

ADVANCES IN
BASIC AND CLINICAL ORAL SCIENCES

CONTEMPORARY ADVANCES IN IMPLANT DENTISTRY

• EDITOR HONGCHANG LAI •

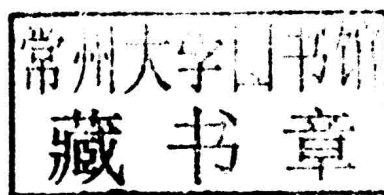


SCIENCE PRESS

ADVANCES IN BASIC AND CLINICAL ORAL SCIENCES

CONTEMPORARY ADVANCES IN IMPLANT DENTISTRY

EDITOR HONGCHANG LAI



SCIENCE PRESS
BEIJING

图书在版编目 (CIP) 数据

当代口腔种植学进展 = Contemporary Advances in
Implant Dentistry: 英文 / 赖红昌主编. —北京:
科学出版社, 2014.9

ISBN 978-7-03-039978-6

I. ①当… II. ①赖… III. ①种植牙—口腔外科学—
英文 IV. ①R782.12

中国版本图书馆 CIP 数据核字 (2014) 第 055063 号

责任编辑: 潘志坚 闵捷

责任印制: 谭宏宇 / 封面设计: 殷靓

科学出版社出版

北京东黄城根北街 16 号

邮政编码 100717

<http://www.sciencep.com>

上海锦佳印刷有限公司印刷

科学出版社发行 各地新华书店经销

*

2014 年 9 月第 一 版 开本: 787×1092 1/16

2014 年 9 月第一次印刷 印张: 11 1/4

字数: 439 000

定价: 120.00 元

(如有印装质量问题, 我社负责调换)

CONTRIBUTORS

Chief Editor

Hongchang Lai Shanghai Jiao Tong University College of Stomatology

Deputy Editors in Chief

Ye Lin Peking University School of Stomatology

Bin Shi School of Stomatology Wuhan University

Zhiyong Zhang Shanghai Jiao Tong University College of Stomatology

Authors

Yiqun Wu Shanghai Jiao Tong University College of Stomatology

Niklaus. P. Lang University of Bern / University of Hongkong

Yufeng Zhang School of Stomatology Wuhan University

Longfei Zhuang The University of Hongkong

Ren Wang Peking University School of Stomatology

Yingxin Gu Shanghai Jiao Tong University College of Stomatology

Shichong Qiao Shanghai Jiao Tong University College of Stomatology

Misi Si Shanghai Jiao Tong University College of Stomatology

Xiaoxiao Zhang Shanghai Jiao Tong University College of Stomatology

Huei-wen lo Shanghai Jiao Tong University College of Stomatology

Zhonghao Chou Shanghai Jiao Tong University College of Stomatology

Xu Zhao Shanghai Jiao Tong University College of Stomatology

Duohong Zou Shanghai Jiao Tong University College of Stomatology

Xiaojun Chen Shanghai Jiao Tong University School of Mechanical
Engineering

PREFACE

Implant dentistry has developed rapidly since the 1960s when Professor P-I Brånemark discovered the direct structural and functional connection between living bone and the surfaces of a load-bearing artificial implant, and nominated the whole process as osseointegration.

This groundbreaking discovery of osseointegration revolutionized the realm of implant dentistry and brought it from being a shunned field into one that became recognized and incorporated into dental school curricula and training programs.

Nowadays, osseointegration and implant dentistry research are at an unprecedented peak. The concepts and strategies in implant dentistry are refreshing every day due to the revolutionary development of medical technology and materials with the support of scientific clinical researches and laboratory studies.

The consequence of the boost in implant dentistry is that the field today is saturated with new implant manufacturers, novel implant designs, bone graft materials, modified implant surfaces and new surgical strategies.

The new concepts and techniques as modified hydrophilic surface, platform switching, tissue engineering, immediate placement, immediate loading, and image-based guides have boomed in the past decade. Thanks to these new innovations, the trend of shortened osseointegration healing time, minimized surgical trauma, and the enlarged indication of the dental implant placement have become the mainstream in this field.

The improvements in implant technology and its practical applications in the clinical are not a sudden breakthrough originated from one specific implant surface, a single treatment procedure, or some particular loading protocol. Rather it can be understood by conceptualizing the individual elements involved in the placing of one or more endosseous implants to support an intraoral prosthesis. It is the refinement of each of these single elements that has contributed to the understanding of osseointegration itself, and improved the technology to solve the patients' problems even further.

However, it is impossible to let the students understand and assimilate all these dazzling concepts without systematic studying. Thus it is vital to tell them where we have come from, where we are, and where we are heading.

What have we achieved in the past decade, and what are emerging as new and innovative developments in the fields of implant dentistry? By learning from our past mistakes we made and knowledge we accumulated, we may be much prepared to meet the future. Hence, this textbook attempts to answer these questions by reflecting on the latest research advances and significant evolutions of current and future applications in implant dentistry.

I hope this book can be an ideal reference for both clinicians and dental students who are interesting in dental implantology.

Last but not the least; I would like to give a sincere thank-you to all the authors and contributors of the book who provided great efforts.

Hongchang Lai
24th May, 2014

INTRODUCTION

In the past 40 years, both clinicians and researchers have witnessed the rapid development of implant dentistry. Advances in implant materials, loading protocols and surgical procedures, etc. have made dental implants an irreplaceable option on the menu of dental care and treatment.

As the main body of dental implants, Implant surfaces have experienced a series of alterations, from turned machined surfaces to roughened ones, in the effort of making osseointegration process faster and more secure. Thanks to the studies on the geometry and surface topography, several surface modifications have been developed and applied, including blasted, acid-etched, oxidized, plasma-sprayed and hydrophilic surfaces, as well as combinations of these procedures. Furthermore, different shapes of the implant body are also available. For example, with the concept “platform switching”, it is possible to achieve better esthetic outcome in the anterior region.

The concept of healing process has shifted as well. With the development of the immediate implantation, flapless surgery and non-submerged healing progress, the trauma of the surgery can be minimized with less and simplified surgical interventions. The loading protocols have also become diversified. The protocols as immediate loading, early loading or late loading have been developed to accommodate specific situations. Meanwhile, during the past 20 years, increasing interest has arisen regarding a concept called “alveolar ridge preservation”, which was defined as “any procedure undertaken at the time of or following an extraction that is designed to minimize external resorption of the ridge and maximize bone formation within the socket.” Hundreds of clinical and animal studies concerning about ridge preservation technique have been published. In these studies, bone substitutes, surgical methods and the soft/hard tissue alteration were included. However, outcomes of the recent studies should be evaluated and new insights under this topic should be explored.

Tissue engineering is an interdisciplinary field that brings together the principles of the life sciences and medicine with those of engineering. In the past 20 years, innovations in the stem cell products, biomaterials and growth factors have provided a tremendous boost for tissue engineering. Bone grafting is one of the areas that have greatly benefited from the current efforts. With the application of the bone tissue engineering, the bone graft procedure would be more cost-effective with less trauma. De novo bone formations in both horizontal and vertical directions benefited tremendously from the use of the new scaffolds, stem cells and growth factors.

The sinus floor elevation (SFE) technique, including transalveolar (TSFE) and lateral (LSFE) approach, has been developed in the past 20 years. After more than twenty years’ application, sinus floor elevation procedure is thought to be a predictable augmentation technique of moderate to high complexity. Researchers and clinicians made their effort to fill the blank and solve the controversy in both theory and practice. Though the necessity of grafting materials in SFE procedure, especially in TSFE is still controversial, both LSFE and TSFE are widely applied for the patients with insufficient bone volume in the posterior maxillary region.

Due to the evolution of the CAD/CAM, CBCT scan, 3-D image reconstruction and rapid prototyping technology, image-based implant therapy is being widely used over the world. Unlike the old model-based implant surgical guides, image-based implant guides can provide highly accurate images of the relevant anatomical regions, and interactive pre-surgical visual planning can be performed in order to detect the best insertion site. With this new guide, implant surgery has become more accurate and accessible, causing less trauma and fewer complications. Furthermore, the method based on optical tracking real-time dynamic navigation technology, known as dynamic navigation have already being used in oral-maxiofacial surgeries in order to achieve real-time information of the patients.

In a word, future implant solutions will require less healing time for osseointegration process, cause fewer mechanical and biological complications, induce less trauma, while providing higher successful rate, more precision, better esthetic outcome and easier access for practitioners.

However, there still are lots of problems that need to be resolved. So far, the identification of the relative contraindication of the dental implant surgery is still a hot spot for researchers. Whether or not patients with severe periodontal disease, diabetes, and osteoporosis are suitable for dental implant insertion is also still under debate, And the consensus of the treatment strategies for these patients are yet

to be studied. Furthermore, application of bisphosphonates is becoming a new problem for dentists. According to recent reports and documents, though the incidence rates of Bisphosphonate Related Osteonecrosis of the Jaw (BRONJ) and implant failure are relatively low in this group of patients, related risks should not be neglected. Further researches and clinical trials with large sample should be performed in order to clarify the pathogenesis and odds ratio of BRONJ and implant failure.

There is no doubt that the evolution of the CBCT provided us with a new radiographic diagnostic approach with less exposure dose and better view of the jaws. However, series of limitations on image-based implant therapy still exist. For example, Stereolithographic surgical guides have the limitation of lacking prosthetic landmarks. Also, accuracy of the images can be interfered by the metal crowns or bridges, which may cause radiation artifacts. The real-time navigation on dental implantation also has several unsolved problems (e.g., when the patients is just under local anesthesia, the registration would be hard to handle) which may interfere the accuracy of the surgery. However, we must admit that image-based implant guide/navigation and digital dentistry will develop promptly in the near future.

Although the timing of implant placement has been discussed for a long time, consensus on treatment strategies is far from being reached. Taking the immediate implantation in sockets as an example, the advantages of this technique are that patient may benefit by having less trauma, shortened treating period and better immediate esthetic outcome. However, the long-term esthetic complications including gingival recession, buccal bone wall resorption or perforation may affect the final outcome. Hence, the indication of the immediate implantation should be strictly implemented and further researches on the alteration of the alveolar ridge after the tooth extraction and dental implant insertion should be performed.

Meanwhile, as one of the most common post-operative complications, the peri-implantitis and peri-implantmucositis are now the focuses of researchers. Though a fair amount of papers discussing topics like animal model of the peri-implant diseases or the treatment plan have been published, the general guide of the treatment or the consensus of the treatment strategies is still under way.

In this book, we will discuss the contemporary advances and latest progresses in implant dentistry. The 11 chapters will cover the contents including surface modifications of the dental implant, the impact of general health, loading protocols, immediate placement and alveolar ridge preservation, surgical procedures of the sinus floor elevation, esthetic considerations of implant-supported restorations, preoperative/postoperative periodontal treatment, and computer-assisted implant placement. This book is an ideal reference for clinicians and dental students.

CONTENTS

PREFACE

INTRODUCTION

CHAPTER I PROGRESS ON DENTAL IMPLANT SURFACE MODIFICATION 001

PART I SURFACE ROUGHNESS OF DENTAL IMPLANTS 001

- 1.1 Roughening of Implants by Titanium Plasma-spraying 002
- 1.2 Roughening of Implants by Grit-blasting 003
- 1.3 Roughening of Implants by Acid-etching 004
- 1.4 Roughening of Implants by Anodization 005

PART II CALCIUM PHOSPHATE COATINGS ON DENTAL IMPLANTS 006

PART III CURRENT TREND AND POTENTIAL WORK IN DENTAL IMPLANT SURFACE MODIFICATIONS 008

- 3.1 Nanotechnology on Implant Surface Modifications 008
- 3.2 Biomimetic Calcium Phosphate Coating 010
- 3.3 Anti-infective Modifications on Implant Surfaces 011

PART IV SUMMARY 014

REFERENCES 014

CHAPTER II IMPACT OF SYSTEMIC FACTORS ON IMPLANT THERAPY 021

PART I SOCIODEMOGRAPHIC 021

- 1.1 Gender 021
- 1.2 Age 021

PART II SYSTEMIC DISEASE 022

- 2.1 Cardiovascular Disease 022
- 2.2 Endocrine Disease 023
- 2.3 Diseases of the Blood System 024
- 2.4 Bone Metabolism Diseases 025
- 2.5 Systemic Autoimmune Diseases 026
- 2.6 Oral Muco-cutaneous Disorders 027

2.7	Medications	027
2.8	Radiotherapy	029
2.9	Habits	029
2.10	Mental Illness	030
REFERENCES		030

CHAPTER III NEW INSIGHTS INTO RIDGE PRESERVATION AFTER TOOTH EXTRACTION 036

INTRODUCTION 036

PART I ANIMAL STUDIES 037

- 1.1 Implants for Ridge Preservation 037
- 1.2 Shape of Implants 038
- 1.3 Bone Substitutes 039
- 1.4 Primary Closure 040

PART II CLINICAL TRIALS 040

- 2.1 Implants for Ridge Preservation 040
- 2.2 Shape of Implants 041
- 2.3 Non-surgical Treatment 041
- 2.4 Bone Substitutes 041
- 2.5 Guided Bone Regeneration (GBR) 044
- 2.6 Primary Closure 044

CONCLUSIONS 044

- 1. Implants for Alveolar Ridge Preservation 044
- 2. Non-surgical Treatment 045
- 3. Bone Substitutes 045
- 4. Guided Bone Regeneration 045
- 5. Primary Closure 045

REFERENCES 045

CHAPTER IV TIMING OF THE IMPLANT PLACEMENT 048

PART I TYPE I PLACEMENT OF AN IMPLANT INTO A TOOTH SOCKET CONCURRENTLY WITH THE EXTRACTION 051

- 1.1 Bone Modelling at Fresh Extraction Sockets: Immediate Implant Placement Versus Spontaneous Healing 051
- 1.2 Soft Tissue Alteration And Aesthetic Outcomes 052
- 1.3 Clinical Recommendations 052

PART II TYPE II PLACEMENT OF AN IMPLANT AFTER SUBSTANTIAL SOFT TISSUE HEALING HAS TAKEN PLACE, BUT BEFORE ANY CLINICALLY SIGNIFICANT BONE FILL OCCURS WITHIN THE SOCKET 053

PART III	TYPE III	PLACEMENT OF AN IMPLANT FOLLOWING SIGNIFICANT CLINICAL AND/OR RADIOGRAPHIC BONE FILL OF THE SOCKET	053
PART IV	TYPE IV	PLACEMENT OF THE IMPLANT INTO A FULLY HEALED SITE	053
		Clinical Recommendations	053
REFERENCES			054

CHAPTER V TIMING OF LOADING PROTOCOLS 057

PART I	DO IMMEDIATE LOADING JEOPARDIZE OSSEointegration?	057
PART II	DEFINITION OF LOADING PROTOCOLS	059
PART III	IS THERE ANY ESSENCIAL DIFFERENCE BETWEEN IMMEDIATE RESTORATION AND IMMEDIATE LOADING?	060
PART IV	DO IMMEDIATE IMPLANTS WITH IMMEDIATE LOADING PREVENT BONE RESORPTION?	061
PART V	HOW DO LOADING PROTOCOLS AFFECT IMPLANT SUCCESS RATE?	065
	Conclusions	065
PART VI	CLINICAL RECOMMENDATIONS (WEBER ET AL. 2009)	066
	6.1 Edentulous Patients	066
	6.2 Partially Edentulous Patients	066
	6.3 Esthetic Zone	066
REFERENCES		067

CHAPTER VI OSTEOINDUCTION, OSTEOCONDUCTION AND OSTEOGENESIS IN BONE REGENERATION 069

INTRODUCTION	069
PART I	OSTEOGENESIS 070
PART II	OSTEOCONDUCTION 070
	2.1 Ceramic-based Scaffolds 071
	2.2 Synthetic Polymer-based Scaffolds 075
	2.3 Natural Polymer-based Scaffolds 079
	2.4 Polymer-ceramic Composites 082
PART III	OSTEOINDUCTION 085
	3.1 Osteoinduction as Originally Defined 085
	3.2 Principle 1: MSC Recruitment 086
	3.3 Principle 2: MSC Cifferentiation to Osteoblasts 088
	3.4 Principal 3: Ectopic Bone Formation 089
	3.5 Experimental Design for Osteoinductive Materials 090
	Summary of Guidelines 090
	Concluding Remarks And Perspectives 090

CHAPTER VII SINUS FLOOR ELEVATION..... 103

INTRODUCTION 103

PART I ANATOMY 103

- 1.1 Shape And Position 103
- 1.2 Pneumatization 103
- 1.3 Septa 104
- 1.4 Schneiderian Membrane 105
- 1.5 Blood Supply 105

PART II DEFINITION OF TERMS 106

PART III LATERAL SINUS FLOOR ELEVATION 106

- 3.1 Origin And History 106
- 3.2 Indications And Contraindications 106
- 3.3 Procedure 106
- 3.4 Complications 107
- 3.5 General Evaluation 108
- 3.6 Advantages And Disadvantages 108

PART IV TRANSALVEOLAR SINUS FLOOR ELEVATION 108

- 4.1 Origin And History 108
- 4.2 Indications And Contraindications 108
- 4.3 Surgical Procedure 108
- 4.4 Complications 109
- 4.5 General Evaluation 110
- 4.6 Advantages And Disadvantages 110

PART V EXTENSIVE THINKING 110

- 5.1 Grafting or Non-grafting ? 110
- 5.2 Lateral or Transcrestal ? 113

REFERENCES 114

CHAPTER VIII ESTHETIC CONSIDERATIONS OF IMPLANT-SUPPORTED RESTORATIONS..... 117

PART I PERI-IMPLANT BIOLOGIC WIDTH 117

PART II EPITHELIUM 117

PART III CONNECTIVE TISSUES 118

PART IV SUPRACRESTAL CONNECTIVE TISSUE 119

PART V SOFT TISSUE BIOTYPE 119

PART VI BONE LEVEL OF ADJACENT TEETH 120

PART VII TREATMENT PLANNING 120

PART VIII	MESIODISTAL POSITION	120
PART IX	OROFACIAL POSITION (LABIOPALATAL POSITION)	121
PART X	IMPLANT ANGULATION	122
PART XI	CORONOAPICAL POSITION	123
PART XII	USE OF PROVISIONAL RESTORATION	123
REFERENCES		124

CHAPTER IX PERIODONTAL PREPARATION BEFORE DENTAL IMPLANT TREATMENT127

PART I	INTRODUCTION	127
1.1	Anatomical Features of Periodontal And Peri-implant Tissue	127
1.2	Microbiota Around Teeth And Implants	128
1.3	Pathogenesis of Periodontitis And Peri-implantitis	128
1.4	Association Between Periodontitis And Peri-implantitis	129
PART II	PERIODONTAL PREPARATION BEFORE DENTAL IMPLANT TREATMENT	131
2.1	Basic Periodontal Examination	131
2.2	Periodontal Prerequisites Before Dental Implant Treatment	132
PART III	SUMMARY	133
REFERENCES		133

CHAPTER X MAINTENANCE OF DENTAL IMPLANTS & PERI-IMPLANT DISEASES ...136

PART I	DEFINITION	136
PART II	PREVALENCE	137
PART III	DIAGNOSIS	137
3.1	Peri-implant Probing	137
3.2	Radiographic Evaluation	138
3.3	Suppuration	138
3.4	Implant Mobility	139
3.5	Peri-implant Crevicular Fluid (PICF) And Saliva Analysis	139
3.6	Risk Indicators	139
3.7	History of Periodontitis	139
3.8	Diabetes And Oral Hygiene	139
3.9	Alcohol Consumption And Smoking	139
3.10	Genetic Traits	140
PART IV	IMPLANT SURFACE CHARACTERISTICS	140
	Couclusion	141
PART V	TREATMENT	141
5.1	Non-surgical Treatment	141
5.2	Surgical Treatment	141

5.3 Laser Therapy	142
-------------------	-----

REFERENCES	142
------------	-----

CHAPTER XI COMPUTER-ASSISTED IMPLANT PLACEMENT 146

PART I STATIC NAVIGATION, BASED ON GUIDED AND CAD/CAM TECHNOLOGY 146

1.1 History	146
1.2 Computer-guided Surgery in Implantology	147
1.3 CAD/CAM Technique Usage	148
1.4 Clinical Report	151

PART II DYNAMIC NAVIGATION SYSTEM 153

2.1 History	153
2.2 The Application of the Image-guided Oral Implantology System (IGOIS) in the Placement of Zygoma Implants	154

REFERENCES	163
------------	-----

CHAPTER I

PROGRESS ON DENTAL IMPLANT SURFACE MODIFICATION

Yingxin Gu, Longfei Zhuang, Hongchang Lai

PART I SURFACE ROUGHNESS OF DENTAL IMPLANTS

- 1.1 Roughening of Implants by Titanium Plasma-spraying
- 1.2 Roughening of Implants by Grit-blasting
- 1.3 Roughening of Implants by Acid-etching
- 1.4 Roughening of Implants by Anodization

PART II CALCIUM PHOSPHATE COATINGS ON DENTAL IMPLANTS

PART III CURRENT TREND AND POTENTIAL

WORK IN DENTAL IMPLANT SURFACE MODIFICATIONS

- 3.1 Nanotechnology on Implant Surface Modifications
- 3.2 Biomimetic Calcium Phosphate Coating
- 3.3 Anti-infective Modifications on Implant Surfaces

PART IV SUMMARY

REFERENCES

Titanium (Ti) and its alloys are extensively used as dental or orthopedic implants due to their good load-bearing properties, excellent biocompatibility and high corrosion resistance. However, clinical long-term success of dental implant is achieved not only because of implant material, but also for other properties like implant design, surgical technique, host-bone quality, load bearing, and surface quality. Surface quality, which refers to mechanical, physicochemical and topographic properties prepared by various surface technologies, is considered as an important factor in implant material. A large amount of literatures have revealed that surface properties of implants play decisive roles for molecular interactions, cellular response and bone regeneration. Over the past decades techniques for the modification of surfaces are evolving rapidly. The purpose of this chapter, therefore, is to provide an introduction to advanced surface modification processes that could be useful in dental implant manufacturing. This Chapter focuses on development in this area over the past 10 years, but earlier work has been included as well where it appeared necessary to give perspective or background for the readers.

PART I SURFACE ROUGHNESS OF DENTAL IMPLANTS

Although the machined smooth Ti implants were once successfully used in clinical practices, there are lots of reports which demonstrate that roughened Ti implant surface can enhance the rate of osseointegration and biomechanical fixation. Especially in the cases of insufficient bone quantity or anatomical limitations, short designed implants with a rough surface have demonstrated more superior clinical outcomes than smooth surfaces. In general, the surface roughness can be classified into three levels according to the size of the features: macro-, micro-and submicro (nano)-sized topographies.

The macro scale is defined as being in the range of tens of microns to millimeters. This scale is directly related to implant geometry, with threaded screw and macroporous surface treatments giving surface roughness of more than 10 μm . Numerous reports have shown that both the early fixation and long-term mechanical stability of the prosthesis can be improved by a high roughness profile compared

with smooth surfaces. The high roughness resulted in mechanical interlocking between the implant surface and bone in growth. However, a major risk with high surface roughness often indicates an increase in peri-implant infection as well as an increase in ionic leakage. A moderate roughness in a range of 1 to 2 μm has been proved to limit these two parameters efficiently.

The micro-topographic profile of dental implants is defined for surface roughness as being in the range of 1 to 10 μm . This range of roughness maximizes the interlocking between mineralized bone and the surface of the implant. A theoretical approach suggested that the ideal surface should be covered with hemispherical pits approximately 1.5 μm in depth and 4 μm in diameter. However, there is a lack of agreement in findings from *in vivo* animal experiments, where the clinical performance of micro-roughened titanium implants is described on the basis of mechanical failure tests and histological considerations. So far, it has been suggested that only a very specific surface topography with a Ra value between 1 and 2 μm provides an optimal surface for bone integration. Numerous studies have shown that surface roughness in this range resulted in greater bone-to-implant contact (BIC) and higher resistance to torque removal than that of other types of surface topography. However, the Cochrane collaboration has not found any clinical evidence demonstrating the superiority of any particular implant surface.

Surface profiles in nanometer size play a critical role in promoting proteins adsorption, osteoblastic cells adhesion and the rate of osseointegration. However, reproducible surface roughness in the nanometer range is difficult to produce with chemical treatments. In addition, the optimal surface nano topography for selective adsorption of proteins leading to the adhesion of osteoblastic cells and rapid

bone apposition is unclear.

With regard to surface modifications, various techniques have been developed in order to create a rough surface and improve the osseointegration of Ti dental implants. Commonly they are divided into three general techniques: add material (e.g., titanium plasma-spraying and calcium phosphate coating), remove material (e.g., acid-etching and sand-blasting), and change the material already present (e.g., anodization).

1.1 Roughening of Implants by Titanium Plasma-spraying

A titanium plasma-spraying (TPS) method has been used for producing rough implant surfaces (Fig. 1-1). This method consists in injecting Ti powders into a plasma torch at a super high temperature. The Ti particles are projected onto the surfaces of the implants where they condense and fuse together, thus forming a film about 30 μm thick. The thickness must reach 40 to 50 μm to be uniform. The resulting TPS coating has an average roughness of around 7 μm , which increases the surface area of the implant. It has been shown that this three-dimensional topography increased the tensile strength at the bone/implant interface. In a pre-clinical study using minipigs, the bone/implant interface formed faster with a TPS surface than with smooth surface implants presenting an average roughness of 0.2 μm . However, particles of Ti have sometimes been found in the bone tissue around the implants. The presence of metallic wear particles from endosseous implants in the liver, spleen, small aggregates of macrophages and even in the para-aortic lymph nodes has also been reported. Metal ions released from implants may be the product of dissolution, fretting and wear, and may be a source of concern due to their potentially harmful local and systemic carcinogenic effects. However, the

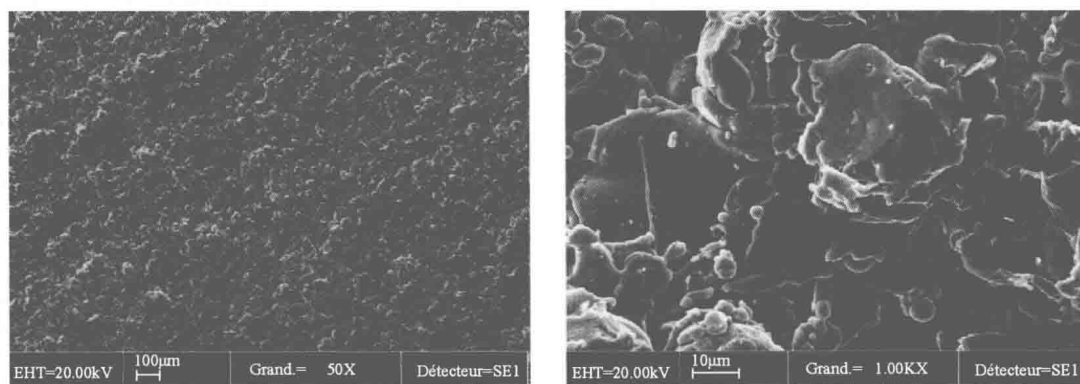


Fig. 1-1 SEM micrographs of a titanium plasma-sprayed (TPS) surface.
(Courtesy of Cam Implants BV, The Netherlands)