Production of Controlled Microgeometric Surface Textures on Metal Implants

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Introduction. Surface microtexturing of dental and orthopaedic implants is an accepted method for improving osseointegration. Texturing is generally produced using surface blasting with abrasives, and acid etching. Abrasive blasting produces microtexture with features in the range of 2-50 μm but can leave blast debris embedded in the implant surface [1]. Acid etching is often used to clean these surfaces and produce additional fine surface texturing with smaller feature sizes. Using these methods it is impossible to control microfeature shape, and it is difficult to produce these textures in defined areas.

We have developed a computer-controlled laser surface microtexturing technique that produces clean, controlled surfaces, with defined microfeature sizes and orientations in defined areas. These surfaces have been produced on flat metal substrates and two types of cylindrical implants including prototype dental implants. This abstract outlines the methods used to produce these surfaces, the resulting surface characteristics, and recent results of bone integration studies.

Materials and Methods. *Surface Design.* Microgrooved surfaces with 8 and 12 μm groove width and depth (16 and 24 μm repeat spacing) were chosen for fabrication based on studies of cell interaction with microtextures [2].

Laser Surface Micromachining. Microgroove patterns were produced on flat and cylindrical commercially-pure titanium and titanium alloy (6% aluminum, 4% vanadium) samples including dental implants supplied by BioLok International (Deerfield Beach, FL). These were produced using a pulsed, computer-controlled Excimer laser system and large-area masking techniques. Controlled sample motion coupled with pulsed laser ablation was used to produce the controlled microstructure patterns seen in Figures 1 and 2. Samples were then cleaned and passivated before sterilization and implantation.

Animal Studies. Canine bone response to these surfaces has been tested in an implantable chamber model, an intramedullary rod model, and a dental implant model using industry standard blast roughened surfaces, machined surfaces, and polished surfaces, of the same composition, as controls. Samples have been evaluated using histological, histomorphometric, and electron microscopic techniques.

Results. *Laser Microtextured Surface Characteristics.* Laser microgrooved surfaces produced by this method have been found to be reproduceable with resolution of structure size as small as 2 μm. The surfaces showed little regional variation and could be produced in well defined areas. Figure 1 shows a low magnification scanning electron micrograph (SEM) of a 12 μm microgrooved surface produced on the 1 mm-wide collar of a titanium alloy dental implant. Figure 2 shows a higher magnification SEM of the same surface. The alloy has been ablated from the grooves and deposited in molten form on the ridges between the grooves.

Animal Study Results. Implant chamber model studies have shown that canine bone grows into channels lined with the microgrooved surfaces faster than channels lined with blast textured surfaces [3]. New bone was also observed to attach directly to these microgrooved surfaces and the trabecular bone adjacent to these surfaces was strongly oriented parallel to the microgrooves. Histologic and electron microscopic results suggested that these surfaces caused orientation of attached cells, which produced oriented extracellular matrix and oriented bone microstructure. This result was confirmed in the canine intramedullary rod model using cylindrical specimens, where bone orientation followed the microgrooves whether they were longitudinal or circumferential.

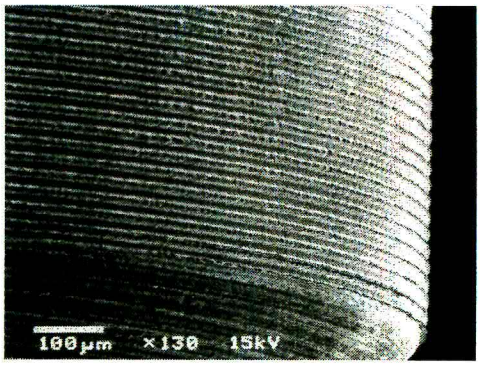

Figure 1

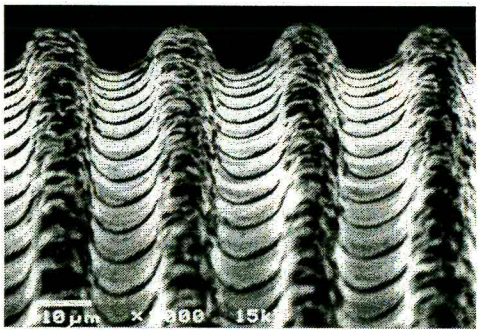

Figure 2

Conclusions. We have developed a laser surface modification method that can be used to produce design-specific microtextures on metal implant surfaces. This method produces surfaces with clean, consistent microstructures, on a micron scale, and can be used to place specific microtextures in highly defined areas. These high-surface-area microtextures show excellent osseointegration and the ability to control the trabecular organization of adjacent bone. They are currently being developed for several biomedical implant applications including dental and orthopaedic implants.

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