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The Role of Laser Texturing and Coating of Commercial Pure Titanium Implants with Silicon Dioxide and Gallium Nitrate in Enhancing Osseointigration in Osteoporosis

(In Vitro and In Vivo Study)

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Abstract

Background: Regarding the osseointegration of dental implants, the surface modification can affect the characterization and bioactivity of implants especially when used in medically compromised cases such as osteoporosis. The effect of implant's surfaces modification by fiber-optic laser texturing followed by coating by pulsed laser deposition on bone tissue reactions was examined using the removal torque test and histopathological/histomorphometric analysis.

Materials and Method: Preparation of implants; Three types of lasers (Nd:YAG, CO_2, and fiber optic) were tested for laser texturing, and according to the resulted hatches configuration including width and depth; fiber optic laser with a central wavelength of 1064 nm and specific variables; power, scanning speed and hatching distance were selected. Thin films of pure SiO_2, $Ga_2(NO_3)_3$ and of both of them; were deposited on CpTi substrates by (Nd:YAG) pulsed laser deposition with pulse energy (700-1000mJ), pulse duration (5ns) at a negative pressure (10^{-5}) Torr.

For the biological part of the study; sixity skeletally mature female white rabbits were divided into 3 groups: sham, induced osteoporosis (bilateral Ovariectomy) with 1.5mg/kg/day dexamethasone for 30 days), and induced osteoporosis with medication (0.18 mg diluted in 10 ml saline in 15 minutes /kg) zoledronate intravenously every week for 30 days. Bone Mineral Density of total body, lumbar spine, and femur was scanned by Dual-Energy X-Ray Absorptiometry at baseline and at 4 and 8 weeks postoperatively.

Bone skeletal structure and implant success were analyzed by high-resolution x-ray examination. Biochemical parameters were determined in serum samples at different time intervals. Five CpTi implants (length: 8 mm, diameter: 3mm) of control, laser, laser & SiO_2, laser & $Ga_2(NO_3)_3$, and laser & $SiO_2/Ga_2(NO_3)_3$ were placed into the right and left femoral bones.

After 4 and 8 weeks of placement, removal torque was measured and histopathological/histomorphometric analyses were performed.

Results: The most advantageous roughness values obtained, in terms of R_a and R_z were (10nm &11.7nm) for round 1 fiber optic laser texturing; and it was (6.53&7.64nm) for laser & $SiO_2/Ga_2(NO_3)_3$. It is possible to manipulate hatch properties such as width, depth, and the chemical composition of the oxide layer using laser texturing. The results showed that by selecting a suitable width (130-152 µm) and depth (198.8 µm) for titanium surface texture; and best film thickness of (52-71µm) for laser & $SiO_2/Ga_2 (NO_3)_3$, osseointegration can be increased.

The highest mean removal torque was in laser & $SiO_2/ Ga_2 (NO_3)_3$with 50.43±0.25 and 50.41±0.23 N.cm in the osteoporotic and medication groups, respectively. The mean values % of histomorphometric parameters in laser & $SiO_2/Ga_2(NO_3)_3$ subgroup showed the best parameters than the control subgroup. Which showed a higher degree of new bone with mild fibrosis and inflammation compared with other implants subgroups, except in induced osteoporotic groups which show severe inflammation.

Conclusion: laser can be used effectively in modifying the surface of CpTi implants using fiber optic laser to form hatches textures, and then using Nd: YAG laser to coat the textured screws by pulsed laser deposition technique. Both of SiO_2 and $Ga_2 (NO_3)_3$ showed synergistic osseointegration action when used in induced osteoporotic rabbits before and after treatment with zoledronic acid. The removal torque data and histological parameters of laser & $SiO_2/Ga_2 (NO_3)_3$ subgroup were higher than the other subgroups.