

LINDHE'S

SEVENTH EDITION

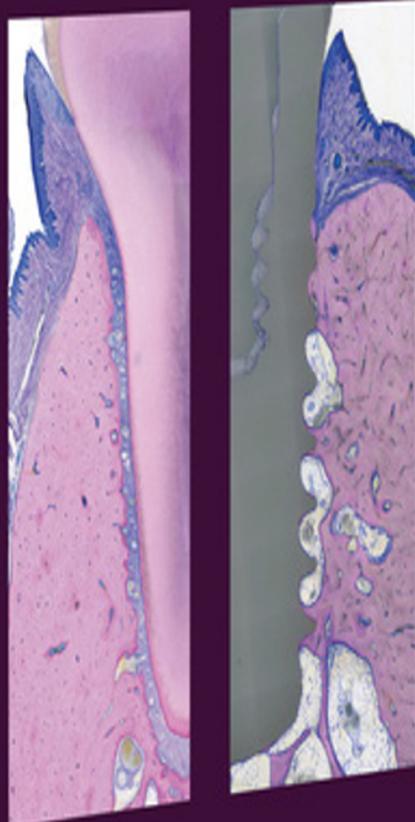
Clinical Periodontology and Implant Dentistry

EDITED BY

Tord Berglundh, William V. Giannobile,
Niklaus P. Lang, and Mariano Sanz

VOLUME

1



WILEY Blackwell

Lindhe's Clinical Periodontology and Implant Dentistry

Seventh Edition

Edited by

Tord Berglundh

Department of Periodontology, Institute of Odontology,
The Sahlgrenska Academy at University of Gothenburg,
Gothenburg, Sweden

William V. Giannobile

Harvard School of Dental Medicine, Boston, MA, USA

Niklaus P. Lang

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

Mariano Sanz

Faculty of Odontology, ETEP (Etiology and Therapy of Periodontal
and Peri-Implant Diseases) Research Group, Complutense
University of Madrid, Madrid, Spain and Department of Periodontology,
Faculty of Dentistry, Institute of Clinical Dentistry,
University of Oslo, Oslo, Norway

WILEY Blackwell

This edition first published 2022
© 2022 by John Wiley & Sons Ltd
© 2015 by John Wiley & Sons Ltd
© 2003, 2008 by Blackwell Munksgaard
© 1983, 1989, 1997 by Munksgaard

All rights reserved. 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 or otherwise, except as permitted by law. Advice on how to obtain permission to reuse material from this title is available at <http://www.wiley.com/go/permissions>.

The right of Tord Berglundh, William V. Giannobile, Niklaus P. Lang and Mariano Sanz to be identified as the authors of the editorial material in this work has been asserted in accordance with law.

Registered Offices

John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial Office

9600 Garsington Road, Oxford, OX4 2DQ, UK

For details of our global editorial offices, customer services, and more information about Wiley products visit us at www.wiley.com.

Wiley also publishes its books in a variety of electronic formats and by print-on-demand. Some content that appears in standard print versions of this book may not be available in other formats.

Limit of Liability/Disclaimer of Warranty

The contents of this work are intended to further general scientific research, understanding, and discussion only and are not intended and should not be relied upon as recommending or promoting scientific method, diagnosis, or treatment by physicians for any particular patient. In view of ongoing research, equipment modifications, changes in governmental regulations, and the constant flow of information relating to the use of medicines, equipment, and devices, the reader is urged to review and evaluate the information provided in the package insert or instructions for each medicine, equipment, or device for, among other things, any changes in the instructions or indication of usage and for added warnings and precautions. While the publisher and authors have used their best efforts in preparing this work, they make no representations or warranties with respect to the accuracy or completeness of the contents of this work and specifically disclaim all warranties, including without limitation any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives, written sales materials or promotional statements for this work. The fact that an organization, website, or product is referred to in this work as a citation and/or potential source of further information does not mean that the publisher and authors endorse the information or services the organization, website, or product may provide or recommendations it may make. This work is sold with the understanding that the publisher is not engaged in rendering professional services. The advice and strategies contained herein may not be suitable for your situation. You should consult with a specialist 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.

Library of Congress Cataloging-in-Publication Data

Names: Berglundh, Tord, 1954– editor. | Giannobile, William V., editor. |
Lang, Niklaus Peter, editor. | Sanz, Mariano (Professor) editor.
Title: Lindhe's clinical periodontology and implant dentistry / edited by
Tord Berglundh, William V. Giannobile, Niklaus P. Lang, Mariano Sanz.
Other titles: Clinical periodontology and implant dentistry
Description: Seventh edition. | Hoboken : John Wiley & Sons, Inc., 2022. |
Preceded by Clinical periodontology and implant dentistry / edited by
Jan Lindhe and Niklaus P. Lang ; associate editors, Tord Berglundh,
William V. Giannobile, Mariano Sanz. 6th edition. 2015.
Identifiers: LCCN 2021028065 (print) | LCCN 2021028066 (ebook) | ISBN
9781119438885 (cloth) | ISBN 9781119438946 (adobe pdf) | ISBN
9781119438953 (epub)
Subjects: MESH: Periodontal Diseases | Dental Implantation | Dental
Implants
Classification: LCC RK667.I45 (print) | LCC RK667.I45 (ebook) | NLM WU
240 | DDC 617.6/93–dc23
LC record available at <https://lcn.loc.gov/2021028065>
LC ebook record available at <https://lcn.loc.gov/2021028066>

Cover Design: Wiley

Cover Image: Courtesy of Niklaus P. Lang

Set in 9.5/12pt Palatino by Straive, Pondicherry, India

Contents

Contributors, xvii

Preface, xxi

Volume 1: BASIC CONCEPTS

Part 1: Anatomy

1 Anatomy and Histology of Periodontal Tissues, 3

Dieter D. Bosshardt, Jan Lindhe, Niklaus P. Lang, and Maurício Araújo

Introduction, 3

Gingiva, 5

Anatomy, 5

Histology, 8

Periodontal ligament, 26

Root cementum, 31

Bone of the alveolar process, 35

Macroscopic anatomy, 35

Microscopic anatomy, 37

Blood supply of the periodontium, 41

Lymphatic system of the periodontium, 46

Nerves of the periodontium, 47

Acknowledgment, 49

2 Bone as a Living Organ, 50

Darnell Kaigler and William V. Giannobile

Introduction, 50

Development, 50

Intramembranous bone formation, 50

Endochondral bone formation, 52

Structure, 52

Osseous tissue, 52

Periosteal tissue, 54

Bone marrow, 56

Function, 57

Mechanical properties, 57

Metabolic properties, 58

Skeletal homeostasis, 59

Healing, 59

Disorders, 61

Conclusion, 66

Acknowledgments, 66

3 The Edentulous Ridge, 68

Maurício Araújo and Jan Lindhe

Clinical considerations, 68

Remaining bone in the edentulous ridge, 71

Classification of remaining bone, 72

Topography of the alveolar process, 73

From an alveolar process to an edentulous ridge, 74

Intra-alveolar processes, 74

Extra-alveolar processes, 81

Topography of the edentulous ridge: summary, 84

4 The Mucosa at Teeth and Implants, 86

Jan Lindhe, Tord Berglundh, Anton Sculean, and Niklaus P. Lang

Gingiva, 86

Dimensions of the supracrestal

attachment, 86

Dimensions of the buccal tissue, 86

Dimensions of the interdental papilla, 88

Peri-implant mucosa, 88

Dimensions of the supracrestal attachment, 89

Structure and composition, 93

Vascular supply, 94

Probing gingiva and peri-implant mucosa, 95

Dimensions of the buccal soft tissue at implants, 96

Dimensions of the papilla between teeth

and implants, 98

Dimensions of the "papilla" between adjacent

implants, 99

5 Osseointegration, 103

Niklaus P. Lang, Tord Berglundh, and

Dieter D. Bosshardt

Introduction, 103

Implant installation, 103

Tissue injury, 103

Wound healing, 104

Cutting and non-cutting implants, 104

Process of osseointegration, 107

Morphogenesis of osseointegration, 111

Overall pattern of implant integration, 111

Biopsy sample observations, 112

Part 2: Epidemiology

6 Epidemiology of Periodontitis, 119

Panos N. Papapanou and Ryan T. Demmer

Introduction, 119

Methodological issues, 119

Examination methods: index systems, 119

Assessment of inflammation of the periodontal tissues, 120

Assessment of loss of periodontal tissue support, 120

- Radiographic assessment of alveolar bone loss, 121
- Assessment of periodontal treatment needs, 121
- Periodontitis “case definition” in epidemiologic studies, 122
- Prevalence of periodontitis, 124
 - Periodontitis in adults, 124
 - Periodontitis in children and adolescents, 127
 - Periodontitis and tooth loss, 132
- Risk factors for periodontitis, 132
 - Introduction: definitions, 132
 - Measures of disease occurrence, 132
 - Measures of association, 133
 - Causal inference and causal models, 134
 - Non-modifiable background factors, 137
 - Environmental, acquired, and behavioral factors, 140
- Concluding remarks, 146
- 7 Epidemiology of Peri-Implant Diseases, 160**
Jan Derks, Cristiano Tomasi, and Tord Berglundh
- Introduction, 160
- Disease definition, 160
- Case definition, 161
 - Peri-implant health, 161
 - Peri-implant mucositis, 162
 - Peri-implantitis, 162
- Examination methods, 162
- Prevalence of peri-implant diseases, 163
 - Extent and severity of peri-implantitis, 163
 - Peri-implantitis and implant loss, 165
- Etiology of peri-implant diseases, 165
- Risk factors for peri-implant diseases, 166
 - Peri-implant mucositis, 166
 - Peri-implantitis: risk factors related to the patient, 167
 - Peri-implantitis: risk factors related to the implant, 168
- Concluding remarks, 169

Part 3: Microbiology

- 8 Dental Biofilms and Calculus, 175**
Philip D. Marsh, Mariano Sanz, Niklaus P. Lang, and Dieter D. Bosshardt
- Introduction, 175
- The human microbiome, 175
- The oral microbiome, 176
- The mouth as a microbial habitat, 176
- Methods to determine the composition and function of the oral microbiome, 178
- The development and composition of the oral microbiome, 178
- Dental biofilm formation, 179
 - Conditioning film formation, 179
 - Reversible and more permanent attachment, 179
 - Co-adhesion, 181
 - Plaque maturation, 181
 - Detachment, 182
- The significance of a biofilm and community lifestyle for microorganisms, 182
- Benefits to the host of a resident oral microbiota., 183
- Biofilms on implant surfaces, 184
- Dental calculus, 186
 - Clinical appearance and distribution, 187
 - Calculus formation and structure, 188

- Attachment to tooth surfaces and implants, 189
- Calculus composition, 191
- Clinical implications, 191
- Conclusions, 192

9 Periodontal and Peri-Implant Infections, 196

- Mike Curtis, Lisa Heitz-Mayfield, and Mariano Sanz*
- Periodontal infections, 196
 - Introduction, 196
 - Microbiological techniques to study the periodontal microbiota, 198
 - Periodontal bacteria and virulence, 207
 - Microbial pathogenesis of periodontal disease, 210
- Peri-implant infections, 212
 - Introduction, 212
 - Peri-implant biofilm formation, 213
 - Surface characteristics of the implant/abutment, 213
 - Local oral environment, 217
 - Oral hygiene and accessibility, 218
 - Microbiota associated with peri-implant mucosal health, 218
 - Microbiota associated with peri-implant infections, 221
 - Periodontal and peri-implant microbiomes in health and disease, 223
 - Patients at risk for peri-implant infections, 224
- Acknowledgment, 225

Part 4: Host–Parasite Interactions

10 Pathogenesis of Gingivitis and Periodontitis, 235

- Gregory J. Seymour, Tord Berglundh, and Leonardo Trombelli*
- Introduction, 235
- Gingivitis, 237
 - Development of the homeostatic lesion, 237
 - The epithelial barrier, 241
- Factors influencing the pathogenesis of gingivitis, 242
 - Vascular response, 242
 - Cellular response, 243
 - Repair potential, 243
- Periodontitis, 244
 - Histopathology of periodontitis, 244
 - B cells in periodontitis, 246
 - Macrophages in periodontitis (M1 and M2), 248
- Conversion of gingivitis to periodontitis, 248
 - The Th1/Th2 paradigm, 249
 - Suppression of cell-mediated immunity, 249
 - T cells and homeostasis, 249
 - Cytokine profiles, 249
 - CD8 T cells, 250
- Control of the Th1/Th2 balance, 250
 - Genetics, 250
 - Innate immune response, 250
 - Nature of the antigen, 251
 - Nature of the antigen-presenting cell, 251
 - Hypothalamic–pituitary–adrenal axis and the sympathetic nervous system, 252
 - Treg/Th17 axis, 252
- Autoimmunity, 254
 - Natural killer T cells, 254
 - B-cell subsets, 254
- Connective tissue matrix destruction, 255
- Bone loss, 255
- Conclusion, 256

11 Systemic and Environmental Modifying Factors, 263

Evanthia Lalla and Panos N. Papapanou

Introduction, 263

Diabetes mellitus, 263

Mechanisms underlying the effect of diabetes on periodontitis, 263

Clinical presentation of the periodontal patient with diabetes, 266

Concepts related to patient management, 266

Tobacco smoking, 272

Mechanisms underlying the effect of smoking on periodontitis, 272

Clinical presentation of the periodontal patient who smokes, 273

Concepts related to patient management, 273

Obesity and nutrition, 276

Osteoporosis, 277

Stress, 278

12 Genetic Susceptibility to Periodontal Disease: New Insights and Challenges, 288

Arne S. Schaefer, Ubele van der Velden,

Marja L. Laine, and Bruno G. Loos

Introduction, 288

Evidence for the role of genetics in periodontitis, 289

Heritability, 290

Heritability of periodontitis among young people, 291

Heritability of periodontitis in adults, 291

Gene mutation of major effect on human disease and its association with periodontitis, 296

Identification of genetic risk factors of periodontitis, 296

Sialic acid binding IG like lectin 5 (*SIGLEC5*) and other potential variants, 298

Defensin alpha-1 and -3 (*DEFA1A3*), 300

CDKN2B antisense RNA 1 (*CDKN2B-AS1*), 300

Miscellaneous genetic associations with periodontitis, 300

Epigenetic signatures, 300

From genetic disease susceptibility to improved oral care, 301

Part 5: Trauma from Occlusion

13 Effect of Load on Periodontal and Peri-Implant Tissues, 307

Jan Lindhe, Niklaus P. Lang, and Tord Berglundh

INTRODUCTION, 307

PART I: PERIODONTAL TISSUES, 307

Definition and terminology, 307

Occlusal trauma and plaque-associated periodontal disease, 308

Clinical trials, 308

Preclinical studies, 309

Plaque-associated periodontitis, 312

Conclusion, 314

PART II: PERI-IMPLANT TISSUES, 315

Orthodontic loading and alveolar bone, 315

Bone reactions to functional loading, 317

Excessive occlusal load on implants, 318

Static and cyclic loads on implants, 321

Load and loss of osseointegration, 322

Masticatory occlusal forces on implants, 322

Tooth-implant supported reconstructions, 324

Part 6: Periodontal Pathology

14 Non-Plaque-Induced Gingival Diseases, 331

Palle Holmstrup and Mats Jontell

Introduction, 331

Genetic/developmental disorders, 332

Hereditary gingival fibromatosis, 332

Specific infections, 333

Bacterial origin, 333

Viral origin, 333

Fungal origin, 337

Inflammatory and immune conditions, 339

Hypersensitivity reactions, 339

Autoimmune diseases of skin and mucous membranes, 342

Granulomatous inflammatory lesions (orofacial granulomatosis), 349

Reactive processes, 351

Epulis, 351

Neoplasms, 352

Premalignant (potentially malignant), 352

Malignancy, 353

Endocrine, nutritional, and metabolic diseases, 356

Vitamin deficiencies, 356

Traumatic lesions, 356

Physical/mechanical trauma, 357

Chemical (toxic) burn, 358

Thermal insults, 359

Gingival pigmentation, 359

15 Plaque-Induced Gingivitis, 368

Leonardo Trombelli, Roberto Farina, and Dimitris N. Tatakis

Clinical features of plaque-induced gingivitis, 368

Diagnostic criteria to assess a gingivitis lesion, 370

Diagnostic criteria to define and grade a gingivitis case, 373

Epidemiology of gingivitis, 374

Impact of gingivitis on patient-reported quality of life, 376

Impact of gingivitis on systemic inflammation, 376

Prognostic value of gingivitis, 378

Potential modifying factors of plaque-induced gingivitis, 378

Smoking, 378

Sex steroid hormones, 380

Malnutrition, 380

Specific systemic diseases and conditions, 380

Systemic drugs, 383

Local factors, 383

Prevention and management of plaque-induced gingivitis, 384

16 Current Classification of Periodontitis, 390

Panos N. Papapanou, Mariano Sanz, and Kenneth Kornman

Introduction, 390

A brief historical perspective: recently used periodontitis classification systems, 390

Need for the new classification, 392

Key concepts and ground rules of the new classification of periodontitis, 392

Assessment of Stage, 392

Assessment of grade, 396

Implementation of the current classification: clinical examples, 398

Interpretational challenges and “gray zones”, 405
 The value of the 2018 periodontitis classification, 406
 Acknowledgment, 406

17 Effect of Periodontal Diseases on General Health: Periodontal Medicine, 409

Francesco D’Aiuto, Filippo Graziani, Panos Papananou, and James Beck

Introduction, 409

Evidence of common biologic mechanisms, 411

Oral microbiome, 412

Systemic inflammation, 412

Atherosclerotic vascular disease, 413

Biologic mechanisms, 413

Epidemiologic evidence, 413

Diabetes mellitus, 422

Biological mechanisms, 422

Epidemiologic evidence, 423

Adverse pregnancy outcomes, 425

Biologic mechanisms, 425

Epidemiologic evidence, 425

Chronic renal disease, 426

Biologic mechanisms, 426

Epidemiologic evidence, 427

Cognitive decline/dementia, 428

Biologic mechanisms, 428

Epidemiologic evidence, 428

Cancer, 429

Biologic mechanisms, 429

Epidemiologic evidence, 429

Conclusion, 430

18 Periodontitis and Systemic Diseases (Cardiovascular Disease and Diabetes): Biological Perspectives for Oral/Periodontal Implications, 439

Alpdogan Kantarci and Hatice Hasturk

Introduction, 439

Plausibility of periodontal disease as a risk factor for diseases at distant tissues, 440

Plausibility of systemic dissemination of oral bacteria, 441

Inflammatory processes as a link between periodontal and systemic diseases, 442

Biological plausibility of a link between periodontal diseases and cardiovascular diseases, 443

Microbial factors, 443

Host factors, 446

Summary, 448

Biological plausibility of a link between periodontal diseases and diabetes, 449

Host factors, 449

Microbial factors, 451

Summary, 454

Conclusion, 455

19 Abscesses, Necrotizing Lesions of the Periodontium, and Endo-Periodontal Lesions, 461

David Herrera and Magda Feres

Introduction, 461

Abscesses in the periodontium, 462

Periodontal abscess, 462

Classification, 462

Etiology, pathogenesis, and histopathology, 463

Microbiology, 464

Diagnosis, 466

Differential diagnosis, 467

Why periodontal abscesses are relevant, 468

Necrotizing periodontal diseases, 469

What are necrotizing periodontal diseases, 469

Classification, 469

Etiology, pathogenesis, and histopathology, 470

Predisposing factors, 470

Diagnosis, 472

Necrotizing gingivitis, 472

Necrotizing periodontitis, 473

Necrotizing stomatitis, 473

Why necrotizing periodontal diseases are relevant, 473

Endo-periodontal lesions, 475

Classification, 475

Etiology, 476

Microbiology, 476

Pathogenesis and histopathology, 478

Risk factors, 479

Clinical presentation and diagnosis, 479

Summary, 481

Part 7: Peri-Implant Pathology

20 Peri-Implant Mucositis and Peri-Implantitis, 491

Tord Berglundh, Jan Lindhe, and Niklaus P. Lang

Introduction, 491

Healthy peri-implant mucosa, 491

Peri-implant mucositis, 492

Clinical features and diagnosis, 492

Clinical models, 493

Preclinical models, 494

Peri-implantitis, 495

Clinical features and diagnosis, 495

Human biopsy material, 496

Preclinical models, 498

Conclusion, 501

Part 8: Tissue Regeneration

21 Periodontal Wound Healing and Regeneration, 505

Darnell Kaigler, Giulio Rasperini, Saso Ivanovski, and William V. Giannobile

Introduction, 505

Wound healing: Outcomes and definitions, 506

Wound healing biology, 508

Phases of wound healing, 508

Factors that affect healing, 509

Periodontal wound healing, 509

Healing after periodontal surgery, 511

Advanced regenerative approaches to periodontal tissue reconstruction, 512

Regenerative surgery, 512

Guided tissue regeneration, 513

Clinical applications of growth factors for use in periodontal regeneration, 514

Cell therapy for periodontal regeneration, 515

Gene therapeutics for periodontal tissue repair, 516

Three-dimensional printed scaffolds for periodontal regeneration, 516

Conclusion, 516

Acknowledgments, 519