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Applicability of bacterial cellulose as an alternative to paper points in endodontic treatment

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ABSTRACT

Dental root canal treatment is required when dental caries progress to infection of the dental pulp. A major goal of this treatment is to provide complete decontamination of the dental root canal system. However, the morphology of dental root canal systems is complex, and many human dental roots have inaccessible areas. In addition, dental reinfection is fairly common. In conventional treatment, a cotton pellet and paper point made from plant cellulose is used to dry and sterilize the dental root canal. Such sterilization requires a treatment material with high absorbency to remove any residue, the ability to improve the efficacy of intracanal medication and high biocompatibility. Bacterial cellulose (BC) is produced by certain strains of bacteria. In this study, we developed BC in a pointed form and evaluated its applicability as a novel material for dental canal treatment with regard to solution absorption, expansion, tensile strength, drug release and biocompatibility. We found that BC has excellent material and biological characteristics compared with conventional materials, such as paper points (plant cellulose). BC showed noticeably higher absorption and expansion than paper points, and maintained a high tensile strength even when wet. The cumulative release of a model drug was significantly greater from BC than from paper points, and BC showed greater compatibility than paper points. Taken together, BC has great potential for use in dental root canal treatment.

1. Introduction

Dental caries results from enamel erosion induced by bacteria and acid, and can progress to infection of the dental pulp if left untreated. Dental pulp necrosis is followed by spread of the infection or leakage of bacterial metabolites, which causes periapical inflammation, and dental root canal treatment is subsequently needed [1] (Fig. 1).

A major goal of dental root canal treatment is to provide complete decontamination of the dental root canal system. Dental root canal asepsis is performed by a series of sequential treatment steps which include mechanical instrumentation and chemical irrigation. Recently various dental root canal treatment techniques have been developed. For example, many substances such as acids, chelating agents, proteolytic enzymes, alkaline solutions, oxidative agents, local anesthetic solutions and saline have been used as root canal irrigants [2]. In addition, the use of ultrasonic energy has been used in tandem with dental root canal irrigation [3–5]. Both approaches are effective in the elimination of bacteria. However, the conventional treatments also have limitations [6], and reactivation of infection is fairly common in root canal treated teeth [7].

The morphology of the dental root canal system is complex and many human dental roots have inaccessible areas, such as the apical canal ramifications and the isthmus, as well as other morphological irregularities [8]. Most endodontic bacteria remain suspended in the fluid phase of the dental root canal, and dense bacterial aggregates adhere to the dental root canal walls [9]. The success of dental root canal treatment is determined by factors such as the removal of pulpal remnants, dentinal fillings, and irrigant solution [9,10].

In conventional dental root canal treatment (Fig. 1) cotton pellets and a paper point (plant cellulose) have commonly been used to dry the dental root canal, which is then plugged with chemical substances, such as calcium hydroxide, aldehydes (e.g. formocresol), halides (e.g. iodine in potassium iodide), calcium hydroxide, antibiotics, or various combinations of these substances, as intracanal medication [6,11]. The cotton pellets and paper points

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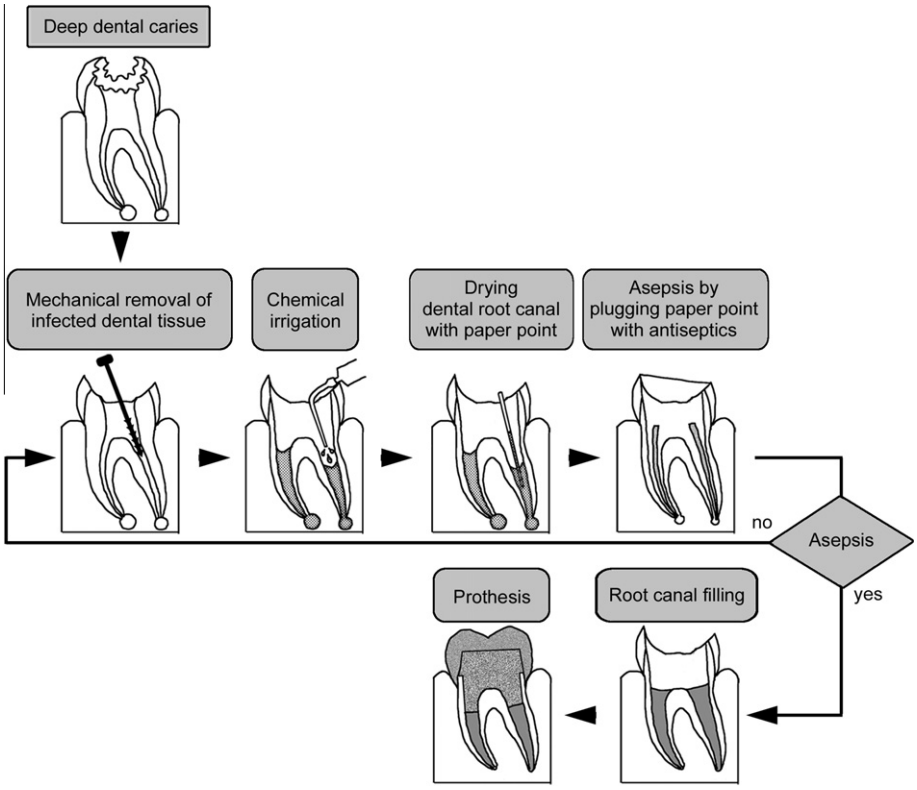

Fig. 1. Schema of dental root canal treatment using a conventional paper point.

traditionally used have remained largely unchanged. Therefore, sterilization of the dental root canal requires a novel treatment material with high absorbency (to remove residue), the ability to improve the efficacy of intracanal medication, and high biocompatibility.

Bacterial cellulose (BC), which is well known as the Asian dessert Nata de Coco, is produced by certain strains of bacteria. The properties and characteristics of BC are substantially different from those of conventional plant cellulose [12–15], and BC is distinguished by a high degree of crystallinity, mechanical strength, and absorptive capacity [16,17]. Furthermore, BC has recently been studied for use as a cartilage scaffold [16,18], component of wound dressing [19], vascular graft [20], and DNA separation medium [21]. Similarly, processed BC products have been studied for guided tissue regeneration in periodontal treatment [22]. It is also utilized in the construction of a commercially available vibration membrane used in the diaphragm of electroacoustic transducers [23].

BC has different properties to plant cellulose, even though both exhibit similar properties when used as a traditional treatment material. We therefore hypothesized that BC will serve as a superior dental canal treatment material for intracanal asepsis. The aim of this study was to clarify the applicability of BC as a novel material for dental canal treatment with regard to solution absorption, expansion, tensile strength, drug release, and biocompatibility.

2. Materials and methods

Test specimens were evaluated for absorbability, expansion, and tensile strength, and the following test solutions that mimic those in the living body were selected: saline, K^+-free electrolyte fluid, and electrolyte fluid. In the biocompatibility evaluation reactions with the following three tissues were examined: subcutaneous tissue, muscle, and the periosteum, as a periapical tissue. The biological tests were performed in compliance with the Guidelines for Animal Experimentation of the Center for Integrated Research in Science, Shimane University.

2.1. Specimen preparation

Two strains of *Acetobacter hansenii* (ATCC 700178 and ATCC 35059, Sumisho Pharma International, Tokyo, Japan) were purchased from the American Type Culture Collection (Manassas, VA), and cell cultures were grown at 28 °C for 72 h at 101.3 kPa pressure (20 vol.% oxygen) in a 15 ml tube. The cell suspension was inoculated with the culture at 10 vol.% in a 10 mm diameter Petri dish. BC wet pellicles were produced by static culture [24] in CSL-Frc medium [25] at 28 °C at 101.3 kPa pressure (20 vol.% oxygen) for 70 (ATCC 700178) or 100 h (ATCC 35059) to a thickness of approximately 1 mm. BC wet pellicles were autoclaved (20 min, 105 °C, 19.6 kPa) in deionized water, and the process was repeated three times. BC sheets were then created by freezing and drying BC wet pellicles using a freeze dryer (FDU-1200, EYALA, Tokyo, Japan) and pressing into sheets with a thickness of approximately 100 μm using a small press (J-1, AS ONE, Osaka, Japan) (Fig. 2). BC sheets were rolled into a point form standardized according to ISO 45 (tip size 45 μm with a 9% taper). Commercially available paper points (PP) (ISO 45 JM paper point, Morita, Osaka, Japan) were used as controls.

Tensile strength was estimated in the uncoiled state using a scanning electron microscope (S-4800, Hitachi, Tokyo, Japan). The specific surface areas of the sheets were estimated by the nitrogen absorption/desorption method (Flowsorb III, Shimadzu, Kyoto, Japan).

2.2. Solution absorption and expansion

BC and PP were weighed with a digital balance (AL104, Mettler-Toledo, Zürich, Switzerland) to a precision of ±0.1 mg to determine