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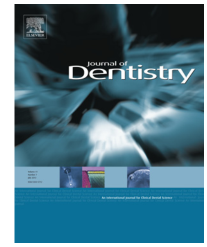

Preparation and characterisation of poly p-phenylene-2,6-benzobisoxazole fibre-reinforced resin matrix composite for endodontic post material: A preliminary study

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ABSTRACT

Objectives: Currently used fibre-reinforced composite (FRC) intracanal posts possess low flexural strength which usually causes post fracture when restoring teeth with extensive loss. To improve the flexural strength of FRC, we aimed to apply a high-performance fibre, poly p-phenylene-2, 6-benzobisoxazole (PBO), to FRCs to develop a new intracanal post material.

Methods: To improve the interfacial adhesion strength, the PBO fibre was treated with coupling agent (Z-6040), argon plasma, or a combination of above two methods. The effects of the surface modifications on PBO fibre were characterised by determining the single fibre tensile strength and interfacial shear strength (IFSS). The mechanical properties of PBO FRCs were characterised by flexural strength and flexural modulus. The cytotoxicity of PBO FRC was evaluated by the MTT assay.

Results: Fibres treated with a combination of Z-6040 and argon plasma possessed a significantly higher IFSS than untreated fibres. Fibre treated with the combination of Z-6040-argon-plasma FRC had the best flexural strength (531.51 ± 26.43 MPa) among all treated fibre FRCs and had sufficient flexural strength and appropriate flexural moduli to be used as intracanal post material. Furthermore, an *in vitro* cytotoxicity assay confirmed that PBO FRCs possessed an acceptable level of cytotoxicity.

Conclusions: In summary, our study verified the feasibility of using PBO FRC composites as new intracanal post material. Although the mechanical property of PBO FRC still has room for improvement, our study provides a new avenue for intracanal post material development in the future.

Clinical significance: To our knowledge, this is the first study to verify the feasibility of using PBO FRC composites as new intracanal post material. Our study provided a new option for intracanal post material development.

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1. Introduction

An endodontically-treated tooth usually becomes susceptible to fracture as a result of factors such as extensive loss of coronal tooth [1], loss of moisture [2], effects of endodontic irrigants and medicine on dentine [3], and bacteria-dentine interaction [4]. To overcome these challenges, an intracanal post is commonly employed to restore the endodontically-treated tooth, especially in the treated tooth with extensive loss of coronal tooth.

Prefabricated posts were introduced in the 1960s with the advent of endodontic therapy [5]. The ideal intracanal post material should possess good aesthetics and good mechanical properties as well as biocompatibility. Traditional intracanal posts used in dentistry were made of metallic material. The main drawback of metal posts was their flexural modulus which was significantly higher than that of dentine, which usually led to root fracture [6]. In addition, metal posts presented shortcomings such as the tendency to cause allergic reactions, the tendency to undergo corrosion (especially if composed of stainless steel) and lack of aesthetic appeal.

Ideal posts should have mechanical properties and behaviour similar to that of teeth, *i.e.*, they should distribute stress evenly and resist fracture [7]. To overcome the shortcomings of metal posts, low-modulus, fibre-reinforced posts were introduced in the 1990s to address the concerns of stainless steel and titanium alloys. The modulus of elasticity of a fibre post is comparable to dentine (~20 GPa) [8] and is 5–10 times less rigid than high-modulus stainless steel or titanium allowing the post to absorb stress and greatly reduce the risk of root fractures [9,10]. Carbon fibre, glass fibre, and quartz fibre have been used as reinforcement for fibre-reinforced composite (FRC) posts [11]. Common benefits of these FRC posts include their appropriate flexural moduli (which are comparable to that of human dentine) [12] as well as improved aesthetics [13]. However, the FRC posts currently used still have shortcomings.

Due to their reduced flexural strength compared to metal, post fracture is the most frequent complication when FRC posts are used to restore teeth with extensive loss of coronal tooth [14]. This shortcoming restricts the clinical application of FRC posts [15]. Therefore, development of an intracanal post material with ideal flexural strength, comparable flexural modulus with dentine, good biocompatibility and aesthetics is necessary. Recent research has focused on improving intracanal post materials by replacing the reinforced fibres in the FRC [16].

A fibre reinforced resin composite material is composed of reinforcing fibres and a resin matrix. Compared to homogeneous materials, composite materials are characterised by better functional and structural design [17].

Improvements in the mechanical properties of composite materials can be achieved by modifying the material properties of the components, thereby changing the overall composition of the FRCs [18]. It has been reported that the mechanical properties of FRCs could be improved by altering their fibre reinforcement fraction, Abdulmajeed et al. [19] suggesting that fibre reinforcement is crucial for the flexural strength of the FRC. Therefore, introducing high performance fibres into the FRC may generate new intracanal post material with better mechanical properties.

Among all high-performance fibres, poly(p-phenylene benzobisoxazole) (PBO) fibre possesses a thermal stability, specific tensile stiffness, and specific tensile strength that surpasses all other fibres [20]. PBO FRCs have been widely used in industry, aviation and the military [21]. In recent years, PBO fibres have been successfully introduced into biomaterials. Lobodzinsk and Laks [22] have successfully incorporated PBO fibres into implantable cardiac leads which possess a superior mechanical strength and flexural modulus as well as excellent electrical conductivity at a reduced diameter. In another case, Tokuda et al. have used PBO fibre composite in the construction of a knitted stent which demonstrates an ability to expand comparable to that of metallic stents while providing better kink resistance [23]. These reports have implied that it is feasible to apply PBO fibres and PBO FRC to the development of other biomedical products such as intracanal posts. Owing to its excellent mechanical characteristics, application of PBO reinforced fibre composites to intracanal posts may provide an intracanal post with high flexural strength. So far, PBO fibres have not yet been used as dental biomaterials. The aim of this study was to evaluate the feasibility of applying PBO fibres to FRCs in order to develop a new intracanal post material.

A major defect of PBO fibres lies in their surface smoothness and chemical inertness which could interfere with their ability to bond to the resin matrix in the FRC [24]. The adhesion between the fibres and the resin is a primary factor in stress transfer and affects the mechanical properties of FRC [25]. It has been reported that improvement in interfacial adhesion strength relies on formation of new chemical bonds between fibre surface and resin matrix [26]. Choosing the proper surface modification method for altering the surface of PBO fibres, so as to increase the interfacial adhesion strength between the fibres and currently used dental resins, is a critical step in development of PBO FRC posts. In this study, we applied two well developed surface modification methods, coupling agent 3-glycidoxy-propyl-trimethoxysilane (Z-6040) and argon plasma, to treat PBO fibres. The modified PBO fibres were incorporated into a currently used epoxy resin matrix to yield FRCs whose mechanical characteristics were evaluated through flexural modulus and flexural strength testing. The null hypothesis of this study is, "there is no significant difference between untreated and surface-modified PBO FRC, regarding the mechanical properties." The cytotoxicity of PBO FRC was also confirmed *in vitro*.

2. Materials and methods

2.1. Materials

For the resin curing system, bisphenol-a-type epoxy resins (E-51), with an epoxy value of 0.48–0.54, was supplied by Wuxi Resin Factory of China. Methyltetrahydrophthalic anhydride (MeTHPA, Jiaxing Jinghua Chemical, China) was used as a curing agent. 2,4,6-tris(dimethylaminomethyl) phenol (DMP-30, Sinopharm Chemical Reagent, China) was used as a curing accelerator. Poly (p-phenylene-2,6-benzobisoxazole) (PBO)