journal of prosthodontic research 62 (2018) 281–286

Contents lists available at ScienceDirect

Journal of Prosthodontic Research

journal homepage: www.elsevier.com/locate/jpor

Review

Framework design and pontics of fiber-reinforced composite fixed dental prostheses — An overview

Leila Perea-Lowery[a,*], Pekka K. Vallittu[a,b]

[a] Department of Biomaterials Science and Turku Clinical Biomaterials Centre-TCBC, Institute of Dentistry, University of Turku, Turku, Finland
[b] University of Turku and City of Turku Welfare Division, Oral Health Care, Turku, Finland

ARTICLE INFO

Article history:
Received 18 December 2017
Received in revised form 3 March 2018
Accepted 9 March 2018

Keywords:
Fiber-reinforced composites
Framework design
Pontics
Fixed dental prostheses

ABSTRACT

Purpose: Fiber-reinforced composite (FRC) fixed dental prostheses (FDPs) have shown good performance in clinical applications due to their good mechanical properties and minimally invasive approach. However, typical failure patterns of FRC FDPs are often localized at the pontic site. That reflects the structural considerations at the framework and pontic location that need to be examined when creating these kinds of prostheses.
Study selection: Peer-reviewed articles and other scientific literature were reviewed for providing up-to-date information on how pontics of FRC FDPs can be made. A thorough literature search was done using PubMed and Google Scholar. Two individuals did an assessment of the articles in order to include those related to pontics and framework design of FRC FDPs. The search terms used were “fiber-reinforced dental prosthesis” and “Pontics of fiber-reinforced dental prosthesis”.
Results: These findings indicate that a cross-sectional fiber design, substructure and thicker pontics made of a variety of materials might reduce failures at the pontic site.
Conclusions: The thickness of pontics of FRC FDPs interrelated with the vertical positioning of the FRC framework influences the load-bearing capacities of prostheses of these kinds. The understanding of the factors involved in the fabrication of pontics of FRC FDPs may overcome the drawbacks identified in these prostheses, thus extending their longevity.

1. Introduction

Fiber reinforced composites (FRC) fixed dental prostheses (FDPs) have performed well in clinical applications due to their good mechanical properties and minimally invasive approach. FRCs have been developed considerably in recent decades [1]. They are formed from a polymeric matrix and reinforcing high aspect ratio fillers [2]. These fillers are fibers that reinforce a structure when it receives load. They are usually designed to effectively reinforce a composite against the direction of stress [3]. Fibers are typically used in the form of continuous unidirectional fibers in FDPs although discontinuous glass FRCs have also been developed and tested [4].

A fiber framework is covered by a veneering composite resin. Those two components must form a cohesive unit to allow the correct transfer of loading forces [5,6]. Recently, more natural materials are being used and tailored to be more anisotropic [7]. The fibrous materials have a major impact on the structural design of elements within the natural materials [8]. The use of more fibrous materials provides a higher tensile strength for the framework, usually in the direction of the fibers. The fracture resistance is increased when multiple fiber layers are used as reinforcement [9,10].

As they are more resilient and provide better esthetics than other composites, FRCs are frequently used in a variety of dental applications, including removable prostheses, fixed dental prostheses, and as reinforcement of composites for single restorations [5,11–15].

Different types of FRCs include tooth-retained and implant-retained prostheses. Tooth-retained FRCs are bonded to the surrounding teeth by well proven enamel and dentin bonding systems. This provides support and allows for the use of a conservative approach [6,14,16]. Scarce reviews have been conducted on the evidence to support the use of FRCs in clinical applications [17]. A 2009 review estimated the overall survival of FRC FPDs to be 73 % at 4.5 years [18], while a 2017 study found an overall survival of FPDs to be 94.4 % at 4.8 years [17]. These reviews support their long-term clinical use, though more studies analyzing clinical evidence need to be completed. Recently, a

* Corresponding author at: Itäinen Pitkäkatu 4B (2nd floor), FI-20520, Turku, Finland.
E-mail address: leiper@utu.fi (L. Perea-Lowery).

https://doi.org/10.1016/j.jpor.2018.03.005
1883-1958/

consensus meeting of experts of FRC FPDs stated that glass FRC FPDs are definitive prosthetic solutions which provide good clinical outcomes at least for five to six years [19]. The longest clinical reports for FRC FDPs are over 20 years.

Many factors impact the survival of the FRC, including the type and quality of the fiber material and the overall design, orientation and volume of the framework [5]. Even though FRCs are used as an alternative to replacing missing teeth, their clinical effectiveness has not always been ideal. Common failures occur from delamination of the veneering material and fracture of the pontic [18]. Adhesive failures are reported as the main clinical problem [5,20]. Adhesive and cohesive failures commonly occur at the pontic site [21]. Different pontic designs, enhanced FRC-adhesive resin interfaces and improved inlay preparations are ways to decrease failures [20]. Debonding often requires replacing the veneering material or rebonding the framework. Water sorption, loss of surface luster and fatigue resistance of adhesive interfaces over time are other possible concerns [5,14]. Despite these disadvantages, the advantages posed by the structural and mechanical aspects of FRC FDPs support their clinical application.

While FRCs are an ideal choice for dental applications, the failure patterns localized at the pontic site reflects the structural considerations that need to be examined when creating these kinds of prostheses. In this review, we aimed to evaluate state-of-the-art information on how pontics of FRC FDPs are made and to relate this information to efficient ways to reduce failures.

2. Internal aspects

2.1. Biomechanical aspects

The mechanical properties of FRC materials used to make fixed prostheses have frequently been described [2]. These properties have been found to be superior to that of non-reinforced composites *in vitro*, though more clinical studies need to be conducted to fully gauge their applicability to long-term clinical use [22–24]. The mechanical properties of FRCs generally depend upon several factors: the fiber type, ratio of fiber to matrix resin, fiber architecture and the quality of the fiber and resin used [14]. In order to assure clinical success, the substructure design, and successful chemical bonding is key [14].

FRC FDPs face different biomechanical loads they must account for. As they are subjected to the same kinds of forces as natural teeth, they must be designed to resist those forces [25]. Masticatory forces vary for each tooth, thus biting force must be carefully considered. FRCs are also subjected to tensile stresses which can cause fractures, and shear stresses which can cause debonding [25]. The ability to resist fatigue is important for the longevity of the FRC. FRCs with high aspect ratios demonstrate high toughness and consequently are better equipped to reduce cracking.

The strength of an FRC is mostly influenced by the type and composition of the reinforcing fiber, as well as the fibers properties. The physical properties of dental FRC materials are influenced by a variety of factors, including: tensile strength and elongation of fiber and polymer matrix, impregnation of fibers with resin, adhesion of fibers to the matrix, surface treatment and type of fibers, orientation of fibers, length of fibers, volume fraction of fibers, number and diameter of fibers and location of FRC in the restoration [26,27].

Failure types of continuous and discontinuous FRCs vary from each other. Continuous unidirectional FRCs exhibit the highest strength of all FRCs with the most strength in the direction of the fiber [7]. Clinical studies have reported that the most common mode of failure observed in continuous FRCs are delamination of the veneering composite [20]. Insufficient support at the pontic area contributes to this kind of failure, which can be rectified by orienting a bundle of fibers perpendicular to the longitudinal fibers [22].

The mechanical properties of the framework can be modified by changing orientation of fibers, content and geometry, also known as cross-sectional arrangement or design [28]. It is suggested that the mechanical properties of a FDP can be influenced by how the fibers are incorporated into the polymer. Fiber geometry has a significant influence on the modulus of elasticity (ratio of stress to strain within the elastic range) and toughness of the framework (amount of energy absorbed in failure) [28–30].

Continuous FRCs include unidirectional and bidirectional design. Unidirectional longitudinal fibers provide their reinforcing effect to FRC restorations when the stress is applied perpendicular to the direction of fibers; that is to say that unidirectional fibers are anisotropic [7]. On the contrary, woven fibers have their reinforcing properties in two directions and are orthotropic [31]. The anisotropic properties of FRCs should be taken into account when designing prosthetic devices. The reasoning for that is that the masticatory forces produce stresses that include bending, shear, tensile, compression and torque [32].

It has been found that reinforcing the woven fiber increases the toughness of the framework [28]. Modulus of elasticity and toughness increase when cross-sectional fibers are included at different parts of a structure; modulus of elasticity increases when cross-sectional designs incorporate fiber reinforcement at the compression side of the prosthetic device. Toughness is increased when fibers are included at the tension side of a prosthesis, and as the amount of reinforcement is increased [28].

While the type of fiber is important in terms of the flexural strength and modulus of elasticity, fiber architecture is considered most important [22]. Fiber disposition into a structure can be separated into unidirectional, bidirectional, woven and braided. The reinforcing efficiency of fibers is dependent upon the fiber components, orientation, the ratio of fiber to resin, and the adhesion between fiber and resin matrix [33]. It is understood that unidirectional fibers that lay perpendicular to the load are more effective than fibers that lay in other directions. When FRC FDPs are placed in high–stress bearing areas, it is recommended to choose a material with a high flexural strength, high elastic modulus, and less deformation [33]. This will allow the denture to perform well without cracking when subjected to the various masticatory forces.

2.2. Fiber framework geometry

An FRC framework made of continuous unidirectional fibers offers high flexural strength and load-bearing capacities. Unidirectional fibers provide the FRC with anisotropic mechanical properties and can effectively reinforce the composite parallel to the direction of stress [34]. Studies have found that posterior prostheses tend to fail at a higher rate than those placed in the anterior zone. However, debonding of the prosthesis is commonly reported for both, anterior and posterior [35]. To offer appropriate resistance against occlusal forces and to prevent debonding, connectors should have a cross-sectional design. Circular shaped frameworks have shown to be superior to rectangular-shaped frameworks in resisting fractures [36]. An increased risk for framework fractures has been found when the cross-sectional design of the connector is flat rather than round and thick in the palate–buccal direction in anterior FRC FPDs [37].

Framework design of FRC FDPs in the anterior and posterior area need to be reinforced with additional bundles of fibers to eliminate risk of delamination of the pontics from the framework. The quantity of the fibers impacts the load-bearing capacity of the framework. It is recommended that one bundle of unidirectional glass fibers of 4000 single fibers (TEX-2400) should be placed in