



# Antibacterial effect of acrylic dental devices after surface modification by fluorine and silver dual-ion implantation

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## ABSTRACT

The purpose of the present study was to examine the effectiveness of fluorine and silver ions implanted and deposited into acrylic resin (poly(methyl methacrylate)) using a hybrid process of plasma-based ion implantation and deposition. The surface characteristics were evaluated by X-ray photoelectron spectroscopy (XPS), contact angle measurements, and atomic force microscopy. In addition, an antibacterial activity test was performed by the adenosine-5'-triphosphate luminescence method. XPS spectra of modified specimens revealed peaks due to fluoride and silver. The water contact angle increased significantly due to implantation and deposition of both fluorine and silver ions. In addition, the presence of fluorine and silver was found to inhibit bacterial growth. These results suggest that fluorine and silver dual-ion implantation and deposition can provide antibacterial properties to acrylic medical and dental devices.

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## 1. Introduction

Recently, medical and dental device-related infections have become common complications [1,2]. According to a public announcement from the National Institutes of Health (NIH), over 80% of all microbial infections are caused by biofilms [3]. Medical and dental device-related infections often require device removal and replacement and additional antibiotic therapy in order to avoid the development of severe complications. These additional treatments are associated with increased mental, physical, and economic stress in patients [4,5].

The oral cavity contains a variety of bacteria. Microbial plaque accumulation surrounding dental devices may cause dental caries [6–9], periodontal disease [10,11], or inflammation of oral soft tissue [12]. In particular, acrylic dentures have complicated shapes and are susceptible to bacterial adhesion. The adhered bacteria can be released from denture plaque into salivary secretions and then aspirated into the lower respiratory tract, causing pneumonia, especially in elderly people or those with disabilities who have a diminished general immune response and pharyngeal reflex [13,14]. Therefore, it is extremely important that all users can clean their dentures completely. General methods of denture plaque removal are mechanical brushing and the use of denture-cleaning tablets. Moreover, evidence-based guidelines for the care and maintenance of complete dentures were published, and 15 methods

were recommended [15]. However, it is actually difficult for children, dependent elderly, or people with disabilities to manage to practise the guidelines because of their inexperience or disability. Therefore, an easy and economic approach to reducing the adherence of biofilms and denture plaque to the acrylic dentures is needed.

In the dental field, microbiological effects of fluoride are well known. In addition, fluoride-coating techniques are also known as protecting against various stains in medical and industrial fields. We previously reported that pure titanium, stainless steel and poly(methyl methacrylate) (PMMA) plates were implanted with fluorine (F) ions, and it showed that the F ion implantation method could apply to each material and indicated that F ion implantation provided stainless steel surfaces with antibacterial activity [16]. Moreover, the great antibacterial property of silver (Ag) is also known generally, and Ag has been used as a disinfectant for centuries. In our previous study, it was shown that stainless steel plates could be implanted and deposited with F and Ag ions simultaneously [17].

Plasma-based ion implantation (PBII) is a promising method for the surface modification of three-dimensional materials [18]. In PBII, the samples are surrounded by high-density plasma and are pulse-biased to high negative potential relative to the chamber wall. Ions generated uniformly in the overlying ion sheath formed uniformly around the samples. So, a sample having a complicated shape can be treated with good conformity and uniformity without beam scanning or special target manipulation. In addition, the use of multiple processes, such as simultaneous and consecutive ion implantation, deposition, and etching, are possible by varying the

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