisting of polymerized monomers acts to protect the fibers from the effect of mechanical damage and moisture and fix their geometrical arrangement, holding them at predetermined positions to provide optimal reinforcement. The interface between the two components plays the vital role of allowing loads to be transferred from the composite used to the fibers .

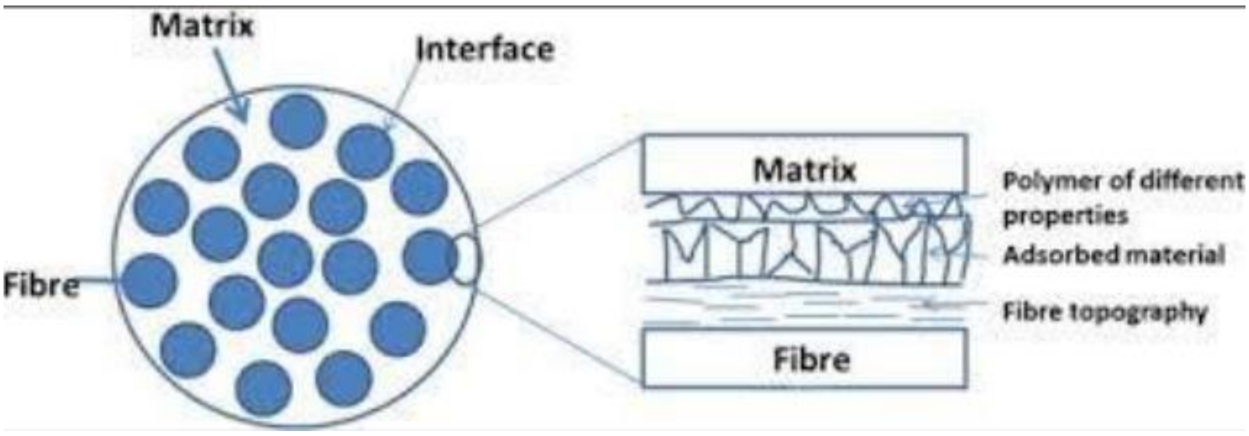

Figure (1) Fiber reinforced composite components

1.2 Advantage and disadvantage of of fiber-reinforced materials:

1. They have highly favorable mechanical properties and their strength-to-weight ratios are superior to those of most alloys

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

3. Superior mechanical property of FRC makes them an ideal material for the restoration of large cavities and for post-endodontic flling

5. FRC restorations offer a minimally invasive, low-cost alternative to conventional restorative dentistry

6. FRC prevents crack propagation in restored teeth

7. It also offers exciting applications in the repair and strengthening of dentures, orthodontic retainers, and the provision of aesthetic custom-made posts and cores

8. They also offer the potential for chairside and laboratory fabrication.**(Kangasniemi et al ,2003)**

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. 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).

4. Uncertain longevity in comparison to traditional techniques **(Freilich MA, et al ,2015)**

1.3.Composition and Architecture of FRC:

1.3.1Fibers:

Fibers 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 **(Vallittu P, 2000).** Carbon, Kevlar (p-phenylene diamine), polyethylene, and glass fibers with micron-scale diameter have been used in either unidirectional or woven orientation as reinforcements for dental FRCs. In dentistry, glass fiber 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 application

Orientation of Fibers:

Mechanical and physical properties are related to the orientation of the reinforcement. Fiber orientation can influence the strength, modulus and coefficient of thermal expansion. Fiber orientation can change the properties of a fiber reinforced polymer from isotropic to anisotropic and even orthotropic.

FRCs can be arranged in different directions ;

(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 a,2003).**

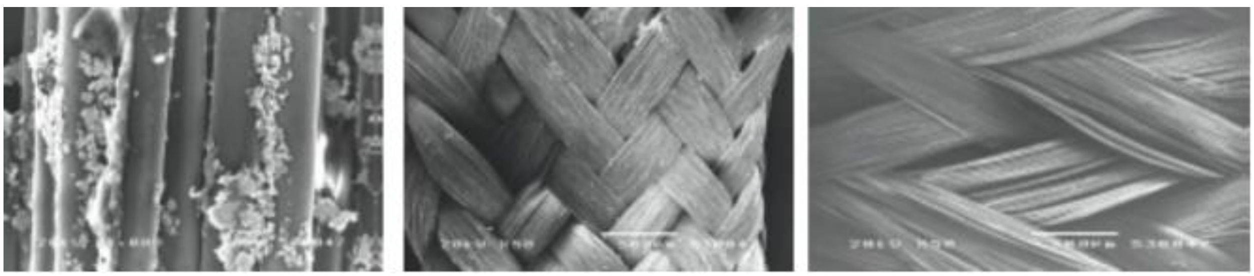

Figure (2): Scanning electron micrographs showing the different architecture of fibers available for dental use. (left to right): Unidirectional and pre-impregnated); Glass span (woven in rope manner); Connect (woven)

1.3.2Resins Used 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 and in-plate shear properties, interaction between the matrix and the fiber and defects in the composite **(Soares CAM et al,2007).** Ideal requirement are that a resin material proposed for incorporation of fibers 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**

MA et al,2001). 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 PK et al ,2009)**

IMPREGNATION OF FIBERS WITH RESIN:

The term describing the penetration of resin material to the spaces between the fibers is called resin impregnation. Resin impregnation relates to the surface wetting properties of fibers by the resin, distance of individual fibers from each other in the fiber product, and viscosity of the resin material. Tightly bound fiber weaves and ribbons are more challenging to wet with the resins **(Matisons J,2009)**.

1.3.3 Fiber-Matrix Interface:

The interfacial adhesion of the fiber/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 fibers, while a chemical covalent bond can be achieved by using appropriate coupling agents . Silanation of fibers has been shown to enhance the surface wettability and improve the adhesion by forming siloxane bridges and hydrogen bonds on the fiber surface **(Lassila LV et al,2004).** The adherence of fibers to the resin matrix is an important quality for good mechanical properties. Fiber 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 fibers. Insufficient adhesion of fibers by resin matrix results in voids and porosities in the fiber-reinforced composite that is susceptible to water sorption. Voids and porosities in the fiber reinforced composite may lower flexural properties and silane coupling agents can optimize chemical and physical bonding between different components in composite materials.

1.4 PROPERTIES OF FRC:

1.4.1 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 the clinical performance of several classes of dental materials, including fiber 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 FRCs may range from approximately 300–1000 MPa, depending on the specimen preparation and geometry **(Seemann R, et al,2015).**

1.4.2 Fracture Toughness:

The fracture toughness of 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 mono methacrylate-based material is lower than in a dimethacrylate-based material. In general, "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 fibers to a polymer to prevent or slow down crack growth **(Tanner J, et al,2018).**

1.4.3 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 the long-term stability of intraoral multiphase materials. By adding fibers to a polymer, the coefficient of thermal expansion decreases. In general, the thermal coefficient varies with the direction of the fibers in a composite rigid fibers appear to prevent the expansion of the matrix in the longitudinal direction, so the matrix is forced to expand in the transverse direction .One of the major concerns in the development of dental materials is physical and chemical durability**(Agrawal A, et al,2014).**

1.4.4 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**(Cacciafesta V, et al,2007).**

1.4.5 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 **(Foek DL, et a,2013).**

1.4.6 Cytotoxicity:

Some substances released from materials are cytotoxic and residual monomers leached out into the oral environment may induce toxic and allergic reactions **(Kumbuloglu O, Özcan et al,2011).**

Chapter two :

Clinical Applications of Fibre Reinforced Composite:

2.1 Clinical Applications of Fiber Reinforced Composite:

2.1.1 Tooth Stabilization and Splints

FRC materials are an excellent choice for the stabilization of hypermobile teeth. 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 embedden 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 2.0 mm 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 **(Vitsentzos SI, et al,2005)** 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 the best choice for rotated or malpositioned teeth.Unidirectional fiber has greater flexure strength and rigidity and is the better choice for highstress situations.
Currently, two categories of fiber reinforcement material can be used for intraoral use: pre-impregnated and non–pre-impregnated

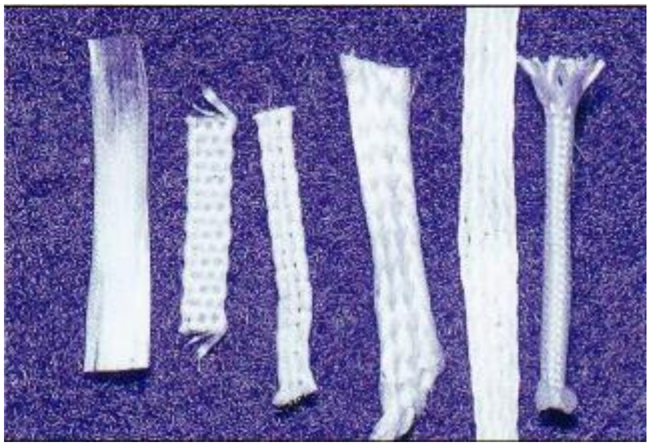

Fig (3)(Left to right) Pre-impregnated splint material (with the resin removed to show glass fibers): Splint-It unidirectional ,Splint-It woven. Non—pre-impregnated polyethylene splint material: Ribbond ,Connect. Non—pre-impregnated glass fibers: GlasSpan tape, GlasSpan rope

Fig (4) Two or three strips of unidirectional Splint-It material inserted into the particulate composite resin bed of the lingual channel and then light polymerized for 60 seconds per strip

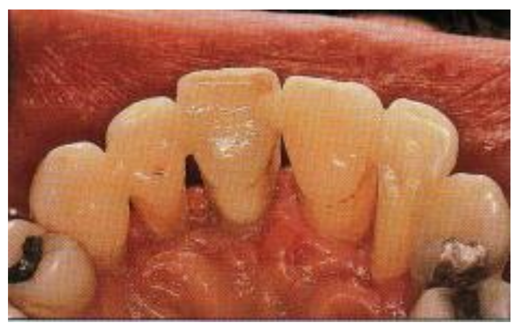

Fig (5) Lingual view of finished FRC lingual slot splint with the orthodontic band-wire stabilization removed

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2.1.2 Conservative treatment of missing Tooth Replacement:

Chair side tooth replacement is an excellent application for fiber reinforcement composite technology, which replaced the old metal frame (resin-bonded prosthesis). The chair side fiber reinforced composite prosthesis offers a fast, minimally invasive approach for tooth replacement that combines all of the benefits of the fiber 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.
Unlike traditional porcelain-fused-to-metal (PFM) bridges or full-ceramic bridges, FRC prostheses do not require extensive tooth preparation. FRC prostheses allow for the use of different retainer types (old filling, inlay, onlay, full-cover crown retainers or completely surface-retained restorations). For the clinical situation, hybrid fixed prosthesis can be prepared by integrating the retainer types onto the same prosthetic structure. However, it should be emphasized that FRC prostheses with a veneering composite offer an alternative, but not a substitute for PFM or full ceramic prosthetic structures, which usually used in the anterior region and the procedure was considered a short-term solution.

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 **(Martin A, et al,2000)**

2.1.3 Post Endodontic Restorations:

The choice of the definitive restoration is strongly dependent on the amount of the remaining tooth structure, the morphology of the tooth, its position in the dental arch, functional loading on the tooth and the esthetic requirements. It is generally accepted that endodontically treated teeth with minimal loss of coronal tooth structure should be restored conservatively with a direct bonded restoration to obturate the access cavity. Adhesive technology is advancing by leaps and bounds every day, making it possible to create conservative and highly aesthetic restorations with direct bonding to the teeth. A significant increase in the fracture resistance of root filled teeth was observed when they were intra coronally restored with a resin composite material. Reinforcing composites with polyethylene fibers and glass fibers has successfully provided superior resistance **(Mannocci F, et al,2002)** The use of FRC restorations in clinical dentistry is increasing, as their potential for extending the range of possible treatment needs met by resin-based composites is being realized.

2.1.4 Endodontic Fiber Reinforced Composite Posts:

Prefabricated fiber reinforced composite posts consist of a resin matrix, in which structural reinforcing carbon fibers or quartz/glass fibers 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.**(Freilich MA, et al,2002)** 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 AM,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 pre impregnated woven fibers (Ribbond, Connect) or glass fibers(ever Stick) to reinforce the root and hold a composite core

Figure (6) Chairside prefabricated and fabricated FRC post procedure.

2.1.5 Repair of Acrylic Resin Prosthesis:

Many clinical studies recommend the use of fiber 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 . However, just like in the case of any other fiber reinforcement, the positioning of fiber is of prime importance to achieve positive results. Both unidirectional and woven lightpolymerized 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 fiber. 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

2.1.6 Chair side Repairs with Light-polymerized FRC:

Effectively any acrylic resin prosthesis or appliance can be repaired with lightpolymerized FRC, which include **(Vallittu,2008):**

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

2.1.7 Orthodontic applications

Applications of fiber reinforced composite in orthodontic practice include:

1. Fixed orthodontic retention appliance **(Aniket Kuma,et al,2016)**
2. Fixed space maintainer
3. Temporary esthetic retention appliance
4. Posttraumatic stabilization splint

Figure(7) Maxillary and mandibular bonded retainers after orthodontic therapy

2.2 Types of fiber post

2.2.1 Carbon fiber posts

Carbon fiber posts (Composipost, C-Post) were the first prefabricated FRC posts introduced to the market in the 1990s . The posts were made of continuous unidirectional carbon fibers embedded in an epoxy matrix **(Karmaker AC, et al,2017)** One of the most important proposed advantages with carbon fiber 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.

Figure (8) Prefabricated carbon fiber reinforced composite posts

2.2.2 Glass Fiber posts:

The glass FRC posts with a translucent or white appearance has been developed as an alternative to the dark carbon fiber posts . The translucency would facilitate the polymerisation process of light-cured luting cements. with a consequent improvement of their mechanical properties **(Vallittu PK ,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 fibers, 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 **(Lassila VP, et al,2014)** therefore, post failure may occur before tooth fracture when force is applied.

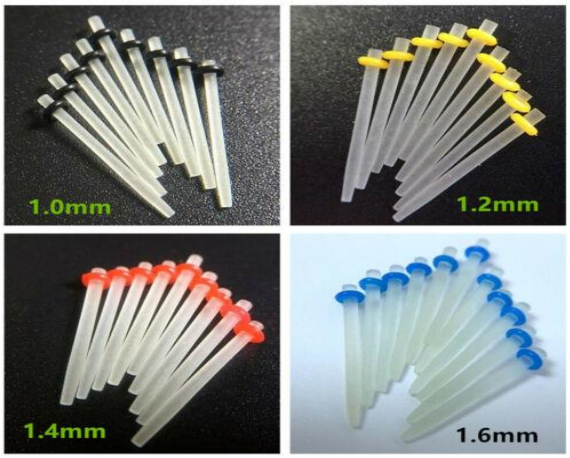

Figure (9) Dental glass fiber post

2.2.3 Customised FRC posts:

These types of fiber posts are also called ―individually formed fiber posts‖. Customised post-and-core systems commonly comprise the use of woven polyethylene (PE) or glass fibers to fabricate endodontic posts that are cemented directly into the root canal. Polyethylene FRC, Ribbond (Ribbond Inc, Seattle, WA, USA), is a post made of plasma treated UHMWPE-woven fiber coated with a dentine bonding agent , which are adapted into the root canal without enlargement and light polymerised in position **(Bell AM, et al ,2002)** Ribbon fiber is biocompatible, aesthetic and translucent. It is used in combination with resin cement and an adhesive, resulting in impact strength and a suitable elastic modulus close to that of dentine **(Eichmiller FC ,2003)** It is believed that PE posts can create a root canal mono-block allowing for a more favourable stress distribution along the root dentine, reducing the incidence of vertical root fracture **(Karlsson U,2011).** However, the strength of PE customized post did not approach that of a cast metal post . A custom-made post system utilising silanated glass fibers impregnated with a semi-IPN polymer matrix has been also developed with the same concept of the individually formed post Because of its pre-curing plastic state, this post can fill the entire space of the root canal with more reinforcing fibers in the cervical portion using minimally invasive preparation and increasing the load-bearing capacity as a potential benefit of this post system **(Ahmed A, 2017)**

Figure (10)customized Polyethylene FRC posts(Ribbond)

Chapter three :

summary

3.1. 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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