Materials Science and Engineering C 59 (2016) 855–862

Contents lists available at ScienceDirect

Materials Science and Engineering C

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

Development of new radiopaque glass fiber posts

Gabriel Furtos [a,*], Bogdan Baldea [b], Laura Silaghi-Dumitrescu [a]

[a] Raluca Ripan Institute of Research in Chemistry, Babes-Bolyai University, Cluj-Napoca, Romania
[b] Dep. of Prosthodontics, Faculty of Dental Medicine, Timisoara, Romania

ARTICLE INFO

Article history:
Received 27 September 2014
Received in revised form 7 October 2015
Accepted 29 October 2015
Available online 31 October 2015

Keywords:
Radiopacity
Fiber reinforced post
X-ray

ABSTRACT

The aim of this study was to analyze the radiopacity and filler content of three experimental glass fiber posts (EGFP) in comparison with other glass/carbon fibers and metal posts from the dental market.
Three EGFP were obtained by pultrusion of glass fibers in a polymer matrix based on 2,2-bis[4-(2-hydroxy-3-methacryloyloxypropoxy)-phenyl]propane (bis-GMA) and triethyleneglycol dimethacrylate (TEGDMA) monomers. Using intraoral sensor disks 27 posts, as well as mesiodistal sections of human molar and aluminum step wedges were radiographed for evaluation of radiopacity. The percentage compositions of fillers by weight and volume were investigated by combustion analysis.
Two EGFP showed radiopacity higher than enamel. The commercial endodontic posts showed radiopacity as follows: higher than enamel, between enamel and dentin, and lower than dentin. The results showed statistically significant differences ($p < 0.05$) when evaluated with one-way ANOVA statistical analysis. According to combustion analyses, the filler content of the tested posts ranges between 58.84 wt.% and 86.02 wt.%. The filler content of the tested EGFP ranged between 68.91 wt.% and 79.04 wt.%.
EGFP could be an alternative to commercial glass fiber posts. Future glass fiber posts are recommended to present higher radiopacity than dentin and perhaps ideally similar to or higher than that of enamel, for improved clinical detection. The posts with a lower radiopacity than dentin should be considered insufficiently radiopaque. The radiopacity of some glass fiber posts is not greatly influenced by the amount of filler.

1. Introduction

Endodontically treated teeth with insufficient coronal dental tissue need posts and a core in order to support the final prosthetic restoration. Some studies showed that posts do not strengthen teeth, and that they are used only to support the retention of a core that does not have sufficient coronal dentin to support occlusal function [1]. Furthermore, the preparation of a post space may increase the risk of root fracture and treatment failure [2]. Factors such as mechanical properties, design, translucency, and radiopacity are very important in selecting a post. The success of the procedure depends on the properties of the post but also on other indirect factors such as cement, core material, crown and the quality of the endodontic treatment. As an esthetic alternative to metal and carbon fiber post, transparent quartz fiber posts with light conductive properties were introduced [3].

While metallic and ceramic posts were radiopaque, the carbon fiber posts introduced in 1990 [4] and the glass fiber posts (GFP) showed insufficient or missing radiopacity [5]. The radiopacity is as important as the recognition of faulty proximal contours, detection of secondary caries [6], voids, marginal adaptation, and interfacial gaps on the radiograph [6,7]. A radiopaque post provides an easy evaluation at the interface with the root canal space [8] and helps the clinician in establishing a correct diagnostic of the technical failures, loss of retention, root fractures, post fracture or periapical lesion [9]. Carbon fiber posts could be clinically and radiographically unremarkable [10]. The main components of GFP are glass fibers and polymers which are practically radiolucent. All glass fibers contain amorphous silicon dioxide as the main component. AR glass fibers with ZrO_2 content could be an alternative to various other glass fibers (E-, R-, or S-) used in dentistry [11–13]. Addition of radiopaque compounds could improve radiopacity — depending on the type of compounds and their quantities [14,15]. For fixation of the post, a radiopaque dental cement is applied to the root canal walls. Unfortunately, in most cases a radiopaque dental cement did not provide sufficient radiopacity [14] for easy radiographic evaluation of post/core assembly; most likely, this was because the cement was applied in a too thin layer around a GFP [16]. Also, an optimal radiopacity of GFP can provide advantages when using new techniques of 3D visualization of tooth and oral structures by cone-beam computerized tomography (CBCT) [17]. Considering that there are many GFP on the commercial market, an evaluation in the same radiographic condition using a reference human dentin and enamel will help clinicians.

Today, using a GFP with improved radiopacity, good mechanical properties, translucency and adhesion to dental cement, could be an

* Corresponding author at: Dep. of Dental Materials, Raluca Ripan Institute of Research in Chemistry, Babes-Bolyai University, 30 Fantanele Street, 400294 Cluj-Napoca, Romania.
E-mail address: gfurtos@yahoo.co.uk (G. Furtos).

http://dx.doi.org/10.1016/j.msec.2015.10.091
0928-4931/

ideal clinical decision. Improving the interfacial adhesion strength between the fiber and the epoxy resin matrix, as well as the mechanical properties was possible using a coupling agent or argon plasma [18]. Replacing the epoxy resin with methacrylate systems similar to the resin matrix for dental restorative treatments, could represent an advantage for adhesion to the dental cement. Using a polymer matrix based on 2,2-bis[4-(2-hydroxy-3-methacryloyloxypropoxy)-phenyl]propane (bis-GMA), triethyleneglycol dimethacrylate (TEGDMA) for obtaining new GFP could create a favorable outcome due to the close chemical compatibility of GFP with the dental cement.

The aim of this study was to investigate the radiopacity and the influence of the filler content of experimental glass fiber posts (EGFP) based on alkaline resistant (AR) glass fibers for improving the radiopacity. These new EGFP were compared to "wired" glass fiber posts (WGFP); "wired" carbon fiber posts (WCFP); carbon fiber posts (CFP) and metal posts (MP). Post materials were also investigated for the percentage of fillers by weight and volume. The null hypotheses were: (1) that there is no difference in radiopacity of posts, human enamel or dentin and (2) that the percentage of fillers by weight and volume could be correlated with the radiopacity of each composite material.

2. Materials and methods

2.1. Materials

The reagent grade chemicals ZrO_2 powder (Aldrich Chemical, Milwaukee, WI, USA), 2,2-bis[4-(2-hydroxy-3-methacryloyloxypropoxy)-phenyl]propane (bis-GMA, Aldrich Chemical, Milwaukee, WI, USA), triethyleneglycol dimethacrylate (TEGDMA, Sigma Chemical, St. Louis, MO, USA). Camphorquinone (CQ) and N,N-dimethylaminoethyl methacrylate (DMAEMA) constituted the photoinitiator system and were supplied by Merck–Schuchardt, Germany. Silane A-174 (γ-methacryloxypropyl-1-trimethoxysilane) was purchased from Aldrich Chemical, Milwaukee, WI, USA, and used as an adhesion promoter for glass fibers. All materials were used as received without any further purification.

2.1.1. Glass fibers

Unidirectional alkaline resistant (AR) glass fibers bundles were treated with γ-methacryloxypropyl-1-trimethoxysilane (silane A-174) — 1 wt.% silane A-174 to the amount of glass fibers. The silane solution was prepared by dissolving silane A-174 in ethanol–water 90/10 vol.% acidified to pH 3.8, and maintained at this level using glacial acetic acid. The glass fiber roving was maintained in this solution for 1 h. After that, the silane layer was dried and cured at 110 °C for 2 h. The A-174 silane is currently used as a coupling agent in dentistry and contains an ester functional group on one end, able to react with the OH-groups of the glass fiber surface after hydrolysis of the methoxy groups from the silane. At the other the A-174 silane features a methacrylate group able to make a new —C—C— covalent bond with methacrylate groups from monomers when the polymerization reaction starts. Thus, the fillers will be compatible with the resin before curing and able to be connected to the polymer matrix after curing.

2.1.2. Obtaining the experimental glass fiber posts

An experimental organic matrix was obtained from bis-GMA (60 wt.%) and TEGDMA (40 wt.%) in which the light-curing initiating system was dissolved, consisting of DMAEMA (1 wt.%) and CQ (0.5 wt.%). The light-curing monomer mixtures (L_0) were mixed with the inorganic fillers (ZrO_2 powder, 20 wt.% and 50 wt.%) for obtaining the light-cured resin composites (L_{20} and L_{50}). Three experimental glass fiber posts were obtained as previously described [19], by pultrusion of unidirectional glass fibers with L_0, L_{20} and L_{50}. EGFP 1 was obtained by applying 0.80 g of light-curing resin (L_0) to 20 cm length of the glass fiber roving, followed by pultrusion of transparent glass tubes of 20 cm length and inside diameter of 1.51 mm. The design for obtaining the EGFP is depicted schematically in Fig. 1. EGFP 2 and 3 were obtained by applying 1.02 g L_{20} and 1.65 g L_{50} to the same length of the glass fiber roving with pultrusion in the same transparent glass tube. The glass fiber roving mixed with excess of light-cured resin composites were guided to enter and pass through the transparent glass tube. Under this force, the fibers undergo a rearrangement and the fibers with ZrO_2 and resin are organized into a compact shape, while air bubbles and excess resin are squeezed out at the entering of the tube. When the glass fiber roving with light-curing resin composites were pultruded until the end of tube, visible light was applied from an Optilux 501 halogen curing light (Kerr/Demetron, λ_{max} 400–505 nm, intensity > 690 mW/cm^2) [19]. The dental curing light guide tip had an 8 mm diameter and was applied on the length of the glass tube mold containing the post, for light-curing 60 s/one section. After curing, the glass fiber posts were pultruded out from the glass mold. The resulting EGFP 1, 2 and 3 can be seen in Fig. 2.

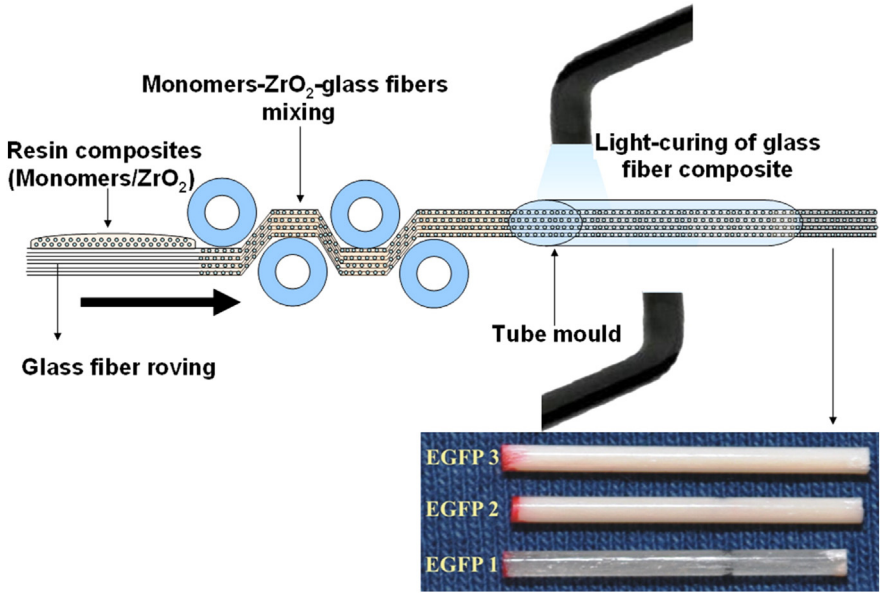

Fig. 1. Schematic design of the obtaining experimental glass fiber posts.