

Saving Dental Implants

Edited by
Georgios E. Romanos



WILEY Blackwell

Saving Dental Implants

Edited by

Georgios E. Romanos

Stony Brook University

School of Dental Medicine, Department of Periodontics and Endodontics

Stony Brook

NY, USA

Department of Oral Surgery and Implant Dentistry

School of Dentistry (Carolinum)

Johann Wolfgang Goethe University

Frankfurt, Germany

WILEY Blackwell

Copyright © 2024 by John Wiley & Sons, Inc. All rights reserved.

Published by John Wiley & Sons, Inc., Hoboken, New Jersey.
Published simultaneously in Canada.

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning, or otherwise, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without either the prior written permission of the Publisher, or authorization through payment of the appropriate per-copy fee to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, (978) 750-8400, fax (978) 750-4470, or on the web at www.copyright.com. Requests to the Publisher for permission should be addressed to the Permissions Department, John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, (201) 748-6011, fax (201) 748-6008, or online at <http://www.wiley.com/go/permission>.

Trademarks: Wiley and the Wiley logo are trademarks or registered trademarks of John Wiley & Sons, Inc. and/or its affiliates in the United States and other countries and may not be used without written permission. All other trademarks are the property of their respective owners. John Wiley & Sons, Inc. is not associated with any product or vendor mentioned in this book.

Limit of Liability/Disclaimer of Warranty: While the publisher and author have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives or written sales materials. The advice and strategies contained herein may not be suitable for your situation. You should consult with a professional where appropriate. Further, readers should be aware that websites listed in this work may have changed or disappeared between when this work was written and when it is read. Neither the publisher nor authors shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

For general information on our other products and services or for technical support, please contact our Customer Care Department within the United States at (800) 762-2974, outside the United States at (317) 572-3993 or fax (317) 572-4002.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic formats. For more information about Wiley products, visit our web site at www.wiley.com.

Library of Congress Cataloging-in-Publication Data:

Names: Romanos, Georgios, editor.

Title: Saving dental implants / edited by Georgios E. Romanos.

Description: Hoboken, NJ : Wiley-Blackwell, 2024. | Includes index.

Identifiers: LCCN 2024007505 (print) | LCCN 2024007506 (ebook) | ISBN

9781119807018 (hardback) | ISBN 9781119807025 (adobe pdf) | ISBN

9781119807032 (epub)

Subjects: MESH: Dental Implants | Dental Implantation

Classification: LCC RK667.I45 (print) | LCC RK667.I45 (ebook) | NLM WU

640 | DDC 617.6/93-dc23/eng/20240405

LC record available at <https://lcn.loc.gov/2024007505>

LC ebook record available at <https://lcn.loc.gov/2024007506>

Cover Design: Wiley

Cover Image: Courtesy of Georgios E. Romanos

Contents

List of Contributors xvi

Foreword xx

Preface xxi

Part I Etiology – Pathogenesis 1

1 Anatomy of the Peri-implant Soft Tissues 3

Anton Sculean, Edward Pat Allen, Dieter D. Bosshardt, and Georgios E. Romanos

Structure of Peri-implant Tissues in Health 3

References 6

2 Prevalence and Risk Factors for Peri-implant Diseases: The Global Diseases 8

Mingyue Lyu and Quan Yuan

Prevalence of Peri-implant Mucositis and Peri-implantitis 8

Risk Factors of Peri-implant Mucositis and Peri-implantitis 9

Systemic Risk Factors 13

Periodontitis 13

Smoking 13

Systemic Diseases 13

Gender 13

Local Risk Factors 13

Plaque 13

Dimensions of Keratinized Tissue 14

Prosthetic Concepts 14

Implant Factors 14

References 15

3 Significance of Radiographic Findings for the Long-term Success of Dental Implants 18

Seyed Hossein Bassir and Georgios E. Romanos

Introduction 18

Peri-implant Bone Levels 18

Type of Radiographs 20

Radiographic Intervals 21

References 23

4 Clinical, Microbiological, and Immunological Risk Indicators of Peri-implant Mucositis and Early Peri-implant Bone Loss 27

Georgios N. Belibasakis, Daniel Manoil, Ali Gürkan, and Nagihan Bostanci

Introduction 27

Diagnostic Epidemiological Aspects of Peri-implant Infections 27

Early Peri-implant Bone Loss and Associated Risk Factors	28
Factors Related to Early Peri-implant Bone Loss	30
Patient	31
Implant Design	32
Surgical Protocols	33
Restorative Protocols	34
The Oral Environment and Microbial Ecology	36
The Microbial Ecosystem of the Peri-implant Niche	36
Peri-implant Microbial Biofilms	36
Profiling of the Full Peri-implant Microbiome	36
Microbial Ecology in Transition from Peri-implant Health to Disease	37
Microbiota Shifts Associated with Early Peri-implant Bone Loss – Infection as Risk Indicator	37
Osseointegration and Peri-implant Tissue Microenvironment	40
Immune Response of the Peri-implant Tissues to Biofilms	40
Diagnostic Potential of Peri-implant Crevicular Fluid	40
Cytokines and Early Peri-Implant Bone Loss – Inflammation as Risk Indicator	41
Conclusions	42
References	42

5 Metallic Nanoparticles as a Risk Factor for Peri-implant Diseases 51

Mattias Pettersson and Georgios E. Romanos

Dental Implants	51
Titanium	52
Immune System	52
Innate and Adaptative Immune System	53
Inflammation	53
Phagocytosis	54
Inflammasomes	54
Foreign Body Reaction	56
Degradation Products from Implants	56
Nanoparticles and the Influence of Immune Cells	56
Orthopedic Implants	57
Tribocorrosion	58
Wear Particles from the Abutment-implant Interface and Implants	58
Wear Particles from Dental Implants and the Impact on Peri-implantitis Disease	58
Acknowledgment	64
References	65

Part II Management from Planning 71

6 Impact of Maintenance on Narrow Diameter Implants 73

Christian Peron and Giuseppe Bavetta

Conclusions	107
References	107

7 Prosthetic Abutment Characteristics and Implant–Abutment Maintenance 110

Rafael Delgado-Ruiz and Georgios E. Romanos

Introduction	110
Tissue Interfaces Around Prosthetic Abutments	112
Characteristics of the Soft Tissue in Contact with the Prosthetic Abutments	113
Prosthetic Abutment Material	114
Biofilm Formation on Different Abutment Materials	115

Prosthetic Abutment Surface	116
Machined Surfaces	116
Micro-Grooved Surfaces	117
Coated Surfaces	118
Functionalized Surfaces	118
The Transmucosal Area of Prosthetic Abutments	118
Transmucosal Designs of Prosthetic Abutments	120
Evaluation of the Emergence Profile of a Prosthetic Abutment	121
Prosthetic Abutment Maintenance	123
Effects of Instrumentation on the Abutment Surface	123
Efficacy of Cleaning Methods	125
Summary of Mechanical, Chemical, Lasers, and Other New Techniques Used for Abutment Decontamination	125
Maintenance Protocols for Implant Abutments	127
Clinical Examples of Implant Abutments and Recommended Decontamination Methods	128
Maintenance for Single Implant Abutments	128
Single Implant-supported Crown	128
Stud Abutments Supporting Overdentures (Including Locator, Ball, and Conus Abutments)	129
Maintenance for Interconnected Implant Abutments	129
Implant Bridges	129
Implant-supported Bar Restorations	129
Evaluation of Deffects of the Abutment/Crown Interface	131
Excess of Ceramic on the Abutment Surface	131
Porosity	132
Inadequate Finishing	133
Excess of Micro-gap Dimensions	133
Alterations of the Abutment Surface	133
Concluding Remarks	134
Acknowledgements	138
References	138

8 Considerations of Implant–abutment Connections for the Longevity of Dental Implants 144

Rafael Delgado-Ruiz, Fawad Javed, and Georgios E. Romanos

Introduction	144
Types of IAC	144
Abutment Retention to the Implant Body	144
One-piece Implants	144
Two-piece Implants	146
Vertical Implant Position of the IAC in Relation to the Bone Level	146
Rationale for Crestal or Subcrestal Implant Placement	147
Vertical Position of the IAC in Relation to the Implant Platform	147
Horizontal Position of the IAC in Relation to the Platform Edges	147
Geometric Design of the IAC Index	148
Angled Indexed Connections	148
Channel Indexed Connections	150
Morse Tapered Connections	151
IAC Design and Sealing Capability Against Bacteria Colonization	155
Mechanisms for Microbial Contamination of the IAC	156
Comparison of Microbial Contamination in Different IAC Designs	159
External and Internal Hexagon Versus Morse Taper	159
Tube-in-tube Versus Flat-to-Flat	160

Maintenance of IACs	160
Addressing the Microgap	163
Recommendations to Reduce the Microgap and its Effects	164
Addressing the Micromovement	164
Recommendations to Reduce the IAC Micromovement	165
Addressing Screw Loosening	165
Recommendations to Reduce Screw Loosening	165
Addressing the Decontamination of the IAC	165
Chlorhexidine	165
Chlorhexidine Used in Combination with Channel Sealers	166
Photodynamic Therapy and Chlorhexidine	166
Other Decontamination Methods	166
Considerations and Recommended Protocols for Maintenance of the IACs	166
References	168

9 The Role of Bone Regeneration in the Maintenance of Dental Implants 178

Nikolaos Soldatos
References 190

10 Soft Tissue Around Implants to Maintain/Reestablish Peri-implant Tissue Health 194

Anton Sculean, Edward Pat Allen, Andrea Rocuzzo, Georgios E. Romanos, and Raluca Cosgarea
Soft-tissue Issues Around Dental Implants 194
 Keratinized Tissue Width 194
 Mucosal Thickness 195
 Peri-implant Mucosal Recessions 197
Soft Tissue Augmentation Procedures 197
 Improvement of Keratinized Tissue Width Around Dental Implants 197
 Improvement of Peri-implant Mucosal Thickness 198
 Improvement of Soft Tissue Height 198
 Coverage of Soft Tissue Dehiscence at Dental Implants 199
References 200

Part III Management of Peri-Implant Diseases 207

11 Periodontal Maintenance in Patients with Peri-implantitis 209

Hanae Saito, Caitlin Darcey, and Mark A. Reynolds
Introduction 209
Modifying Factors and Considerations 210
 Host-level 210
 Systemic Considerations 210
 History of Periodontitis 210
 History of Peri-implant Mucositis 211
 Implant-level 211
 Bacterial Biofilm 211
 Prosthesis Design 212
Elements of a Implant Maintenance Appointment 213
 Review of Health Status 214
 Review of Dental Status 214
 Review Radiographs 214
 Oral Examination 214
 Oral Hygiene Assessment 215
 Biofilm Removal 215

Methods for Biofilm Removal During Implant Maintenance	215
Mechanical Methods	215
Chemical Adjuncts	216
Miscellaneous Adjuncts	216
Oral Hygiene Instruction	216
Assess the Effectiveness of the Current Maintenance Plan	216
Interval and Considerations	216
Host-level Considerations	216
Implant-level Considerations	217
When a Return to Active Therapy is Warranted	217
Applying These Guidelines to Three Clinical Scenarios	217
Summary	219
References	219

12 Surgical Treatment of Peri-implantitis 223

Georgios E. Romanos

Clinical Cases	227
Case 1 Peri-implantitis Therapy and Implant Surface Decontamination with Hydroxyl Peroxide	227
Case 2 Peri-implantitis Therapy in a Heavy Smoker	228
Case 3 Laser-assisted Implant Surface Decontamination and Peri-implantitis Therapy	230
Case 4 Peri-implantitis Treatment Before Functional Loading	230
Case 5 Peri-implantitis Treatment with Autogenous Bone Grafting Material	232
Case 6 Laser-Supported Treatment of Severe Peri-implantitis Defect	232
Case 7 Laser-Supported Treatment of Peri-implantitis	234
Case 8 Treatment in a Heavy Smoker using CO ₂ Laser Decontamination and Bone Mineral as a Grafting Material	236
Case 9 Peri-implantitis Treatment with a Diode Laser	237
Case 10 Treatment of Peri-implantitis in a Diabetes Patient Using a Pulsed 980 nm Diode Laser	238
Case 11 Treatment of Peri-implantitis Using a Pulsed 980 nm Diode Laser	238
Case 12 Peri-implantitis Therapy in Conjunction with Growth Factors	241
References	263

13 Lasers in Surgical Therapy of Peri-implantitis 266

Nathan E. Estrin, Akira Aoki, Anton Sculean, Richard J. Miron, and Georgios E. Romanos

Introduction	266
Diode Lasers for Peri-implantitis Therapy	267
Effects of Diode Lasers on Titanium Surfaces	267
Clinical Studies	268
Summary of Diode Lasers in Peri-implant Therapy	268
Nd:YAG Lasers in Peri-implantitis Therapy	268
Summary of Nd:YAG Laser in Peri-implant Therapy	269
Erbium Lasers in the Peri-implantitis Therapy	269
Tissue Ablation and Wound Healing Following Erbium Laser Irradiation	269
Effects of Erbium Lasers on Titanium Surfaces	271
In Vivo Studies of Erbium Lasers in Peri-implantitis Therapy	272
Clinical Studies	272
Non-surgical Therapy	272
Surgical Therapy	273
Summary of Er:YAG Lasers in Surgical Peri-implant Therapy	274
CO ₂ Lasers	276
CO ₂ Lasers in Peri-implantitis Therapy	277
Summary of CO ₂ Lasers in Surgical Peri-implant Therapy	277
Photodynamic Therapy	277

Photodynamic Therapy in the Surgical Therapy of Peri-implantitis	280
Summary of PDT Remarks	280
Conclusions	280
References	281

14 Implant Surface Modification as a Method of Implant Maintenance Applications, Limitations, and Risks of Implantoplasty 287

Philip L. Keeve and Fouad Khoury

Introduction	287
Treatment	288
Indications	292
Surgical Procedure	293
Decontamination	298
Biofilm Formation	300
Roughness	301
Biocompatibility	303
Overheating	304
Particle Remnants	304
Fracture/Reducing Diameter	305
Results	307
Treatment Success	308
Follow-Up Care/SPT	308
Discussion	309
Limitations	310
Conclusion	310
References	311

15 Non-surgical Antimicrobial Photodynamic and Photothermal Therapy in Treatment of Peri-implant Mucositis and Peri-implantitis 317

Manolis Vlachos and Ioannis Fourmouis

Introduction	317
Photodynamic Therapy	317
Photothermal Therapy	319
Abbreviations	331
References	332

16 Removal of Implants: Guidelines of Explantation Techniques 335

Thomas G. Wiedemann

Introduction	335
Overview of Removal Techniques and Factors for Decision-making	335
Factors for Decision-making	335
Reasons for Implant Removal	336
Implant Removal Techniques	337
Non-bone Removal Techniques	337
Tooth Extraction Set	337
Counter-torque-Technique	337
Reverse Screw Technique	338
Bone Removal Techniques	339
Surgical Removal Using High Speed Burs and Elevator/Forceps	339
Piezo-surgical Removal	339
Piezoelectric and Grafted Removal Technique for Removal of Blade Implants	340
Trephine Drill Technique	340

Laser-assisted Explantation	342
Alternative Techniques	342
Bony Lid Approach	342
Partial Explantation/Coronal Resection	343
Clinical Guidelines for Explantation of Osseointegrated Oral Implants	343
Conclusion	344
References	344

Part IV Contributing Factors 347

17 Risks and Opportunities for Cement-retained Implant Restorations 349

Kenneth S. Kurtz and Alexa Schweitzer

Introduction	349
Retrievability	350
CAD/CAM	351
Cement Selection	351
Strategies to Minimize Cement Excess Expressed into Sulcus	352
Digital Versus Analog	352
Abutment Margination	352
Peri-implantitis Incidence Relating to Cement Displaced into the Sulcus	353
References	354

18 Implant Supportive Maintenance for Fixed Prosthetic Rehabilitations: The Patient with the Complete Arch Fixed Implant–supported Rehabilitation: Prosthetic Concepts to Optimize Maintenance Protocols 357

K. Michalakis, S. Misci, A. Abdallah, D. Vasilaki, and H. Hirayama

The Metal-acrylic Hybrid Prosthesis	358
Prognosis and Maintenance of Metal-acrylic Hybrid Prostheses	360
Bacterial Adhesion to Metal-acrylic Hybrid Prostheses	362
The Shift to Metal–Ceramics	364
Modern CAD/CAM Framework Materials	364
Zirconia-based Prostheses	366
Milled Titanium Frameworks	368
High-strength Polymers	368
Prosthetic Design – Impact on Maintenance	369
Conclusions	374
References	376

19 Prosthetic Rehabilitations to Optimize Maintenance and Implant Long-term Success 381

Silvia Brandt

Introduction	381
Attachment Systems for Removable Superstructures	381
Long-term Evaluation	381
Complications and Maintenance	382
How to Select an Attachment System?	382
Decision Level 1: People-related Factors	382
Decision Level 2: Tissue-related Factors	382
Decision Level 3: Simulation-related Factors	383
Prostheses Retained by Double-crowns	383
History of Telescopic Crowns	384
Friction-type (Cylindrical Crown) Telescopes	384
Resilience-type (Clearance Crown) Telescopes	384

Cone-type (Conical Crown) Telescopes	384
Gold-on-zirconia Double Crowns	385
The “Frankfurt Principle”	385
Indications and Limitations	385
Clinical and Technical Process	388
Specific Workflow Considerations	389
Primary and Secondary Crowns	389
Fabrication of the Tertiary Structure	398
Intraoral Bonding	398
Travel Denture	410
References	412

20 Implant Prostheses Planning and Maintenance for the Aging Population 414

Judy Chia-Chun Yuan, Fatemeh S. Afshari, and Lily T. Garcia

Introduction	414
Rapid Oral Health Deterioration in Elderly Patients	415
Treatment Modalities	416
Recall and Maintenance in Elderly Patients	418
Conclusion	420
References	425

21 Disinfection of Implant Prosthetic Components Before Delivery 427

Fawad Javed, Rafael Delgado-Ruiz, and Georgios E. Romanos

Background	427
Objective	427
Literature Search Strategy	427
Methods of Implant Abutment Disinfection	427
Argon Plasma	427
Chlorhexidine	428
Nanoparticles	429
Hydrogen Peroxide	429
Ethyl Alcohol	430
Iodine	431
Citric Acid	431
Authors’ Perspective	431
Abbreviations	431
References	432

22 Home Care for the Implant Patient 435

Marisa Roncati

Introduction and Key Issues	435
Rationale and Relevance of Home Care	435
How to Motivate and Inform Implant Patients on Effective Home Care	440
How Much Time Should be Spent on Motivation?	441
Essential Home Care Tools and Technique	441
Important and Useful Clinical Recommendation	442
Toothbrush and Brushing Technique	444
Tongue Brushing	447
Interdental Brush	448
Digital Brush	449
Disclosing Solution	454

Tufts	454
Floss	454
Special Floss	457
Promote Healthy Lifestyle	459
References	459

23 Role of Compliance in Oral and Implant Health Maintenance: Significance, Risk Factors and Suggestions 461

Fawad Javed, Abeer Al-Zawawi, and Georgios E. Romanos

Background	461
Introduction	461
Modern Dentistry and Critical Thinking	461
Complications in Dental Procedures and Their Consequences	462
What is Compliance?	462
Compliance and Non-compliance in Healthcare	462
Common Risk Factors of Non-compliance	463
Patient-related Factors	463
Dental Anxiety/Phobia	463
Gender	464
Age	464
Previous Unpleasant Experience/s of Patients	465
Demographics-related Factors	465
Education and Socioeconomic Status	465
Treatment-related Factors	465
Complexity and Duration of Treatment	465
Non-effectiveness of Therapy	465
Communication and Trust Between the Patient and Dental Professional	465
Suggestions	466
Steps Toward Compliance: Authors' Opinion	466
References	467

24 Systemic Factors and Peri-implant Health 471

Fawad Javed

Introduction	471
Dental Implants in Patients with Diabetes Mellitus	471
Dental Implants in Patients with Cardiovascular Diseases	472
Dental Implants in Patients with Hepatic Disorders	473
Dental Implants in Patients with Psychological Disorders	474
Dental Implants in Patients with HIV/Acquired Immune Deficiency Syndrome	474
Dental Implants in Patients with Eating Disorders	475
Dental Implants in Patients with Autism Spectrum Disorders	476
Dental Implants in Patients with Crohn's Disease	476
Conclusion	478
Conflict of Interest Disclosure	478
References	478

Part V Potential Future Solutions 483

25 Zirconia as a Viable Implant Material in Implant Dentistry 485

Sammy Noubissi and Saurabh Gupta

Current Problems in Implant Dentistry	485
Corrosion	485

Clinical Significance of Corrosion	486
Osteolysis and Bone Loss	486
Peri-implantitis	487
Immune Reactions to Metal Alloy Implants	487
Cellular Immunity	488
Humoral Immunity	488
Allergies/Metal Hypersensitivity	488
Zirconia as an Implantable Material	490
Manufacturing Processes of Zirconia	490
Hard Machining Process	491
Powder Injection Molding	491
3D Printing	492
Surface Modification Techniques	493
Sandblasting	493
Acid-etching	493
Selective Infiltration Technique	493
Polishing	494
Laser Treatment	494
Ultraviolet Light Treatment	494
Coating	494
Biofunctionalization	495
Self-assembly	495
Fracture Resistance of Zirconia Implants	495
Biological Outcome of Zirconia Implants	496
Muco-integration	496
Osseointegration	497
Market Growth with Zirconia Implants	497
Conclusion	498
References	498

26 Ceramic Implants 503

Joan Pi Anfruns

Introduction 503

Zirconia 503

 Manufacturing 504

 Osseointegration 505

 Soft Tissue Integration 507

 Long-term Maintenance 508

 Conclusions 508

References 508

27 Photofunctionalization in the Treatment of Peri-implantitis 511

Robert Miller

Surface Characteristics of Metallic Oxide Surfaces 512

Osteoblast Attachment and Migration 513

Osteoblast Differentiation and Bone Density 514

Electrostatic Condition and Hydrophilicity 515

Antibacterial Effect 515

Intraoral Use of Photofunctionalization 515

References 520

28	Improvement of Osseointegration Through Autologous Growth Factors	522
	<i>Andrea Palermo</i>	
	Introduction	522
	Growth Factors	523
	Preparation of CGF	525
	In vitro Trial	526
	Results	528
	Implants with CGF In vivo	529
	Discussion	530
	Conclusion	531
	References	531
29	Plasma Cleaning for Implant Surfaces to Improve Implant Success	534
	<i>Kameron Farhadi and Georgios E. Romanos</i>	
	Introduction	534
	Plasma Cleaning	535
	Types of Plasma	535
	Benefits	535
	Atmospheric-pressure Plasma Systems and Devices for Cleaning Implant Surfaces	537
	Transferred Arcs	537
	Dielectric Barrier Discharge	537
	Plasma Jet	539
	Low-pressure Plasma Systems and Devices for Cleaning Implant Surfaces	539
	Conclusions	541
	References	541
30	Dental Implant Maintenance and Prosthetic Preventive Care for Implant Longevity	545
	<i>Rafael Delgado-Ruiz, Fawad Javed, and Georgios E. Romanos</i>	
	Introduction	545
	Definition of Implant Health, Maintenance, and Patient's General Health	548
	Implant Maintenance Protocols	548
	Implant Prosthodontics Maintenance Protocols	551
	Patient's Function and Quality of Life in Maintenance Protocols	554
	Health Impact Profile-14	557
	Oral Implant Impact Profile	557
	Food Intake Ability	557
	Concluding Remarks	557
	References	557
	Index	560

List of Contributors

A. Abdallah

Department of Restorative Sciences and Biomaterials
Boston University Henry M. Goldman
School of Dental Medicine
Boston, MA
USA

Fatemeh S. Afshari

Department of Restorative Dentistry
University of Illinois at Chicago College of Dentistry
Chicago, IL
USA

Edward Pat Allen

Center for Advanced Dental Education
Dallas, TX
USA

Joan Pi Anfruns

Private Practice
Los Angeles, CA
USA and
Department of Oral and Maxillofacial Surgery
UCLA School of Dentistry
Los Angeles, CA
USA

Abeer Al-Zawawi

Department of Periodontics and Community Dentistry
College of Dentistry
King Saud University
Riyadh
Saudi Arabia

Akira Aoki

Department of Periodontology
Tokyo Medical and Dental University
Tokyo, Japan

Seyed Hossein Bassir

Private Practice
Los Angeles, CA
USA

Giuseppe Bavetta

Private Practice
Palermo, Italy

Georgios N. Belibasakis

Division of Oral Diseases
Department of Dental Medicine
Karolinska Institute
Huddinge, Stockholm
Sweden

Dieter D. Bosshardt

Department of Periodontology
School of Dental Medicine
University of Bern
Bern
Switzerland

Robert K. Schenk Laboratory for Oral Histology
School of Dental Medicine
University of Bern
Bern
Switzerland

Nagihan Bostanci

Division of Oral Diseases, Department of Dental Medicine
Karolinska Institute
Huddinge, Stockholm
Sweden

Silvia Brandt

Department of Prosthodontics, Center for Dentistry
and Oral Medicine (Carolinum)
Goethe University Frankfurt
Frankfurt am Main
Germany

Judy Chia-Chun Yuan

Department of Restorative Dentistry
University of Illinois at Chicago College of Dentistry
Chicago, IL
USA

Raluca Cosgarea

Department of Periodontology, Conservative and
Preventive Dentistry
University of Bonn, Bonn
Germany

Caitlin Darcey

US Navy Periodontics Residency, Naval Postgraduate
Dental School
Bethesda, MD

Uniformed Services University of the Health
Sciences
Bethesda, MD

Rafael Delgado-Ruiz

Department of Prosthodontics and Digital Technology
Stony Brook University
Stony Brook, NY
USA

Nathan E. Estrin

Lake Erie College of Osteopathic Medicine
School of Dental Medicine
Bradenton, FL
USA

Kameron Farhadi

Department of Periodontics & Endodontics
School of Dental Medicine
Stony Brook University
Stony Brook, NY
USA

Ioannis Fourmouis

Department of Periodontology
School of Dentistry
NKUA
Athens
Greece

Lily T. Garcia

Texas A&M University School of Dentistry
Dallas, TX
USA

Saurabh Gupta

Zirconia Implant Research Group
Silver Spring, MD
USA

Private Practice Dentistry
Bangalore, Karnataka
India

Ali Gürkan

Department of Periodontology, School of Dentistry
Ege University
Bornova
Turkey

H. Hirayama

Department of Restorative Sciences and Biomaterials
Boston University Henry M. Goldman
School of Dental Medicine
Boston, MA
USA

Fawad Javed

Department of Orthodontics and Dentofacial Orthopedics
Eastman Institute for Oral Health, University of Rochester
Rochester, New York
USA

Philip L. Keeve

Private Dental Clinic Fachzahnarzt Zentrum Weser
Hameln
Germany

Fouad Khoury

Private Dental Clinic Schloss Schellenstein
Olsberg
Germany

Department of Oral & Maxillo-Facial-Surgery
University Muenster
Muenster
Germany

Kenneth S. Kurtz

Department of Prosthodontics & Digital Technology
Stony Brook University, School of Dental Medicine
Stony Brook, NY
USA

Departments of Dentistry & Otorhinolaryngology
Montefiore Medical Center/Albert Einstein
College of Medicine
Bronx, NY
USA

Department of Dentistry, Northwell/Zucker
School of Medicine
New Hyde Park, NY
USA

Mingyue Lyu

State Key Laboratory of Oral Diseases, National Clinical
Research Center for Oral Diseases
West China Hospital of Stomatology, Sichuan University
Chengdu, China

Daniel Manoil

Division of Oral Diseases, Department of Dental Medicine
Karolinska Institute
Huddinge, Stockholm
Sweden

Division of Cariology and Endodontics
University Clinics of Dental Medicine, Faculty of
Medicine, University of Geneva
Geneva, Switzerland

K. Michalakos

Department of Restorative Sciences and Biomaterials
Boston University Henry M. Goldman
School of Dental Medicine
Boston, MA
USA

Robert Miller

Department of Oral Implantology ACDRC
Palm Beach State College
FL, USA

Richard J. Miron

Department of Periodontology
University of Bern
Bern
Switzerland

S. Misci

Department of Restorative Sciences and Biomaterials
Boston University Henry M. Goldman
School of Dental Medicine
Boston, MA
USA

Sammy Noubissi

Zirconia Implant Research Group
Silver Spring, MD
USA

Private Practice Dental Implantology
Silver Spring, MD
USA

Andrea Palermo

Implant Dentistry
College of Medicine and Dentistry Birmingham
Birmingham
UK

Christian Peron

Private Practice
Torino, Italy

Mattias Pettersson

Division of Prosthetic Dentistry, Department of
Odontology, Faculty of Medicine
Umeå University
Umeå, Sweden

Mark A. Reynolds

Department of Advanced Oral Sciences and Therapeutics
Division of Periodontics
University of Maryland School of Dentistry
Baltimore, MD

Andrea Rocuzzo

Department of Periodontology, School of
Dental Medicine
University of Bern
Bern
Switzerland

Georgios E. Romanos

Department of Periodontics and Endodontics
School of Dental Medicine
Stony Brook University
Stony Brook, NY
USA

Department of Oral Surgery and Implant Dentistry
School of Dentistry (Carolinum)
Johann Wolfgang Goethe University
Frankfurt, Germany

Marisa Roncati

Department of Translational Medicine
School of Dentistry, University of Ferrara
Ferrara, Italy

Hanae Saito

Department of Advanced Oral Sciences and Therapeutics
Division of Periodontics
University of Maryland School of Dentistry
Baltimore, MD

Alexa Schweitzer

Division of Prosthodontics, Department of Dentistry
Montefiore Medical Center
Bronx, NY
USA

Anton Sculean

Department of Periodontology
University of Bern
Bern
Switzerland

Nikolaos Soldatos

Department of Regenerative and Reconstructive Sciences
Division of Periodontics, School of Dentistry
Oregon Health Science University
Portland, OR
USA

D. Vasilaki

Division of Prosthodontics
University of Connecticut School of Dental Medicine
Farmington, CT
USA

Manolis Vlachos

Dental Excellence
Private Dental Clinic
Athens
Greece

Thomas G. Wiedemann

Department of Oral and Maxillofacial Surgery
New York University – College of Dentistry
New York, NY
USA

Quan Yuan

State Key Laboratory of Oral Diseases, National Clinical
Research Center for Oral Diseases
West China Hospital of Stomatology
Sichuan University
Chengdu, China

Foreword

It is great honor to write this foreword for George Romanos's incredible textbook. Congratulations to him for bringing together experts from around the world to add their knowledge and expertise to help us better know the state of the art when it comes to prevention and management of peri-implantitis. What is so impressive is that the chapters have both clinical and academic emphases so that the reader will be able to deal with the everyday problems that we all have in our practices.

What is so impressive is that there are many ways to treat this very important problem. The use of lasers, photo dynamics, and implantoplasty with and without bone and

soft tissue grafting each have their own chapters. Wow, this is very special.

I know you will enjoy this book, and it will help you manage your patients at a higher level. Congratulations again to George and all the authors.

Well done!

*Dennis P Tarnow DDS
Clinical Professor of Periodontology and
Director of Implant Dentistry
Columbia University College of Dental Medicine*

Preface

The increased number of peri-implant complications, such as peri-implant mucositis and peri-implantitis demand the need for a comprehensive analysis of the anatomical conditions, the etiological and risk factors for the disease pathology, medical and prosthodontic aspects, and *last but not least* the management of these clinical entities.

The patient's request for treatment with dental implants puts the responsibility on every clinician to present the pros and cons of this type of therapy and the specifics of pre-implantological diagnostics, treatment methodology, prosthetic concepts, and further maintenance visits.

In "Saving Dental Implants," I have tried to present global treatment approaches and concepts, established philosophies in practice for the last 20 years, but also future aspects of the management of the disease progression. I am excited and proud to have recruited leaders in this field, who have seen how implant therapy has an impact on patients' lives. Our patients deserve the best functional and esthetic outcomes. The foreword in this book, written by Dr. Dennis Tarnow, highlights the past, present, and future of dental Implants.

I would like to thank everyone who provided the effort to illustrate their clinical and research expertise based

on daily practice. This book should be a tool for every clinician and a resource of knowledge, to prepare the foundation around dental implant treatment and how to manage peri-implant diseases focused on long-term predictability. I highlight in this book periodontal, prosthetic, and biomaterial aspects and challenges, for sustainable and long-term successful clinical outcomes. It is an opportunity to gain knowledge, find inspiration, and engage in clinical practices that can prepare each one of us to build the critical thinking we need to treat ailing dental implants.

I would like to thank the Publisher's team and all the authors for supporting me from the beginning. We took on the challenge of the management of peri-implant problems as an opportunity for education, research, and clinical practice advancement. Special thanks to my loving family for their continuous support of my academic work.

Georgios Romanos

*Georgios E. Romanos, DDS, PhD, Prof Dr med dent
Stony Brook University, School of Dental Medicine,
Stony Brook, NY, USA*

Part I

Etiology - Pathogenesis

1

Anatomy of the Peri-implant Soft Tissues

Anton Sculean¹, Edward Pat Allen², Dieter D. Bosshardt^{1,3}, and Georgios E. Romanos⁴

¹ Department of Periodontology, University of Bern, Bern, Switzerland

² Center for Advanced Dental Education, Dallas, TX, USA

³ Robert K. Schenk Laboratory for Oral Histology, School of Dental Medicine, University of Bern, Bern, Switzerland

⁴ Department of Periodontics and Endodontics, School of Dental Medicine, Stony Brook University, Stony Brook, NY, USA

Dental implants anchor into the jawbone through direct contact between the bone and the implant, a process known as “osseointegration.” Recent evidence suggests that the sustained success and survival of implants are not exclusively contingent on “osseointegration” but also on the soft tissues enveloping the transmucosal section of the implant, which serves as a barrier between the peri-implant bone and the oral cavity (Figure 1.1). This soft tissue seal, often referred to as the “peri-implant mucosa,” plays a crucial role in the overall health and longevity of dental implants [1]. The attachment of soft tissue to the implant functions as a biological seal, ensuring optimal conditions and thwarting the onset of peri-implant infections, such as peri-implant mucositis and peri-implantitis. Consequently, the peri-implant soft tissues play a pivotal role in ensuring the long-term survival of implants [1].

As soft tissue develops around teeth during tooth eruption, it forms a seal that protects the supporting tissues – namely, the alveolar bone, periodontal ligament, and cementum – from exposure to the oral cavity [2]. In contrast, the peri-implant mucosa is established after the oral soft and hard tissues undergo a healing process to accommodate the osseointegrated implants. The following section provides a concise overview of the key anatomical features of peri-implant tissues.

Structure of Peri-implant Tissues in Health

During the process of wound healing following the accommodation of dental implants, the features of the peri-implant mucosa are established [3] (Figures 1.2–1.4). Berglundh et al. [4] conducted an examination in dogs to

investigate the anatomical and histological features of the peri-implant mucosa formed in a two-stage procedure, comparing them with the gingiva around teeth.

It was revealed that the peri-implant mucosa consists of a keratinized oral epithelium located at the external surface. This epithelium is connected to a thin non-keratinized sulcular epithelium facing the abutment and terminating in junctional epithelium, equivalent to the junctional epithelium around teeth, termed as peri-implant junctional epithelium. The peri-implant junctional epithelium terminates 2 mm apical to the coronal soft tissue margin and 1.0–1.5 mm coronal to the peri-implant bone crest. The mean supracrestal soft tissue, including sulcus depth, measured 3.80 mm around implants and 3.17 mm around teeth (Figures 1.2–1.4).

While no statistically significant difference was observed in the height of the junctional epithelium and sulcus depth between implants and teeth, the height of the soft connective tissue was statistically significantly greater around implants than around teeth. The peri-implant junctional epithelium and the soft connective tissue adjacent to the abutment appeared to be in direct contact with the implant–abutment surface [4].

In summary, this study demonstrated that the peri-implant mucosa exhibits comparable anatomical features to those of gingiva around teeth [4].

Subsequent studies provided evidence that a similar mucosal attachment formed on titanium in conjunction with different implant systems [5, 6] and around intentionally non-submerged and initially submerged implants [7, 8, 9]. However, the peri-implant junctional epithelium was significantly longer in initially submerged implants to which an abutment was connected later than in intentionally non-submerged implants [9].



Figure 1.1 Clinical image depicting a healthy soft tissue around an osseointegrated implant. *Source:* Photo: Prof. Dr. Georgios Romanos.

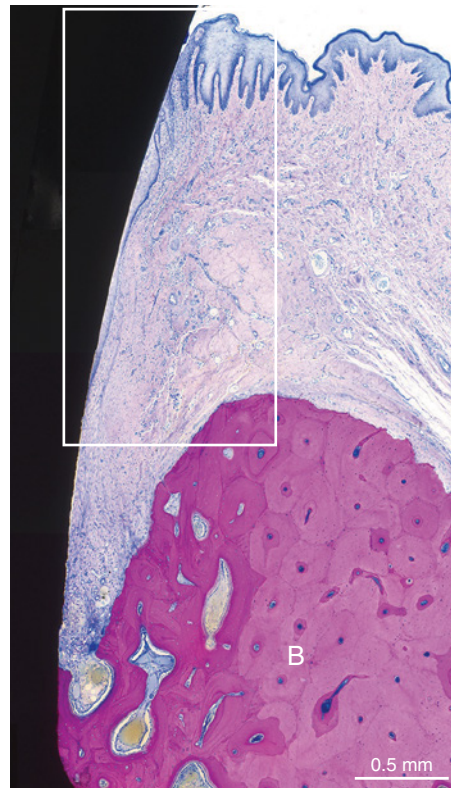


Figure 1.3 Higher magnification depicting the supracrestal peri-implant soft tissues consisting of oral and sulcular epithelium and connective tissue adhesion to the implant surface. *Source:* Photo: Prof. Dieter D. Bosshardt.

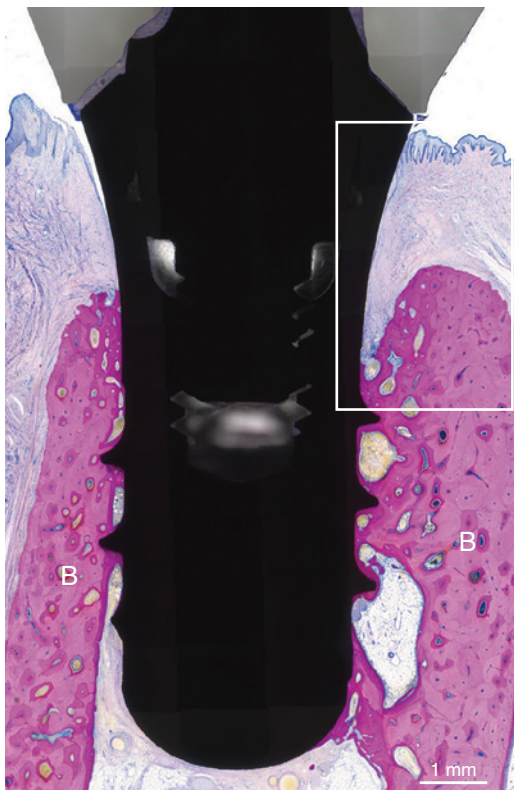


Figure 1.2 Photomicrograph of an osseointegrated titanium dental implant depicting the direct bone-implant contact and the supracrestal soft tissue implant contact. *Source:* Photo: Prof. Dieter D. Bosshardt.

The biologic width (i.e., the supracrestal soft tissue) was revisited in a further dog experiment after abutment connection to the implant fixture with or without a reduced vertical dimension of the oral mucosa (Berglundh and Lindhe [10]). While the peri-implant junctional epithelium was about 2mm long, the supra-alveolar soft connective tissue was about 1.3–1.8mm high. Interestingly, sites with a reduced mucosal thickness consistently revealed marginal bone resorption, adjusting the width of the supracrestal soft tissue. Evaluating the biologic width around one- and two-piece titanium implants that healed either non-submerged or submerged in dog mandibles, Hermann et al. [11] suggested that the gingival margin is located more coronally, and the biologic width is more like teeth in association with one-piece non-submerged implants compared to either two-piece non-submerged or two-piece submerged implants. These findings were later confirmed in a comparably designed dog study with another implant system [12].

Several studies have evaluated the impact of surface topography (i.e., surface roughness measurements) on the peri-implant mucosa. Cochran et al. [13] failed to show any differences in the dimensions of the sulcus depth, peri-implant junctional epithelium, and soft connective tissue

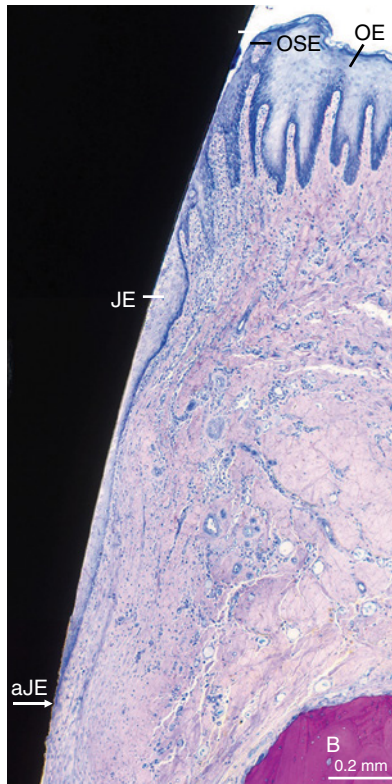


Figure 1.4 Higher magnification of the coronal portion of the supracrestal peri-implant soft tissues. The oral and sulcular epithelium are clearly visible. A more diffuse inflammatory infiltrate, located immediately adjacent to the junctional and sulcular epithelium is visible. Source: Photo: Prof. Dieter D. Bosshardt.

contact to implants with a titanium plasma-sprayed (TPS) surface or a sandblasted acid-etched surface. Abrahamsson et al. [14, 15] observed similar epithelial and soft connective tissue components on a rough (acid-etched) and smooth (turned) titanium surface. The biologic width (i.e., supracrestal soft tissue) was greater on the rough surface; however, without a statistically significant difference from that around a smooth surface.

Findings from two human histologic studies revealed less epithelial downgrowth and a longer soft connective tissue in conjunction with oxidized or acid-etched titanium compared to a machined surface [16]. In a study in baboons, Watzak et al. [17] showed that implant surface modifications had no significant effect on the biologic width after 18 months of functional loading. Following a healing period of 3 months, nano-porous TiO_2 coatings of one-piece titanium implants showed a similar length of peri-implant soft connective tissue and epithelium as the uncoated, smooth neck portion of the control titanium implants in dogs [18]. Schwarz et al. [19] suggested that soft tissue integration was more influenced by hydrophilicity than by microtopography.

Several studies revealed that the epithelial cells attach to different implant materials in a comparable way to that of the junctional epithelial cells to the tooth surface via hemidesmosomes and a basal lamina [3].

Analyzing the intact interface between soft connective tissue and titanium-coated epoxy resin implants, the parallel orientation of collagen fibrils to the titanium layer was confirmed [20, 21]. Since implants lack a cementum layer that can invest the peri-implant collagen fibers, the attachment of the soft connective tissue to the transmucosal portion of an implant is regarded as being weaker than the soft connective tissue attachment to the surface of a tooth root. Therefore, improving the quality of the soft tissue-implant interface is considered to be of great relevance for maintaining healthy peri-implant tissues [3].

Studies on the distribution of the collagen types on the peri-implant soft tissues have been evaluated by different research groups. Chavrier et al. [22] examined collagen types I, III, and IV as well as noncollagenous glycoproteins (i.e., laminin and fibronectin), and they could not find any significant structural differences between peri-implant mucosa and gingiva. However, Chavrier et al. [22] underlined the clinical importance of collagen type III and fibronectin in keratinized mucosa surrounding implants, because these proteins seem to promote connective tissue repair around implants after the second surgical stage (implant uncovering) or in case of an inflammatory response.

Romanos et al. [23] emphasized the role of collagen type V in peri-implant soft tissues. Specifically, Romanos et al. [23] evaluated the extracellular matrix quality around non-submerged implants with clinically healthy conditions in humans and demonstrated a higher amount of collagenase-resistant matrix containing collagen type V, when implants are one-piece with a transmucosal highly polished neck (without implant-abutment microgap). These collagen fibers in a filament-type distribution were oriented in a different way in the stroma. The fibers were more intense around the blood vessels and nerves, and in some areas, formed parallel fibrillar bundles. The structural differences may be responsible for the defense of peri-implant keratinized gingival connective tissues to bacterial penetration, because of the high amount of the collagen type V-component, which is responsible for the higher collagenase stability.

In contrast to these findings, the peri-implant inflamed tissues showed no difference in terms of collagen type distribution like that around teeth with inflamed gingiva. The collagen type V is the main component of the inflamed granulation tissue around teeth and implants [24]. The authors concluded that quantitative analyses of peri-implant versus periodontal soft tissues may be important to confirm morphologic studies in the peri-implant soft tissues. The localization of collagen type V in the tissue may

be of great theoretical and clinical importance and may modify significantly soft tissue management.

The wound healing sequence leading to the establishment of the soft tissue sealing at implants has been evaluated by Berglundh et al. [25]. Immediately after implant placement, a coagulum occupied the implant-mucosa interface. Numerous neutrophils infiltrated the blood clot, and at four days, an initial mucosal seal was established. In the next few days, the area with the leukocytes decreased and was confined to the coronal portion, whereas fibroblasts and collagen dominated the apical part of the implant-tissue interface. Between one and two weeks of healing, the peri-implant junctional epithelium was about 0.5 mm apical to the mucosal margin. At two weeks, the peri-implant junctional epithelium started to proliferate in the apical direction. After two weeks, the peri-implant mucosa was rich in cells and blood vessels. At four weeks of healing, the peri-implant junctional epithelium migrated further apically and occupied now 40% of the total soft tissue implant interface. The soft connective tissue was rich in collagen and fibroblasts and well-organized. The apical migration of the peri-implant junctional epithelium was completed between six and eight weeks, and the fibroblasts formed a dense layer over the titanium surface at that time.

From 6 to 12 weeks, maturation of the soft connective tissue had occurred, and the peri-implant junctional epithelium occupied about 60% of the entire implant soft tissue interface. Further away from the implant surface, the number of blood vessels was low, and fibroblasts were located between thin collagen fibers running mainly parallel to the implant surface. The findings indicated that the soft tissue adherence to transmucosal (i.e., non-submerged) implants made of commercially pure titanium with a polished surface in the neck portion requires at least six weeks [25]. The findings from animals were corroborated also in humans by Tomasi et al. [26], indicating that a soft tissue barrier adjacent to titanium implants may form completely within eight weeks. Further studies provided evidence indicating that in animals (i.e., dogs), the dimensions of the soft tissue seal (i.e., the biological width or supracrestal soft tissue) around implants are stable for at least 12 [13, 27] or 15 months, respectively [28].

In conclusion, soft peri-implant mucosa is a physiological barrier between the oral mucosa and peri-implant bone. It is the protective core of the implant surrounding bone and the anatomical structure promoting resistance to functional loads and responsible for the immunological host-tissue response.

References

- 1 Lindhe, J., Wennström, J.L., and Berglundh, T. (2008). The mucosa at teeth and implants. Chapter 3. In: *Clinical Periodontology and Implant Dentistry*, 5e (ed. J. Lindhe, N.P. Lang, and T. Karring), 69–85. Blackwell Munksgaard.
- 2 Bosshardt, D.D. and Lang, N.P. (2005). The junctional epithelium: from health to disease. *Journal of Dental Research* 84 (1): 9–20.
- 3 Sculean, A., Gruber, R., and Bosshardt, D.D. (2014). Soft tissue wound healing around teeth and dental implants. *Journal of Clinical Periodontology* 41 (Suppl 15): S6–S22.
- 4 Berglundh, T., Lindhe, J., Ericsson, I. et al. (1991). The soft tissue barrier at implants and teeth. *Clinical Oral Implants Research* 2 (2): 81–90.
- 5 Buser, D., Weber, H.P., Donath, K. et al. (1992). Soft tissue reactions to non-submerged unloaded titanium implants in beagle dogs. *Journal of Periodontology* 63: 225–235.
- 6 Abrahamsson, I., Berglundh, T., Wennstrom, J., and Lindhe, J. (1996). The peri-implant hard and soft tissues at different implant systems. A comparative study in the dog. *Clinical Oral Implants Research* 7: 212–219.
- 7 Arvidson, K., Fartash, B., Hilliges, M., and Kondell, P.A. (1996). Histological characteristics of peri-implant mucosa around Branemark and single-crystal sapphire implants. *Clinical Oral Implants Research* 7: 1–10.
- 8 Abrahamsson, I., Berglundh, T., Moon, I.S., and Lindhe, J. (1999). Peri-implant tissues at submerged and non-submerged titanium implants. *Journal of Clinical Periodontology* 26: 600–607.
- 9 Weber, H.P., Buser, D., Donath, K. et al. (1996). Comparison of healed tissues adjacent to submerged and non-submerged unloaded titanium dental implants. A histometric study in beagle dogs. *Clinical Oral Implants Research* 7: 11–19.
- 10 Berglundh, T. and Lindhe, J. (1996). Dimension of the periimplant mucosa. Biological width revisited. *Journal of Clinical Periodontology* 23: 971–973.
- 11 Hermann, J.S., Buser, D., Schenk, R.K. et al. (2001). Biologic Width around one- and two-piece titanium implants. *Clinical Oral Implants Research* 12: 559–571.
- 12 Pontes, A.E., Ribeiro, F.S., Iezzi, G. et al. (2008). Biologic width changes around loaded implants inserted in different levels in relation to crestal bone: histometric evaluation in canine mandible. *Clinical Oral Implants Research* 19: 483–490.
- 13 Cochran, D.L., Hermann, J.S., Schenk, R.K. et al. (1997). Biologic width around titanium implants. A histometric analysis of the implant-to-gingival junction around unloaded and loaded nonsubmerged implants in the