DENTAL MATERIALS 29 (2013) e45–e52

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Mechanical properties and micro-morphology of fiber posts

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ARTICLE INFO

Article history:
Received 23 May 2011
Accepted 1 November 2012

Keywords:
Glass fiber posts
Flexural properties
Three-points bending test
Structural characteristics
Scanning electron microscopy
Tessellation techniques

ABSTRACT

Objectives. To evaluate flexural properties of different fiber posts systems and to morphologically characterize their micro-structure.

Methods. Six types of translucent fiber posts were selected: RelyX Post (3M ESPE), Para-Post Taper Lux (Colthéne-Whaledent), GC Fiber Post (GC), LuxaPost (DMG), FRC Postec Plus (Ivoclar-Vivadent), D.T. Light-Post (RTD). For each post system and size, ten specimens were subjected to a three-points bending test. Maximum fracture load, flexural strength and flexural modulus were determined using a universal loading device (5848 MicroTester®, Instron). Besides, for each system, three intact posts of similar dimensions were processed for scanning electron microscopy to morphologically characterize the micro-structure. The following structural characteristics were analyzed: fibers/matrix ratio, density of fibers, diameter of fibers and distribution of fibers. Data were statistically analyzed with ANOVA.

Results. Type and diameter of posts were found to significantly affect the fracture load, flexural strength and flexural modulus ($p < 0.05$). Regarding maximum fracture load, it was found to increase with post diameter, in each post system ($p < 0.001$). Regarding flexural strength and flexural modulus, the highest values were recorded for posts with the smallest diameter ($p < 0.001$). Finally, structural characteristics significantly varied among the post systems tested. However, any correlation has been found between flexural strength and structural characteristics.

Significance. Flexural strength appeared not to be correlated to structural characteristics of fiber posts, but it may rather be affected by mechanical properties of the resin matrix and the interfacial adhesion between fibers and resin matrix.

1. Introduction

In the last few decades, fiber-reinforced posts have widely been used to restore endodontically treated teeth with a severe loss of dental structure to improve the retention of the build-up material, as alternative to metallic post-and-cores [1–3]. Because their elastic modulus is similar to that of the dentin, they more uniformly distribute stresses along the post-cement–dentin interface and to the remaining tooth structure, thus avoiding stress concentration and minimizing the risk of vertical root fractures [4–6]. Due to the increasing demand of esthetic restorations quartz or glass-fiber posts (white or translucent) have been introduced into the market [7].

Current fiber posts are composed of unidirectional fibers (carbon, quartz or glass) embedded in a resin matrix [1,2].

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0109-5641/$ – see front matter
http://dx.doi.org/10.1016/j.dental.2012.11.001

Fibers are responsible for resistance against flexure, while the resin matrix provides resistance against compression stress and may interact with functional monomers contained in the adhesive cements [8]. It is a general thought that the larger the diameter of the post the higher their resistance to fracture. Some previous researches focused on the effect of the fiber/matrix ratio (surface occupied by fibers per square millimeters) on the flexural properties of fiber posts [9,10]. Others intended to correlate the overall circumference of fibers per square millimeter to the fracture resistance of fiber posts [11]. Regrettably, they revealed contradictory results and it is still not clear how structural characteristics of fiber posts may influence their flexural properties.

The three-point bending test is universally used in material science to test the flexural properties of composite materials [10]. To evaluate structural characteristics of fiber posts scanning electron microscopy (SEM) can be used in order to calculate density and diameter of fibers, fibers/matrix ratio and distribution of fibers. SEM also allows structural defects as bubbles and voids to be detected [9–11]. In partcular, (in)homogeneous distribution of strengthening fibers into a resin matrix may play an important role to determine the mechanical behavior of the whole composite structure. In material science, various methods have been developed for characterizing the spatial distribution of discrete secondary phase bodies on two-dimensional sections [12]. They include field methods, measuring quantities such as number density or area fraction in test areas of varying size, inter-particle spacing methods, most of which are based on the measurement of nearest neighbor distances between particle centroids, and tessellation methods, which are considered more accurate to investigate clustering [13,14]. In details, the Dirichlet (Voronoi) tessellation method is a geometrical technique for partitioning a particles array into a unique set of convex polyhedral, frequently referred to as Voronoi cells, each of which is associated with and contains one of the particles. The tessellation analysis represents particles as point objects. Particle size and morphology are not considered when generating the tessellation. The perimeter of the Voronoi polygons associated with the particles circumscribes all the particles in the plane that are closer to that particle than to any other in the particle array. The boundary of the polygons is the locus of those points that are equidistant from the selected particle and the neighbor particle. Thus, the immediate neighborhood of any particle is then fully and conveniently defined in terms of points sharing cell edges. Clearly, this technique not only uniquely partitions the plane but also yields a unique definition of neighbors. Moreover, some properties of the tessellation may be derived analytically.

Aim of this study was to evaluate flexural properties of different fiber post systems and to morphologically characterize the micro-structure, in order to evaluate whether or not structural characteristics may influence the flexural strength. The hypotheses tested were that (1) the type of fiber post and (2) the diameter of posts affect the flexural properties of different post systems and that structural characteristics, namely (3) density of fibers, (4) diameter of fibers, (5) fibers/matrix ratio and (6) distribution of fibers influence flexural strength.

2. Materials and methods

Six translucent fiber posts systems reinforced with continuous unidirectional fibers were tested (Table 1). Three more fiber posts of similar dimensions were processed for the morphological analysis (scanning electron microscopy).

2.1. *Three-points bending test (Fig. 1)*

For each fiber post system, ten specimens of all different sizes, as provided by manufacturers, were subjected to a three-point bending test using a universal loading device (5848 MicroTester®, Instron, Norwood, MA, USA). Each test was performed according to the ISO 10477 standard at a cross-head speed of 1 mm/min with a loading angle of 90°. The cross-sectional diameter of loading tip and extreme supports was 2 mm. The span length (distance between the two supports) was fixed at 10.0 mm. In order to exclude the conical end of some posts from the loading application area, the parallel-sided cylindrical part of the post was considered to be the specimen.

Maximum fracture load, flexural strength and flexural modulus were measured and load–deflection curves were recorded with PC-software (Bluehill 2).

Flexural strength (δ_f) was calculated from the formula:

$$\delta_f = \frac{8F_{max}l}{\pi d^3}$$

with F_{max} being the applied load (N) at the highest point of load–deflection curve, l being the span length (10.0 mm), and d being the diameter of the specimens.

Flexural modulus (E_f) was calculated from the formula:

$$E_f = \frac{S4l^3}{3\pi d^4}$$

with $S = F/D$ being the stiffness (N/m) and D being the deflection corresponding to load F at a point in the straight-line portion of the trace.

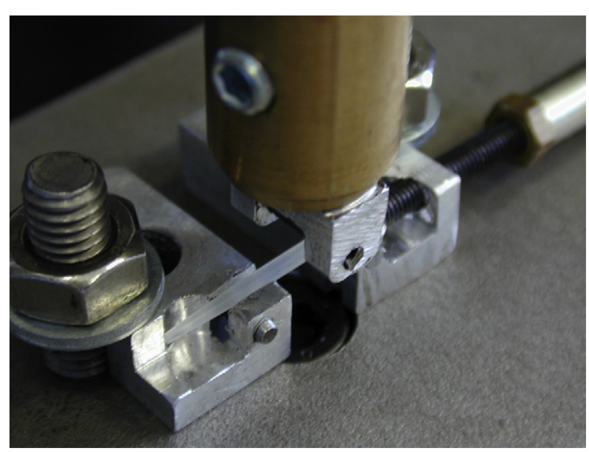

Fig. 1 – Study set-up. Three-points bending test. A span length of 10.0 mm was considered, in order to exclude the conical end of some posts from the loading application area.