Cell and Tissue Response to Modified by Laser-induced Periodic Surface Structures Biocompatible Materials for Dental Implants

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Abstract: The use of femtosecond laser-induced periodic surface structures (LIPSS) for dental implants surface modification for improving cell adhesion and proliferation is reported. Results demonstrated higher response of cells on modified surface compared to untreated ones.
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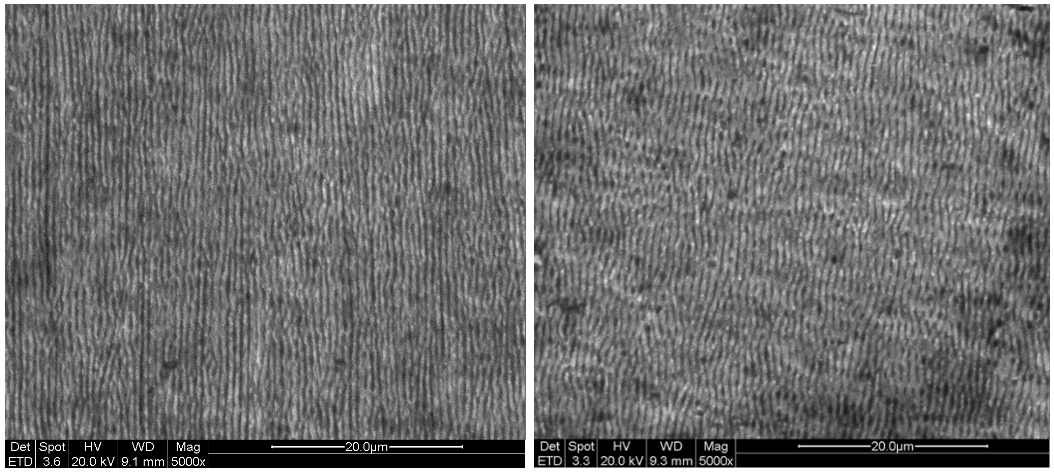
1. Introduction.

Excellent mechanical properties, chemical resistance and biocompatibility allow for usage of various Ti and Zr alloys in orthopedics and dental surgery. Statistically, 50 % of implant losses are defined as late losses, which occur due to loss of bone support [1]. In all cases the key point of implant failure is imbalance of osteointegration processes. The osteointegration is the direct anchorage of an implant by the formation of bony tissues around the implant without the growth of fibrous tissues at the bone implant interfaces [2]. This process starts directly after implantation from blood protein and growth factors absorption on implant surface with further cell attachment and proliferation [3]. Bone progenitor cells like mesenchimal stem cells (MSCs) and lining osteoblast produce collagen with further mineralisation and bone remodeling. In this paradigm, surface topography and wettability are key parameters in determining implant/tissue interaction and osteointegration. Alloy surface should be modified to improve implants biological response and promote faster osteointegration with greater efficiency. Roughness of the implant should enhance the attachment, proliferation, and differentiation of progenitor bone cells while the implant is in contact with the surrounding tissues to accelerate bone attachment. It is also important the integration of the soft tissues (mucous membrane, the skin) with the surface of the implant. For these reasons the surface can be modified to improve implants biological response and promote faster osteointegration with greater efficiency.

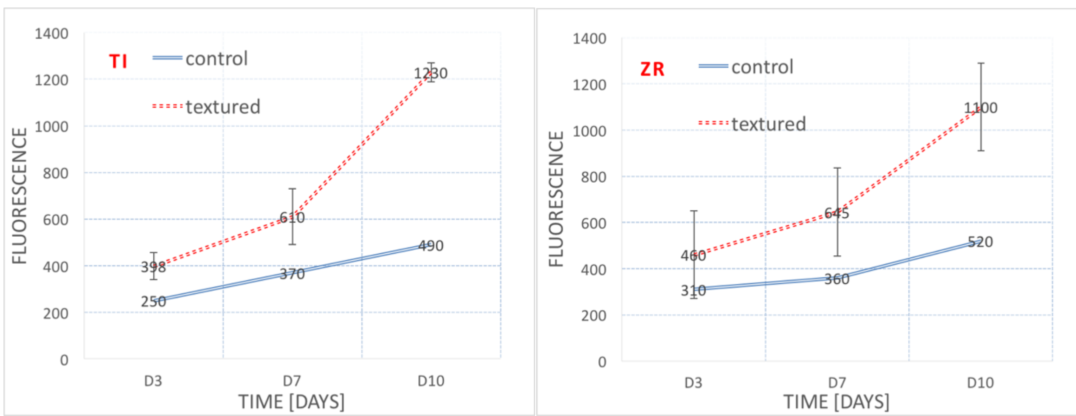
A surface modification which satisfy all these requirement can be the generation of laser-induced periodic surface structures (LIPSS) generated by ultra-short laser pulse**s.** The most common theories for LIPSS creation involve the interference of Surface Electromagnetic Wave (SEW) with the incident laser wave at the surface that excite surface plasmon-polariton (SPP) wave [4]. Applications of surface-treated nanostructures have been demonstrated in various fields including mechanic, medical and photovoltaic industries [5,6]. Although the outcomes are encouraging some problems on material and process control have to be solved prior the transfer to industrial applications. Here a method to generate High Regular LIPSS (HR-LIPSS) is presented. This low-cost and high-speed method has potential applications in several fields, such as mechanics, photonics, micro-fluidic and, as in this case, medical one due the high uniformity, robustness and repeatability.

The morphology of LIPSS-induced structures was investigated by SEM. Images of periodic nanostructures (Fig. 1) reveal successfully obtained by irradiation of the samples by the linear-polarized femtosecond laser light. One can see the nanostructures are homogeneously distributed and parallel to each other on both pure Zr and Ti alloy. The irradiated samples, along wit control samples (smooth and flat surface) were implanted for in-vivo experiments in order to evaluate the growth of three types of cells: erythrocytes, fibroblasts and leucocytes. After the subcutaneous implantation both of Ti and Zr control samples with smooth surface were not covered with cells and fibers, but implants treated by LIPSS were completely covered with connective fibers and cells. Furthermore, LIPSS modified surface leads to significant growing of fibroblast cells during 10 days in-vitro experiment as compared to smooth ones. While the biological explanation for this behavior is not completely know there are evidences that nanotextured surfaces enhance the deposition of proteins that are the precursors for the next cells and connecting tissues proliferation that is very important to create a barrier between the internal environment and the external environment in the area of the implant.



a b

Fig. 1. Modified surfaces of Ti6Al4V (a) and Zr (b) by laser induced periodic surface structures (LIPSS).



a b

Fig. 2. AlamarBlue (AB) fluorescence in different time point after the HDFa seeding on Ti6Al4V alloy (a) and Zr (b) with LIPSS modified surface.

In conclusion we report that Human Dermal Fibroblasts (HDFa) cultivation on Ti6Al4V alloy and pure Zr modified by LIPSS surfaces shown significant cell proliferation for modified surfaces at the 7th and 10th implantation days compared the smooth alloy. This open the great potential for use of LIPSS as dental implants surface modification.

2. References

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