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Electrophoretic encapsulation for slow release of vancomycin from perpendicular TiO_2 nanotubes grown on Ti6Al4V electrodes

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Abstract

Ordered perpendicular TiO_2 nanotubes (TNT) with 405 to 952 nm length and 60 to 90 nm diameter were grown via 40 to 120 min anodization of Ti6Al4V flat substrates. The samples were called TNT-40, −60, −80, −100, and −120. Vancomycin was loaded on the bare and anodized electrodes by separate immersion and electrophoretic (EP) deposition procedures. EP loading resulted in storage capacity of 5221.86 μg cm^{-2} for TNT-80 which was much higher than 1036.75 μg cm^{-2} of immersed sample. Drug release comprised of three stages: (i) burst release (78% for the bare, and 23% for the TNT-80 sample), (ii) gradual transport (21% for the bare, and 64% for the TNT-80 sample), and (iii) equilibrium. Transfer from all electrophoretically loaded TNT samples obeyed semi-infinite diffusion mechanism with a diffusion coefficient of 1.5×10^{-15} cm^2 s^{-1}. However, for bare specimens, external transfer prevailed. Anti-bacterial tests showed a bacteria-free region of 318 mm^2 on the drug-loaded anodized samples during the initial stage of drug release; while 254 mm^2 of bacteria-free region existed on the drug-loaded bare plates. Drug loading capacity of the anodized samples was enough for most biomedical applications. Ti6Al4V anodization proved a viable strategy for prosthesis drug loading and release.

1. Introduction

Eager interest in utilization of Ti base implants for hard tissue replacement has flourished during recent years [1–4]. Appropriateness of titanium base alloys has been ascertained by their biocompatibility, mechanical strength, low density and suitable electrochemical performance [2, 5]. Inadequate bioactivity has, however, been considered as a deplorable weakness in titanium and most other metallic alloys [6, 7]. Although the implants can provide many benefits, they may incur some problems such as infections and hence increase in the after treatment costs. A matter of concern has been local inflammation, bacterial infection (osteomyelitis) and bone destruction which impair bone healing [8, 9]. Compensation of these complications has been a challenging treatment of infections which has involved prolonged courses of high-dose intravenous and oral antibiotics for infection clearance [10].

Alternative methods should be considered so as to overcome the infection problem [11]. An appropriate strategy to conquer the limitations involved in the applications of implants has been the localized drug delivery. Thus, the flexibility during the drug releasing process and also the optimized parameters must be accounted for in the design of the TNTs-based drug-delivery systems [12].

In order to control release of the drugs, different TNTs-based systems' strategies have been utilized [12–17]. Dip coating has been used as the simplest way of antibiotic loading on the manufactured implants [13–16]. Slow charging, long procedure, uncontrollable loading and poor drug penetration which result in unregulated release are some drawbacks of this procedure. To attain long-term drug delivery, Ordikhani *et al* [17] have electrodeposited drug-chitosan composite onto Ti substrate. They have announced the electrophoretic method as a single-step, facile and repeatable technique for loading glycopeptide antibiotic on implant.

Conventional drug usage have encountered many limitations like low drug solubility, weak selectivity, poor biodistribution, malicious side effects and uncontrolled pharmacokinetics. A remedy for these problems is local