Materials Letters 121 (2014) 89–92

Contents lists available at ScienceDirect

Materials Letters

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

Polyethylene-glycol coated maghemite nanoparticles for treatment of dental hypersensitivity

Ali Dabbagh [a,*], Noor Hayaty Abu Kasim [b], Marina Mohd Bakri [b], Hakimeh Wakily [b], Chanthiriga Ramasindarum [b], Basri Johan Jeet Abdullah [a]

[a] Faculty of Medicine, University of Malaya, 50603 Kuala Lumpur, Malaysia
[b] Faculty of Dentistry, University of Malaya, 50603 Kuala Lumpur, Malaysia

ARTICLE INFO

Article history:
Received 22 June 2013
Accepted 21 January 2014
Available online 27 January 2014

Keywords:
Magnetic materials
Biomaterials
Nanoparticles
Diffusion

ABSTRACT

Dental hypersensitivity is a common oral problem that is directly related to the number and the diameter of dental tubules. Therefore, the occlusion of the tubules using compounds capable of penetrating and precipitating into dental tubules may result in a long-lasting remedy to this problem. In this in-vitro study, the ability of polyethylene-glycol coated maghemite nanoparticles for treating dental hypersensitivity was investigated. Due to their superparamagnetic characteristics, these nanoparticles are susceptible to navigation inside the dental tubules via an external magnetic field. The experiments were performed in various durations for the purpose of determining the optimum time for the effective occlusion of dental tubules. Our findings showed that the polymer-coated maghemite nanoparticles exhibited a significant potential for reducing the permeability of dental tubules by occluding the open tubular area after a 120 min.

1. Introduction

Dental hypersensitivity is defined as "a short sharp pain arising from exposed dentin in response to stimuli typically thermal, evaporative, tactile, osmotic, or chemical and which cannot be ascribed to any other form of defect, pathology, or disease" [1]. In other words, it means a painful response to stimuli(s) that is not normally associated with pain [2]. The main cause of dental hypersensitivity is open dental tubules (microscopic channels in the dentin), which serve as direct links between the external environment and the pulp. Previous studies have demonstrated that the dental tubules in hypersensitive dentins are larger in both number and diameter compared to non-sensitive dentin [3]. Therefore, it can correctly be assumed that the severity of dental hypersensitivity is related to the number and width of dental tubules.

Dental tubule occlusion is one of the principal strategies for the treatment of dental hypersensitivity which involves the use of compounds that can precipitate inside the tubules and plug their orifices. However, the micron-sized diameter of dental tubules presents a physiological limitation for diffusion of large therapeutic compounds. Therefore in this protocol, fine particle size is crucial as it allows a faster and deeper deposition of particles inside the dental tubules. Based on this fact, several biomaterials have been synthesized in the nanoscale for treatment of dental hypersensitivity, including gold [4], hydroxyapatite [5], carbonate apatite [6], calcium oxide–mesoporous silica [7], and nanolipid carriers [8]. Although these agents have yielded promising results, the navigation of such nanoparticles inside the tubules remains a challenge [9].

In this research, we have studied the possibility of using polyethylene-glycol coated maghemite nanoparticles (PEG-MNPs) for treating dental hypersensitivity. We assumed that the maghemite nanoparticles (MNPs) could be navigated inside the tubules via an external magnetic field. The PEG coating acts as a protective layer for minimizing the aggregation and biofouling of MNPs in physiological conditions for long periods [10–12]. The biocompatibility of both PEG and maghemite compounds makes the PEG-MNPs attractive candidates for the fast and effective treatment of dental hypersensitivity.

2. Materials and methods

Maghemite nanoparticles were synthesized via the modification of the recipes described in literature [13,14]. In our method, the synthesis was performed in an aqueous medium and air atmosphere (instead of nitrogen) for a more facile production of nanoparticles. In a typical synthetic process, 1.0 mL of 2 M ferrous sulfate heptahydrate ($FeSO_4 \cdot 7H_2O$) and 3.5 mL of 1 M ferric

* Corresponding author. Tel.: +603 7949 4422; fax: +603 7956 2253.
E-mail address: dabbagh.ali@siswa.um.edu.my (A. Dabbagh).

0167-577X/$ - see front matter © 2014 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.matlet.2014.01.120

chloride ($FeCl_3$) were mixed in 25 mL of distilled water, and then 25 mL of ammonium hydroxide (NH_4OH, 33% NH_3 in water) solution was added dropwise under vigorous stirring. After 2 h, the synthesized maghemite nanoparticles were separated using a magnetic field, washed with ethanol, and dried in 80 °C for 24 h.

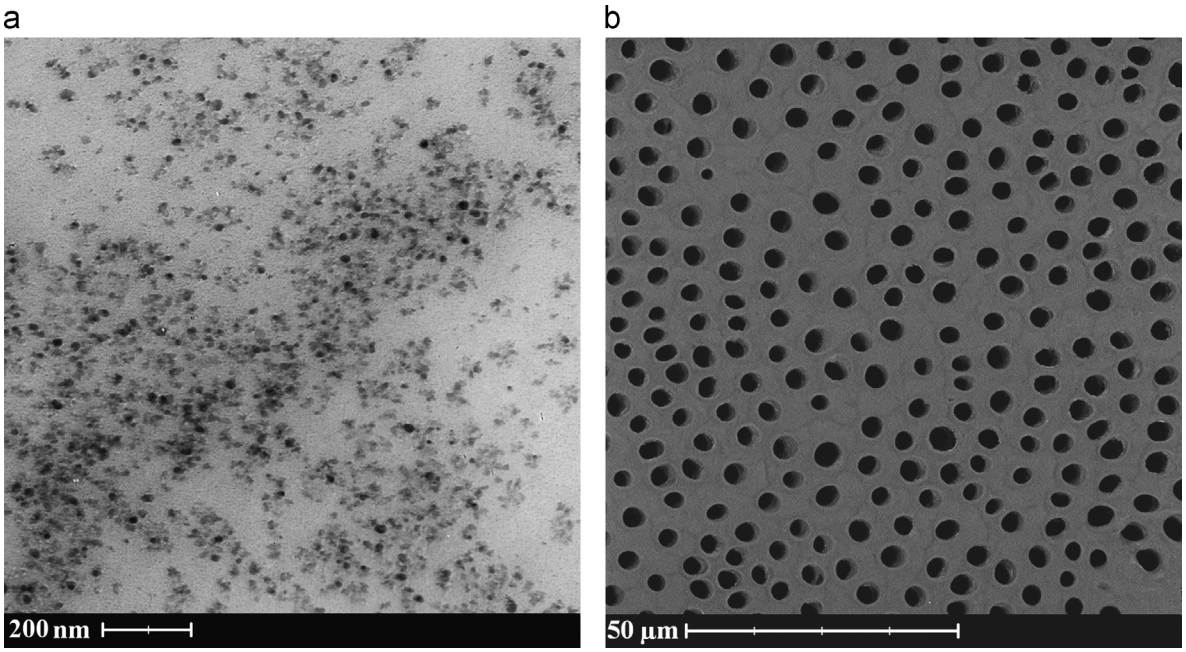

Fig. 1. (a) TEM image of PEG-MNPs synthesized by "graft-to" method. (b) A typical specimen before treatment. The smear layer is completely removed and dental tubules are open (magnification: 2260 ×).

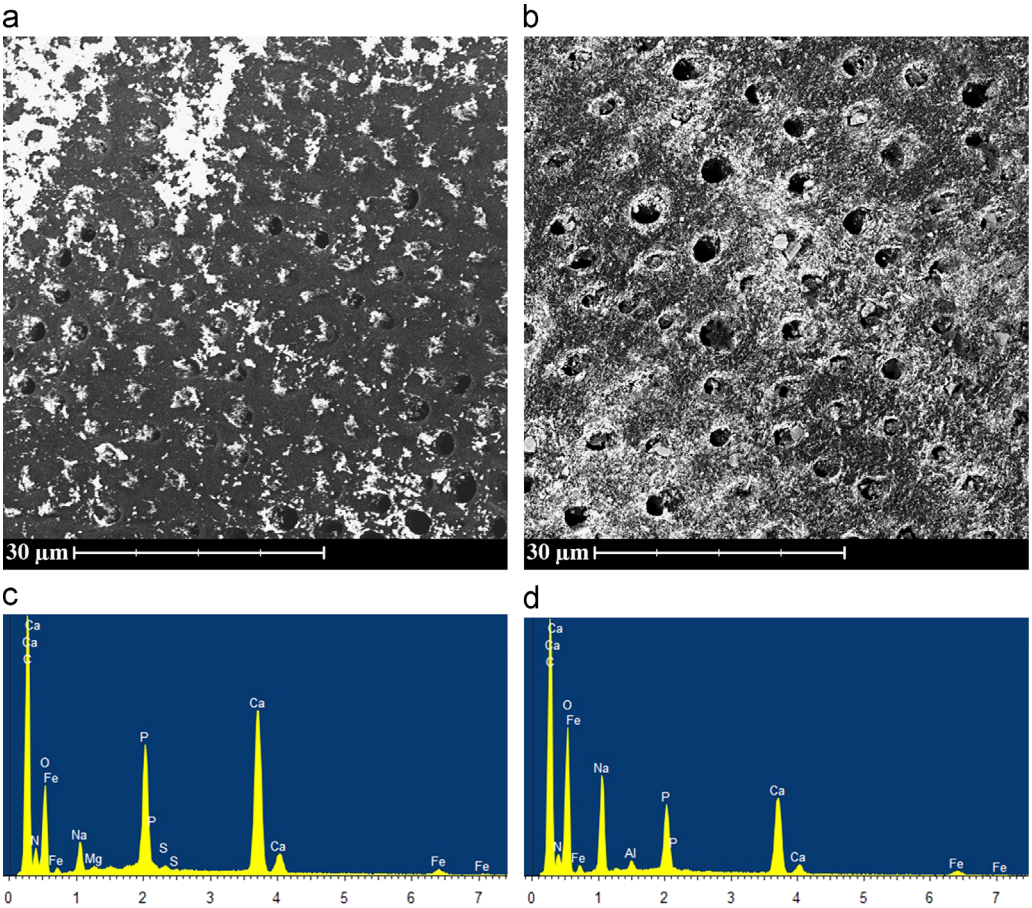

Fig. 2. Two different tubular occlusion modes by PEG-MNPs in M60 specimens, before rinsing with water: (a) intra-tubular precipitation and (b) superficial obliteration (magnification: 4000 ×). EDX analysis of particles (c) attached to the tubular walls and (d) obliterated the tubular openings.