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Collagen coating for bioactivation of the titanium implant surface

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Implant materials are used to replace damaged or irreversibly lost parts of the body, providing support, restoring functionality, and contributing to the improvement of patients' quality of life. With the global aging population and due to different traumas, injuries, and degenerative diseases among various demographic groups, there is an increasing demand for implant materials, among which metallic implant materials, especially titanium and its alloys, are most commonly used [1,2]. As titanium implant materials, despite exhibiting good biocompatible properties (including corrosion resistance), belong to the group of bioinert materials, various procedures for surface modification or coating with bioactive substances are employed for their surface bioactivation [1,2].

Collagen is the most abundant protein in the human body and is found in the skin, bones, muscles, tendons, and ligaments. It provides strength and structure to tissues, helping to maintain their shape and integrity. Collagen is made up of amino acids, primarily glycine, proline, and hydroxyproline, which are essential for its structure and function. There are several types of collagens, each with specific roles in the body. Overall, collagen plays a crucial role in supporting skin elasticity, joint health, and overall tissue integrity [3,4]. Enhancement of the implant's integration into surrounding bone through coatings using bioactive organic molecules has been approached in various ways [1,2,5,6]. Among the biomacromolecules used, collagen has been widely explored as a ubiquitous component of the extracellular matrix with a positive effect on cell adhesion, proliferation, and migration [1,2,7].

The aim of this study was the surface modification of the titanium material by collagen coating to improve the osteconductivity of the underlying implant material. The uncoated and collagen-coated Ti substrates were immersed in the Fusayama artificial saliva solution as simulated body fluid for three months to test collagen coating's bioactivity on the basis of monitoring the spontaneous calcium phosphate deposit formation. The corrosion behaviour of the unmodified and the collagen-coated titanium was tested *in situ* employing electrochemical impedance spectroscopy (EIS) during prolonged immersion artificial saliva solution under *in vitro* conditions. The morphology, microstructure and chemical composition of the substrates were characterized by scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDS) and attenuated total reflection Fourier-transform infrared spectroscopy (ATR-FTIR) prior and after artificial saliva solution immersion. Additionally, quantum chemical calculations at the density functional theory level (DFT) enabled a determination of a formation mechanism of the collagen coating onto the titanium surface and investigation of interactions occurring during spontaneous calcium phosphate deposit formation.

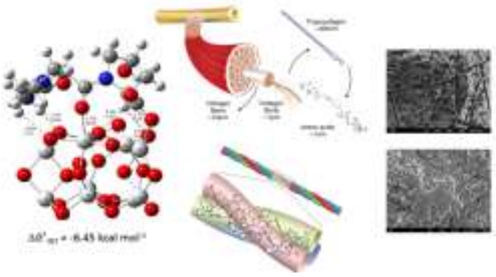

Figure 1. $(TiO_2)_{10}$–collagen binding mechanism as predicted by DFT calculation, collagen chemical structure, SEM images of collagen-modified Ti implant surface prior and after prolonged immersion in the artificial saliva solution.

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