Implant Surfaces and their Biological and Clinical Impact

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Preface

This book presents an overview of implant surfaces and their clinical impact. We learnt about surface impacts already in the infancy of osseointegration, but it was first with the advent of reliable topographical measurement techniques during the 1990s that a more profound knowledge of surface importance was available. Since then, research has identified a number of different surface characteristics of an assumed clinical importance; these include micro-surfaces, nano-surfaces, and chemically or physically induced surface alterations. This book includes contributions from many world-leading scientists in the implant surface discipline. Methodological overviews are coupled with reports from experimental and clinical studies. The most commonly used oral implant surfaces include acid-etched, blasted, fluoride-treated, and anodized surfaces that are summarized in several chapters. Orthodontic implants are covered in one chapter.

This book cites predominantly oral implants, since orthopedic implants, at least so far, have been characterized mainly by macro-changes of implant surfaces. A porous surface to the orthopedic surgeon is porous coated, i.e., a macroscopic surface alteration, whereas a porous surface to the dentist is a microporous surface. Few studies about hip arthroplasties have included a surface microscopic analysis. We see it as important for orthopedic surgeons to realize the clinical potential of surface microscopical alterations as well as for oral surgeons to realize aseptic loosening phenomena that in all probability are as common for dental implants as for orthopedic ones. Orthopedic and oral implants work well, but certainly not so good that one cannot have even better clinical results with understanding the nature of the oral implant surfaces. In orthopedics, clinical long-term results are commonly based on the frequency of reoperation that can be criticized for presenting somewhat idealized results, while in dentistry, osseointegration has been seen as a somewhat mystical key for success, although in reality osseointegration is but a foreign body response. Hence, both disciplines have to learn from one another to further improve clinical outcomes for the future, which is why this book may be worthwhile reading for orthopedic surgeons as well as dentists.

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Editors

Tomas Albrektsson, MD, PhD, ODhc, RCPSG was a member of Branemark's original osseointegration team and has since worked with and patented oral implants as well as hip implants. Albrektsson has authored numerous scientific papers on implants, and he lectures frequently worldwide. He continues working as Emeritus Professor at the Department of Biomaterials, Gothenburg University, and as a Visiting Professor at the Department of Prosthodontics, Malmö University, Sweden.

Ryo Jimbo, DDS, PhD received his DDS degree at the Nagasaki University School of Dentistry in 2004 and defended his PhD thesis at the same school in 2007. Jimbo has had specialist education in prosthodontics and has in addition worked in oral and maxillofacial surgery. He was a visiting researcher at the Department of Biomaterials, Gothenburg University, between 2009 and 2010 and is Associate Professor at the Department of Prosthodontics, Malmö University, since 2010. His current research is centered on implant basic and clinical research, with a special interest in nanotechnology applications in implant dentistry.

Ann Wennerberg, DDS, PhD worked 11 years in a private dental practice before she joined the Department of Biomaterials, Gothenburg University, in the late 1980s. She presented her PhD thesis *On Surface Roughness and Implant Incorporation* in 1996 and a few years later was appointed Professor and Head of the Department of Prosthodontics at Gothenburg University. She moved to the Dental School of Malmö as Head of Prosthodontics in 2008. Ann Wennerberg has published numerous papers on implant surfaces and clinical results of oral implants and is today the leader of a most active research group at her department.

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Overview of Surface Evaluation Techniques

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Ann Wennerberg, Ryo Jimbo, and Tomas Albrektsson

Abstract

Surface characterisation is necessary if we want to understand biological processes influenced by surface properties and eventually their clinical importance. In addition, we need surface characterisation if researchers want to distinguish between the components forming the implant surface, i.e. topography, chemistry, physics and mechanics. The techniques should provide objective data to decrease the possibility for subjective interpretation and biases. This chapter is a brief overview of commonly used evaluation techniques of the four different surface properties with the emphasis on topographical evaluations.

Surface Topography

Implant surface topography can be measured with three principally different techniques.

Mechanical stylus instruments: a cantilever with a tip of several microns is drawn over the surface for one profile measurement; the movements of the cantilever are registered, and data with respect to surface height and spatial variation can be achieved. Several profiles are added to achieve a 3D image and more stable numerical values of the various surface parameters. The measuring range can be several millimetres (Fig. 1.1). The resolution in height is down to the nanometre level, but in the spatial direction the resolution is only 2 μm or more due to the size of the tip. The main drawback with the technique for oral implants is that due to the small dimension of the threaded area, the tip will have great difficulties to reach the flank area; thus, measurements have to be performed on less curved areas such as the marginal portion of the implant that may not be representative for the entire implant surface.

Optical instruments: in particular interferometry has been found appropriate for measuring a

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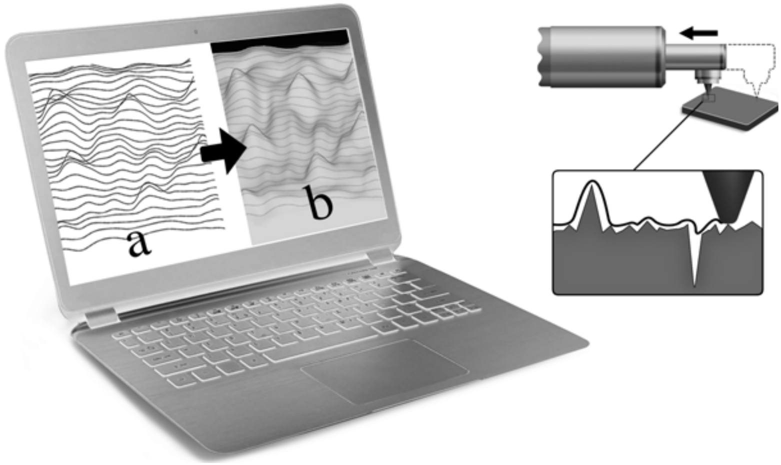

Fig. 1.1 A drawing of a mechanical stylus equipment clearly demonstrating the influence of the stylus tip. The measured profile is significantly smoother than the real surface (Figure produced by Braian Development AB, Malmö, Sweden)

Fig. 1.2 A drawing of an optical profiler. Due to the noncontact technique, the horizontal resolution is increased. The light beam can follow the irregularities quite well (Figure produced by Braian Development AB, Malmö, Sweden)

huge variation of implant surfaces, from smooth to rough surface modifications. The technique uses reflecting light as an optical stylus (Fig. 1.2). The measuring range is within a few millimetres. The technique provides high resolution, down to the nanometre level in height direction but is limited in spatial direction to approximately 0.3 µm; thus, the technique is most appropriate for surface characterisation at the micrometre level. In relation to oral implants, one big advantage with the technique is the possibility to access all parts of the implant, even flank areas, which is important since these areas are the largest part of the implant that is in contact with the surrounding bone. One disadvantage with optical instruments is that studied objects need some reflecting capacity, at least 4 % of the incident light as a minimum.

Atomic force microscopy (*AFM*): AFM can work in principle in three different modes of operation, contact, noncontact and tapping mode. The instrument uses a tip and cantilever with similar principle as the stylus instrument but with a huge difference in size. The AFM tip is in the range of a few to approximately 20 nm in diameter. The tip can be in contact with the surface during measurements or above it with the help of van der Waals forces. The measuring area is rather small, typically in the submicron range. The resolution can approach molecular levels both in height and spatial directions which makes it possible to measure nanostructures. However, many implants have a surface that is too rough for the equipment; thus, for oral implants the application is limited to rather smooth surfaces.