

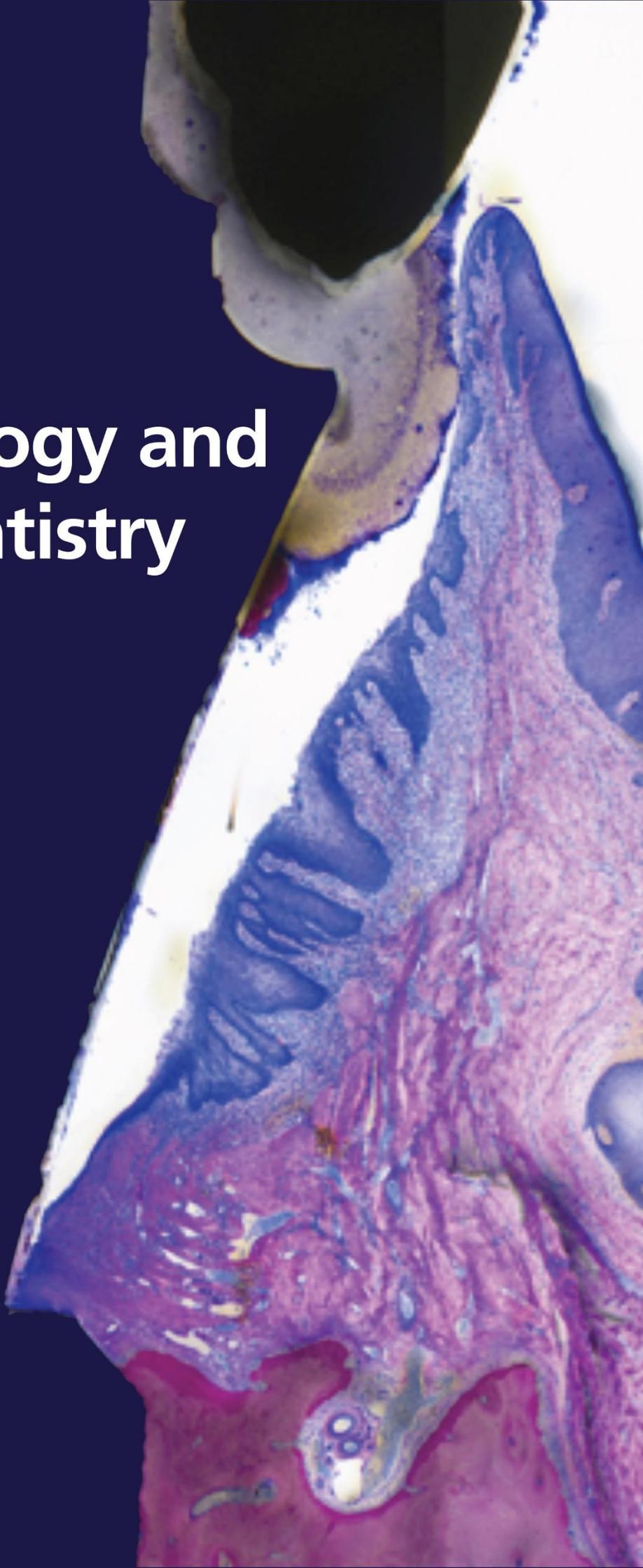
TWO-VOLUME SET

Clinical Periodontology and Implant Dentistry

SIXTH EDITION

Edited by
Niklaus P. Lang
Jan Lindhe

WILEY Blackwell



Clinical Periodontology and Implant Dentistry

Clinical Periodontology and Implant Dentistry

Sixth Edition

Edited by

Niklaus P. Lang
and
Jan Lindhe

Associate Editors

Tord Berglundh
William V. Giannobile
Mariano Sanz

WILEY Blackwell

Volume 1

BASIC CONCEPTS

Edited by

Jan Lindhe
Niklaus P. Lang

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

Registered Office
John Wiley & Sons, Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial Offices
9600 Garsington Road, Oxford, OX4 2DQ, UK
The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK
1606 Golden Aspen Drive, Suites 103 and 104, Ames, Iowa 50010, USA

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at www.wiley.com/wiley-blackwell

The right of the author to be identified as the author of this work has been asserted in accordance with the UK Copyright, Designs and Patents Act 1988.

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 the UK Copyright, Designs and Patents Act 1988, without the prior permission of the publisher.

Designations used by companies to distinguish their products are often claimed as trademarks. All brand names and product names used in this book are trade names, service marks, trademarks or registered trademarks of their respective owners. The publisher is not associated with any product or vendor mentioned in this book. It is sold on the understanding that the publisher is not engaged in rendering professional services. If professional advice or other expert assistance is required, the services of a competent professional should be sought.

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 a specific method, diagnosis, or treatment by health science practitioners for any particular patient. The publisher and the author 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 fitness for a particular purpose. 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. Readers should consult with a specialist where appropriate.

The fact that an organization or Website is referred to in this work as a citation and/or a potential source of further information does not mean that the author or the publisher endorses the information the organization or Website may provide or recommendations it may make. Further, readers should be aware that Internet Websites listed in this work may have changed or disappeared between when this work was written and when it is read. No warranty may be created or extended by any promotional statements for this work. Neither the publisher nor the author shall be liable for any damages arising herefrom.

Library of Congress Cataloging-in-Publication Data

Clinical periodontology and implant dentistry / edited by Niklaus P. Lang and Jan Lindhe ; associate editors, Tord Berglundh, William V. Giannobile, Mariano Sanz. – Sixth edition.
p. ; cm.

Includes bibliographical references and index.

ISBN 978-0-470-67248-8 (cloth)

I. Lang, Niklaus Peter, editor. II. Lindhe, Jan, editor. III. Berglundh, Tord, 1954–, editor. IV. Giannobile, William V., editor. V. Sanz, Mariano (Professor), editor.

[DNLM: 1. Periodontal Diseases. 2. Dental Implantation. 3. Dental Implants. WU 240] RK361

617.6'32–dc23

2015003147

A catalogue record for this book is available from the British Library.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Cover image: courtesy of Dieter D. Bosshardt, University of Berne, Switzerland
Cover design by Meaden Creative

Set in 9.5/12 pt Palatino LT Std by SPi Publisher Services, Pondicherry, India

Contents

Contributors, xix

Preface, xxv

Volume 1: BASIC CONCEPTS

Edited by Jan Lindhe and Niklaus P. Lang

Part 1: Anatomy

1 Anatomy of Periodontal Tissues, 3

Jan Lindhe, Thorild Karring, and Maurício Araújo

Introduction, 3

Gingiva, 5

Macroscopic anatomy, 5

Microscopic anatomy, 8

Periodontal ligament, 25

Root cementum, 29

Bone of the alveolar process, 34

Macroscopic anatomy, 34

Microscopic anatomy, 36

Blood supply of the periodontium, 41

Lymphatic system of the periodontium, 45

Nerves of the periodontium, 45

Acknowledgment, 46

2 Bone as a Living Organ, 48

*Hector F. Rios, Jill D. Bashutski,
and William V. Giannobile*

Introduction, 48

Development, 48

Intramembranous bone formation, 48

Endochondral bone growth, 48

Structure, 50

Osseous tissue, 50

Periosteal tissue, 53

Bone marrow, 53

Function, 55

Mechanical properties, 55

Metabolic properties, 55

Skeletal homeostasis, 57

Healing, 57

Disorders, 58

Conclusion, 63

Acknowledgment, 63

3 The Edentulous Ridge, 65

Maurício Araújo and Jan Lindhe

Clinical considerations, 65

Remaining bone in the edentulous ridge, 68

Classification of remaining bone, 68

Topography of the alveolar process, 69

From an alveolar process to an edentulous ridge, 70

Intra-alveolar processes, 70

Extra-alveolar processes, 78

Topography of the edentulous ridge: Summary, 80

4 The Mucosa at Teeth and Implants, 83

*Jan Lindhe, Jan L. Wennström,
and Tord Berglundh*

Gingiva, 83

Biologic width, 83

Dimensions of the buccal tissue, 83

Dimensions of the interdental papilla, 84

Peri-implant mucosa, 85

Biologic width, 86

Quality, 90

Vascular supply, 91

Probing gingiva and peri-implant mucosa, 92

Dimensions of the buccal soft tissue

at implants, 94

Dimensions of the papilla between teeth

and implants, 95

Dimensions of the "papilla" between adjacent

implants, 96

5 Osseointegration, 100

Jan Lindhe, Tord Berglundh, and Niklaus P. Lang

Introduction, 100

Implant installation, 100

Tissue injury, 100

Wound healing, 101

Cutting and non-cutting implants, 101

Process of osseointegration, 104

Morphogenesis of osseointegration, 108

Overall pattern of implant integration, 108

Biopsy sample observations, 109

6 From Periodontal Tactile Function to Peri-implant Osseoperception, 112

Reinhilde Jacobs

Introduction, 112

Neurophysiologic background, 113

Trigeminal neurosensory pathway, 113

Neurovascularization of the jaw bones, 113

- Mandibular neuroanatomy, 113
- Maxillary neuroanatomy, 115
- Histologic background, 115
 - Periodontal innervation, 115
 - Peri-implant innervation, 117
- Testing tactile function, 118
 - Neurophysiologic assessment, 118
 - Psychophysical assessment, 118
- Periodontal tactile function: Influence of dental status, 118
- From periodontal tactile function to peri-implant osseoperception, 119
- From osseoperception to implant-mediated sensory–motor interactions, 120
 - Clinical implications of implant-mediated sensory–motor interactions, 120
- Conclusion, 121

Part 2: Epidemiology

- 7 Epidemiology of Periodontal Diseases, 125**
Panos N. Papapanou and Jan Lindhe
- Introduction, 125
- Methodologic issues, 125
 - Examination methods: Index systems, 125
 - Periodontitis “case definition” in epidemiologic studies, 127
- Prevalence of periodontal diseases, 130
 - Periodontitis in adults, 130
 - Periodontitis in children and adolescents, 135
 - Periodontitis and tooth loss, 138
- Risk factors for periodontitis, 138
 - Introduction: Definitions, 138
 - Non-modifiable background factors, 141
 - Environmental, acquired, and behavioral factors, 143
- Concluding remarks, 154
- Acknowledgment, 156

Part 3: Microbiology

- 8 Dental Biofilms, 169**
Philip David Marsh
- Introduction, 169
- The mouth as a microbial habitat, 169
- Significance of a biofilm and community lifestyle for microorganisms, 171
- Formation of dental biofilms, 172
- Structure of dental biofilms, 175
- Microbial composition of dental biofilms, 177
- Benefits to the host of a resident oral microbiota, 178
- Concluding remarks, 179
- 9 Dental Calculus, 183**
Dieter D. Bosshardt and Niklaus P. Lang
- Clinical appearance and distribution, 183
- Calculus formation and structure, 185
- Attachment to tooth surfaces and implants, 186
- Calculus composition, 188
- Clinical implications, 188
- Conclusion, 189

- 10 Periodontal Infections, 191**
Mike Curtis
- Introduction, 191
- Dysbiosis of the oral microbiota in periodontal disease, 193
- Early microscopic and cultural microbiology investigations, 195
- Advent of anaerobic microbiologic techniques, 195
- Targeted microbiologic analyses: Rise of specificity, 198
 - Cultural and immunochemical studies, 198
 - Nucleic acid-based techniques for bacterial identification, 200
- Serologic analyses, 203
- Challenge of the unculturable bacteria, 204
- The Human Oral Microbe Identification Microarray, 205
- High throughput sequencing revolution, 206
- Genetic variation, 206
- Influence of a biofilm lifestyle, 208
- Periodontal bacteria and virulence, 210
- Microbial pathogenesis of periodontal disease, 212
- Conclusion, 216
- Acknowledgment, 217
- 11 Peri-implant Infections, 222**
Lisa Heitz-Mayfield, Ricardo P. Teles, and Niklaus P. Lang
- Introduction, 222
- Peri-implant biofilm formation, 222
 - Surface characteristics of the implant/abutment, 223
 - Local oral environment, 225
 - Oral hygiene and accessibility, 226
- Microbiota associated with peri-implant mucosal health, 227
- Microbiota associated with peri-implant infections, 229
- Patients at risk for peri-implant infections, 232
- Anti-infective treatment and microbiologic effects, 232
 - Non-surgical mechanical therapy, 232
 - Non-surgical mechanical therapy and adjunctive antimicrobial agents, 233
 - Surgical access and implant surface decontamination, 233

Part 4: Host–Parasite Interactions

- 12 Pathogenesis of Gingivitis, 241**
Gregory J. Seymour, Leonardo Trombelli, and Tord Berglundh
- Introduction, 241
- Development of gingival inflammation, 241
 - The initial lesion, 241
 - The early lesion, 243
- Individual variations in the development of gingivitis, 246
- Factors influencing the development of gingivitis, 247
 - Microbiologic factors, 247
 - Predisposing factors, 247
 - Modifying factors, 247
 - Repair potential, 251

13 Pathogenesis of Periodontitis, 256*Gregory J. Seymour, Tord Berglundh, and Leonardo Trombelli*

Introduction, 256

Histopathology of periodontitis, 257

Established or progressive lesion, 257

Advanced lesion, 257

B cells in periodontitis, 259

T cells in periodontitis: The Th1/Th2

paradigm, 260

Suppression of cell-mediated immunity, 260

T cells and homeostasis, 260

Cytokine profiles, 261

CD8 T cells, 261

Immunoregulation in periodontitis, 262

Genetics, 262

Innate immune response, 263

Nature of the antigen, 263

Nature of the antigen-presenting cell, 263

Hypothalamic–pituitary–adrenal axis and the sympathetic nervous system, 264

Treg/Th17 axis, 264

Autoimmunity, 265

NK T cells, 265

B-cell subsets, 265

Connective tissue matrix destruction, 265

Bone loss, 266

Conclusion, 266

14 Modifying Factors, 270*Evanthia Lalla and Panos N. Papapanou*

Introduction, 270

Diabetes mellitus, 270

Mechanisms underlying the effect of diabetes on periodontitis, 270

Clinical presentation of the periodontal patient with diabetes, 272

Concepts related to patient management, 277

Tobacco smoking, 278

Mechanisms underlying the effect of smoking on periodontitis, 279

Clinical presentation of the periodontal patient who smokes, 279

Concepts related to patient management, 280

Obesity and nutrition, 282

Osteoporosis and osteopenia, 283

Psychosocial stress, 284

15 Genetic Susceptibility to Periodontal Disease: New Insights and Challenges, 290*Arne S. Schäfer, Ubele van der Velden,**Marja L. Laine, and Bruno G. Loos*

Introduction, 290

Evidence for the role of genetics in periodontitis, 291

Heritability, 292

Heritability of aggressive periodontitis (early-onset periodontitis), 293

Heritability of chronic periodontitis, 296

Gene mutation of major effect on human disease and its association with periodontitis, 297

Identification of genetic risk factors of periodontitis, 297

ANRIL, CAMTA1/VAMP3, GLT6D1, COX-2, and NPY, 301

Epigenetic signatures, 304

From genetic disease susceptibility to improved oral care, 306

Part 5: Trauma from Occlusion**16 Trauma from Occlusion: Periodontal Tissues, 313***Jan Lindhe and Ingvar Ericsson*

Definition and terminology, 313

Trauma from occlusion and plaque-associated periodontal disease, 314

Analysis of human autopsy material, 314

Clinical trials, 316

Animal experiments, 317

Conclusion, 323

17 Trauma from Occlusion: Peri-implant Tissues, 325*Niklaus P. Lang and Tord Berglundh*

Introduction, 325

Orthodontic loading and alveolar bone, 325

Bone reactions to functional loading, 327

Excessive occlusal load on implants, 327

Static and cyclic loads on implants, 330

Load and loss of osseointegration, 331

Masticatory occlusal forces on implants, 332

Tooth–implant supported reconstructions, 333

Part 6: Periodontal Pathology**18 Non-Plaque-Induced Inflammatory Gingival Lesions, 339***Palle Holmstrup and Mats Jontell*

Gingival diseases of specific bacterial origin, 339

Gingival diseases of viral origin, 340

Herpes virus infections, 340

Gingival diseases of fungal origin, 342

Candidosis, 342

Histoplasmosis, 344

Gingival lesions of genetic origin, 345

Hereditary gingival fibromatosis, 345

Gingival diseases of systemic origin, 346

Mucocutaneous disorders, 346

Allergic reactions, 354

Other gingival manifestations of systemic conditions, 355

Traumatic lesions, 357

Chemical injury, 358

Physical injury, 358

Thermal injury, 359

Foreign body reactions, 360

19 Plaque-Induced Gingival Diseases, 366*Angelo Mariotti*

Classification criteria for gingival diseases, 366

Plaque-induced gingivitis, 368

Plaque-induced gingivitis on a reduced periodontium, 369

Gingival diseases associated with endogenous hormones, 370

Puberty-associated gingivitis, 370

- Menstrual cycle-associated gingivitis, 370
- Pregnancy-associated gingival diseases, 370
- Gingival diseases associated with medications, 371
 - Drug-influenced gingival enlargement, 371
 - Oral contraceptive-associated gingivitis, 372
- Gingival diseases associated with systemic diseases, 372
 - Diabetes mellitus-associated gingivitis, 372
 - Leukemia-associated gingivitis, 373
 - Linear gingival erythema, 373
- Gingival diseases associated with malnutrition, 374
- Gingival diseases associated with heredity, 374
- Gingival diseases associated with ulcerative lesions, 375
- Treatment of plaque-induced gingival diseases, 375
- Significance of gingivitis, 376
- Acknowledgment, 376

20 Chronic Periodontitis, 381

Denis Kinane, Jan Lindhe, and Leonardo Trombelli

- Clinical features of chronic periodontitis, 381
- Gingivitis as a risk factor for chronic periodontitis, 382
- Susceptibility to chronic periodontitis, 384
- Prevalence of chronic periodontitis, 384
- Progression of chronic periodontitis, 385
- Risk factors for chronic periodontitis, 385
- Bacterial factors, 385
 - Age, 386
 - Smoking, 386
 - Systemic disease, 386
 - Stress, 387
 - Genetics, 387
- Scientific basis for treatment of chronic periodontitis, 387

21 Aggressive Periodontitis, 390

Maurizio S. Tonetti and Andrea Mombelli

- Classification and clinical syndromes, 391
- Epidemiology, 393
 - Primary dentition, 394
 - Permanent dentition, 394
 - Screening, 396
- Etiology and pathogenesis, 399
 - Bacterial etiology, 400
 - Genetic aspects of host susceptibility, 404
 - Environmental aspects of host susceptibility, 407
 - Current concepts, 407
- Diagnosis, 408
 - Clinical diagnosis, 408
 - Microbiologic diagnosis, 410
 - Evaluation of host defenses, 410
 - Genetic diagnosis, 412
- Principles of therapeutic intervention, 412
 - Elimination or suppression of the pathogenic flora, 412

22 Necrotizing Periodontal Disease, 421

Palle Holmstrup

- Nomenclature, 421
- Prevalence, 422
- Clinical characteristics, 422
 - Development of lesions, 422
 - Interproximal craters, 423
 - Sequestrum formation, 424
 - Involvement of alveolar mucosa, 424
 - Swelling of lymph nodes, 424
 - Fever and malaise, 425
 - Oral hygiene, 425
 - Acute and recurrent/chronic forms of necrotizing gingivitis and periodontitis, 426

- Diagnosis, 426
 - Differential diagnosis, 426
- Histopathology, 427
- Microbiology, 428
 - Microorganisms isolated from necrotizing lesions, 428
 - Pathogenic potential of microorganisms, 428
- Host response and predisposing factors, 430
 - Systemic diseases, 430
 - Poor oral hygiene, pre-existing gingivitis, and history of previous necrotizing periodontal diseases, 431
 - Psychological stress and inadequate sleep, 431
 - Smoking and alcohol use, 432
 - Caucasian ethnicity, 432
 - Young age, 432
- Treatment, 432
 - Acute phase treatment, 432
 - Maintenance phase treatment, 434

23 Effect of Periodontal Diseases on General Health, 437

Panos N. Papapanou and Evanthia Lalla

- Introduction, 437
- Atherosclerotic vascular disease, 438
 - Biologic plausibility, 438
 - Epidemiologic evidence, 440
- Adverse pregnancy outcomes, 448
 - Definitions and biologic plausibility, 448
 - Epidemiologic evidence, 449
- Diabetes mellitus, 451
 - Biologic plausibility, 451
 - Epidemiologic evidence, 452
- Other associations, 455
 - Chronic renal disease, 455
 - Pulmonary infections, 455
- Concluding remarks, 456

24 Abscesses in the Periodontium, 463

David Herrera, Arie J. van Winkelhoff, and Mariano Sanz

- Introduction, 463
- Classification and etiology, 463
- Prevalence, 464
- Pathogenesis and histopathology, 464
- Microbiology, 465
- Diagnosis, 466
 - Differential diagnosis, 467
- Treatment, 467
- Complications, 469
 - Tooth loss, 469
 - Dissemination of the infection, 469

25 Lesions of Endodontic Origin, 472

Gunnar Bergenholtz, Domenico Ricucci, and José F. Siqueira, Jr

- Introduction, 472
- Disease processes of the dental pulp, 473
 - Causes, 473
 - Progression and dynamic events, 473
 - Accessory canals, 477
 - Periodontal tissue lesions to primary root canal infection, 480
 - Post-treatment endodontic lesions, 487
- Effects of periodontal disease and periodontal therapy on the condition of the pulp, 489

- Influences of periodontal disease, 489
- Influence of periodontal treatment measures, 490
- Root dentin hypersensitivity, 492

Part 7: Peri-implant Pathology

26 Peri-implant Mucositis and Peri-implantitis, 505

Tord Berglundh, Jan Lindhe, and Niklaus P. Lang

- Definitions, 505
- Peri-implant mucosa, 505
- Peri-implant mucositis, 505
 - Clinical features and diagnosis, 505
 - Clinical models, 506
 - Preclinical models, 506
- Peri-implantitis, 508
 - Clinical features and diagnosis, 508
 - Human biopsy material, 509
 - Preclinical models, 510
- Prevalence of peri-implant diseases, 513
 - Peri-implant mucositis, 513
 - Peri-implantitis, 513
- Risk factors for peri-implantitis, 515
 - Patients at risk, 515
 - Design of suprastructure, 515
 - Implant surface characteristics, 515
- Conclusion, 516

Part 8: Tissue Regeneration

27 Periodontal Wound Healing, 521

Hector F. Rios, D. Kaigler, Christoph A. Ramseier, G. Rasperini, and William V. Giannobile

- Introduction, 521
- Wound healing: Outcomes and definitions, 521
- Wound healing biology, 523
 - Phases of wound healing, 523
 - Factors that affect healing, 524

- Periodontal wound healing, 525
 - Healing after periodontal surgery, 526
- Advanced regenerative approaches to periodontal tissue reconstruction, 528
 - Regenerative surgery, 529
 - Guided tissue regeneration, 529
 - Clinical applications of growth factors for use in periodontal regeneration, 529
 - Cell therapy for periodontal regeneration, 530
 - Gene therapeutics for periodontal tissue repair, 532
- Conclusion, 533
- Acknowledgment, 533

28 Concepts in Periodontal Tissue Regeneration, 536

Thorkild Karring and Jan Lindhe

- Introduction, 536
- Regenerative periodontal surgery, 537
- Periodontal wound healing, 537
 - Regenerative capacity of bone cells, 542
 - Regenerative capacity of gingival connective tissue cells, 542
 - Regenerative capacity of periodontal ligament cells, 543
 - Role of epithelium in periodontal wound healing, 545
 - Root resorption, 545
- Regenerative concepts, 546
 - Grafting procedures, 547
 - Root surface biomodification, 548
 - Guided tissue regeneration, 549
- Assessment of periodontal regeneration, 551
 - Periodontal probing, 551
 - Radiographic analysis and re-entry operations, 552
 - Histologic methods, 552
- Conclusion, 552

Index, i1

Volume 2: CLINICAL CONCEPTS

Edited by Niklaus P. Lang and Jan Lindhe

Part 9: Examination Protocols

29 Examination of Patients, 559

Giovanni E. Salvi, Tord Berglundh, and Niklaus P. Lang

- Patient's history, 559
 - Chief complaint and expectations, 559
 - Social and family history, 559
 - Dental history, 560
 - Oral hygiene habits, 560
 - Smoking history, 560
- Medical history and medications, 560
- Genetic testing before periodontal and implant therapy, 560
- Signs and symptoms of periodontal diseases and their assessment, 560
 - Gingiva, 562
 - Keratinized mucosa at implant recipient sites, 563

- Periodontal ligament and root cementum, 563
 - Alveolar bone, 569
- Diagnosis of periodontal lesions, 569
 - Gingivitis, 570
 - Parodontitis, 570
- Oral hygiene status, 571
- Additional dental examinations, 571
- Conclusion, 571

30 Diagnostic Imaging of the Periodontal and Implant Patient, 574

Bernard Koong

- Introduction, 574
- Interpretation of the radiologic examination, 575
- Basic prerequisites, 576
 - Radiologic anatomy, 576
 - Pathology, 576
 - Imaging modality, 577
 - Viewing conditions, 577

Key steps in interpretation, 577
 Recognizing the presence of an abnormality, 577
 Radiologic evaluation of a lesion, 577
 Interpretation of the findings, 580

Radiologic interpretation in relation to inflammatory periodontal disease, 580
 Key radiologic features, 580
 Related factors, 590
 Differential diagnosis, 590

Pathology involving other regions of the jaws and adjacent structures, 591

Frequency of periodontal radiologic examinations, 591

Implant imaging, 591

Imaging modalities, 593
 Intraoral radiographs, 593
 Panoramic radiographs, 596
 Conventional tomography, 598
 Multislice/multidetector computed tomography and cone-beam computed tomography, 598
 Magnetic resonance imaging, 603
 Comparison of radiation dose levels, 604

31 Patient-Specific Risk Assessment for Implant Therapy, 609
Giovanni E. Salvi and Niklaus P. Lang
 Introduction, 609
 Systemic factors, 609
 Medical conditions, 609
 Medications, 611
 Age, 612
 Growth considerations, 612
 Untreated periodontitis and oral hygiene habits, 612
 History of treated periodontitis, 613
 Compliance with supportive periodontal therapy, 613
 Smoking history, 614
 Genetic susceptibility traits, 614
 Conclusion, 615

Part 10: Treatment Planning Protocols

32 Treatment Planning of Patients with Periodontal Diseases, 621
Giovanni E. Salvi, Jan Lindhe, and Niklaus P. Lang
 Introduction, 621
 Treatment goals, 621
 Systemic phase, 622
 Initial (hygienic) phase, 622
 Corrective phase (additional therapeutic measures), 622
 Maintenance phase (supportive periodontal therapy), 622
 Screening for periodontal disease, 622
 Basic periodontal examination, 622
 Diagnosis, 624
 Treatment planning, 625
 Initial treatment plan, 625
 Pretherapeutic single tooth prognosis, 626
 Case presentation, 628
 Concluding remarks, 633
 Case report, 633
 Patient S.K. (male, 35 years old), 635

33 Treatment Planning for Implant Therapy in the Periodontally Compromised Patient, 641
Jan L. Wennström and Niklaus P. Lang
 Prognosis of implant therapy in the periodontally compromised patient, 641
 Strategies in treatment planning, 642
 Treatment decisions: Case reports, 642
 Posterior segments, 642
 Tooth versus implant, 645
 Aggressive periodontitis, 645
 Furcation problems, 646
 Single-tooth problem in the esthetic zone, 650
 Conclusion, 650

34 Systemic Phase of Therapy, 654
Niklaus P. Lang, Christoph A. Ramseier, and Hans-Rudolf Baur
 Introduction, 654
 Protection of the dental team and other patients against infectious diseases, 654
 Protection of the patient's health, 655
 Prevention of complications, 655
 Infection, specifically bacterial endocarditis, 655
 Bleeding, 656
 Cardiovascular incidents, 657
 Allergic reactions and drug interactions, 657
 Systemic diseases, disorders or conditions influencing pathogenesis and healing potential, 657
 Specific medications: Bisphosphonates as a threat to implant therapy, 657
 Control of anxiety and pain, 658
 Tobacco cessation counseling, 658
 Conclusion, 659

Part 11: Initial Periodontal Therapy (Infection Control)

35 Motivational Interviewing, 663
Christoph A. Ramseier, Jeanie E. Suwan, and Delwyn Catley
 Health behavior change counseling in periodontal care, 663
 The challenge, 664
 Communication with the periodontal patient, 664
 OARS, 665
 Understanding motivational interviewing, 665
 General principles, 666
 Giving advice, 666
 Agenda setting, 667
 Readiness scale, 667
 Evidence for motivational interviewing, 668
 Evidence in general health care, 668
 Evidence in dental care, 668
 Patient activation fabric, 670
 Band I: Establish rapport, 670
 Band II: Information exchange, 672
 Band III: Closing, 672
 Ribbon A: Communication style, 672
 Ribbon B: Health behavior change tools, 672
 Case examples, 672
 Oral hygiene motivation I, 672
 Oral hygiene motivation II, 673
 Tobacco use cessation, 674
 Conclusion, 675

36 Mechanical Supragingival Plaque Control, 677

*Fridus van der Weijden, Dagmar Else Slot,
José J. Echeverría, and Jan Lindhe*

Importance of supragingival plaque removal, 677

Self-performed plaque control, 678

Brushing, 679

Motivation, 679

Oral hygiene instruction, 680

Toothbrushing, 680

Manual toothbrushes, 680

Electric (power) toothbrushes, 687

Electrically active (ionic) toothbrush, 690

Interdental cleaning, 690

Dental floss and tape, 691

Woodsticks, 692

Interdental brushes, 693

Adjunctive aids, 695

Dental water jets/oral irrigators, 695

Tongue cleaners, 696

Foam brushes, swabs or tooth towelettes, 697

Dentifrices, 697

Side effects, 698

Brushing force, 698

Toothbrush abrasion, 699

Importance of instruction and motivation in mechanical plaque control, 701

Acknowledgments, 703

37 Chemical Oral and Dental Biofilm Control, 717

David Herrera and Jorge Serrano

Rationale for supragingival biofilm control, 717

Oral hygiene products, 718

Mechanical biofilm control, 718

Limitations, 718

Chemical biofilm control, 718

Mechanism of action, 719

Categories of formulations, 720

Ideal features, 720

Evaluation of activity of agents for chemical biofilm control, 720

In vitro studies, 720

In vivo studies, 721

Home-use clinical trials, 722

Active agents, 723

Antibiotics, 723

Enzymes, 723

Amine alcohols, 723

Detergents, 724

Oxygenating agents, 724

Metal salts, 724

Stannous fluoride, 724

Other fluorides, 725

Natural products, 725

Essential oils, 725

Triclosan, 726

Bisbiguanides, 727

Quaternary ammonium compounds, 730

Hexetidine, 730

Povidone iodine, 731

Other evaluated products, 731

Future approaches, 731

Delivery formats, 731

Mouth rinses, 731

Dentifrices, 732

Gels, 732

Chewing gums, 732

Varnishes, 732

Lozenges, 732

Irrigators, 733

Sprays, 733

Sustained-release devices, 733

Clinical indications for chemical plaque control:

Selection of agents, 733

Single use, 733

Short-term use for the prevention of dental biofilm formation, 733

Short-term use for therapy, 734

Long-term use for the prevention of dental biofilm formation, 735

Long-term use for the prevention of other oral conditions, 735

Conclusion, 736

38 Non-surgical Therapy, 749

Jan L. Wennström and Cristiano Tomasi

Introduction, 749

Goal of non-surgical pocket/root instrumentation, 749

Debridement, scaling, and root planing, 750

Instruments used for non-surgical pocket/root debridement, 750

Hand instruments, 750

Sonic and ultrasonic instruments, 753

Ablative laser devices, 754

Approaches to subgingival debridement, 755

Full-mouth instrumentation protocols, 755

Full-mouth disinfection protocols, 755

Clinical outcomes following various approaches to pocket/root instrumentation, 756

Microbiologic outcomes following various approaches to pocket/root instrumentation, 756

Considerations in relation to selection of instruments and treatment approach, 759

Selection of instruments, 759

Selection of treatment approach, 759

Re-evaluation following initial non-surgical periodontal treatment, 760

Efficacy of repeated non-surgical pocket/root instrumentation, 761

Part 12: Additional Therapy**39 Periodontal Surgery: Access Therapy, 767**

Jan L. Wennström and Jan Lindhe

Introduction, 767

Techniques in periodontal pocket surgery, 767

Gingivectomy procedures, 768

Flap procedures, 770

Modified Widman flap, 773

Regenerative procedures, 777

Distal wedge procedures, 778

Osseous surgery, 780

Osteoplasty, 780

Ostectomy, 781

General guidelines for periodontal surgery, 782

Objectives of surgical treatment, 782

Indications for surgical treatment, 782

Contraindications for periodontal surgery, 783

Local anesthesia in periodontal surgery, 783

- Instruments used in periodontal surgery, 785
- Selection of surgical technique, 788
- Root surface instrumentation, 790
- Root surface conditioning/biomodification, 791
- Suturing, 791
- Periodontal dressings, 792
- Postoperative pain control, 794
- Post-surgical care, 794
- Outcome of surgical periodontal therapy, 795
 - Healing following surgical pocket therapy, 795
 - Clinical outcome of surgical access therapy in comparison to non-surgical therapy, 796
- 40 Treatment of Furcation-Involved Teeth, 805**
Gianfranco Carnevale, Roberto Pontoriero, and Jan Lindhe
- Terminology, 805
- Anatomy, 806
 - Maxillary molars, 806
 - Maxillary premolars, 807
 - Mandibular molars, 807
 - Other teeth, 808
- Diagnosis, 808
 - Probing, 810
 - Radiographs, 810
- Differential diagnosis, 811
 - Trauma from occlusion, 811
- Therapy, 812
 - Scaling and root planing, 812
 - Furcation plasty, 812
 - Tunnel preparation, 814
 - Root separation and resection, 814
 - Regeneration of furcation defects, 822
 - Extraction, 825
- Prognosis, 825
- Conclusion, 828
- 41 Endodontics and Periodontics, 830**
Gunnar Bergenholtz, Domenico Ricucci, Beatrice Siegrist-Guldener, and Matthias Zehnder
- Introduction, 830
- Infectious processes of endodontic origin in the periodontium, 831
 - General features, 831
 - Clinical presentations, 832
 - Distinguishing lesions of endodontic origin from periodontitis, 834
 - Endo-perio lesions: Diagnosis and treatment aspects, 838
 - Endodontic treatment and periodontal lesions, 840
- Iatrogenic root perforations, 841
 - Occurrence, 841
 - Diagnosis, 841
 - Treatment approaches, 841
- Vertical root fractures, 843
 - Mechanisms, 843
 - Occurrence, 844
 - Clinical signs and symptoms, 845
 - Diagnosis, 848
 - Treatment considerations, 849
- Cemental tears, 849
 - Diagnosis and treatment, 849
- Root malformations, 850
 - Diagnosis, 850
 - Treatment considerations, 850
- Root surface resorptions, 850
 - Cervical invasive root resorptions, 851
- 42 Treatment of Peri-implant Mucositis and Peri-implantitis, 861**
Tord Berglundh, Niklaus P. Lang, and Jan Lindhe
- Introduction, 861
- Treatment strategies, 861
- Non-surgical therapy, 861
- Surgical therapy, 862
 - Implant surface decontamination, 864
- Reconstructive procedures, 865
- Re-osseointegration, 865
- Conclusion, 868
- 43 Antibiotics in Periodontal Therapy, 870**
Andrea Mombelli and David Herrera
- Introduction, 870
- Principles of antibiotic use in periodontics, 871
 - Is periodontitis an infection and should it be treated as one?, 871
 - Specific characteristics of the periodontal infection, 871
 - Should antimicrobial therapy be aimed at specific pathogens?, 872
 - Drug delivery routes, 872
- Systemic antibiotics, 873
 - Combination antimicrobial drug therapy, 875
 - Adverse reactions, 876
 - Systemic antimicrobial therapy in clinical trials, 876
 - Timing of systemic antibiotic therapy, 877
 - Selection of patients who may benefit most from systemic antibiotics, 878
 - Minimizing the risk of the development of antimicrobial antibiotic resistance, 880
- Local antimicrobial therapy, 881
 - Local antimicrobial therapy in clinical trials, 881
 - Minocycline ointment and microspheres, 881
 - Doxycycline hyclate in a biodegradable polymer, 882
 - Metronidazole gel, 882
 - Tetracycline in a non-resorbable plastic co-polymer, 882
 - Azithromycin gel, 883
 - Chlorhexidine products, 883
 - Comparative evaluation of treatment methods, 883
 - Local antibiotics in clinical practice, 884
- Conclusion, 884
- 44 Local Drug Delivery for the Treatment of Periodontitis, 891**
Maurizio S. Tonetti and Pierpaolo Cortellini
- Introduction, 891
- Periodontal pharmacokinetics, 892
 - Pocket volume and clearance, 892
 - Development of periodontal local delivery devices, 892
- Antimicrobial effects of local delivery devices, 893
- Efficacy of local delivery devices, 894
- Clinical indications for treatment of periodontitis with adjunctive local delivery devices, 896
- Local conditions, 896
- Special patient groups, 896
- Conclusion, 897

Part 13: Reconstructive Therapy

45 Regenerative Periodontal Therapy, 901

Pierpaolo Cortellini and Maurizio S. Tonetti

- Introduction, 901
- Classification and diagnosis of periodontal osseous defects, 901
- Clinical indications, 903
- Long-term effects and benefits of regeneration, 903
- Evidence for clinical efficacy and effectiveness, 908
- Patient, defect, and tooth prognostic factors, 911
 - Patient factors, 912
 - Defect factors, 913
 - Tooth factors, 914
- Factors affecting the clinical outcomes in furcations, 915
- Relevance of the surgical approach, 915
- Surgical approach to intrabony defects, 918
 - Papilla preservation flaps, 918
 - Postoperative regimen, 934
 - Postoperative period and local side effects, 934
 - Surgical and post-surgical morbidity, 935
- Barrier materials for regenerative surgery, 937
 - Non-bioresorbable materials, 937
 - Bioresorbable materials, 937
 - Membranes for intrabony defects, 938
 - Membranes for furcation involvement, 938
- Bone replacement grafts, 943
 - Grafts for intrabony defects, 943
 - Grafts for furcation involvement, 945
- Biologically active regenerative materials, 946
 - Growth factors for intrabony defects, 947
 - Growth factors for furcation involvement, 947
 - Enamel matrix derivatives for intrabony defects, 948
 - Enamel matrix derivatives for furcation involvement, 949
- Combination therapy, 949
 - Combination therapy for intrabony defects, 949
 - Combination therapy for furcation involvement, 953
 - Root surface biomodification, 954
- Clinical potential and limits for regeneration, 954
- Clinical strategies, 955
- Clinical flowcharts, 957
- Conclusion, 960

46 Mucogingival Therapy: Periodontal Plastic Surgery, 969

Jan L. Wennström and Giovanni Zucchelli

- Introduction, 969
- Gingival augmentation, 970
 - Gingival dimensions and periodontal health, 970
 - Marginal tissue recession, 972
 - Marginal tissue recession and orthodontic treatment, 975
 - Gingival dimensions and restorative therapy, 978
 - Indications for gingival augmentation, 979
 - Gingival augmentation procedures, 979
 - Healing following gingival augmentation procedures, 981
- Root coverage, 985
 - Root coverage procedures, 987
 - Selection of surgical procedure for root coverage, 1001

- Clinical outcome of root coverage procedures, 1002
 - Soft tissue healing against the covered root surface, 1007
 - Interdental papilla reconstruction, 1010
 - Surgical techniques, 1011
 - Crown-lengthening procedures, 1013
 - Excessive gingival display, 1013
 - Exposure of sound tooth structure, 1016
 - Ectopic tooth eruption, 1019
 - Deformed edentulous ridge, 1022
 - Prevention of soft tissue collapse following tooth extraction, 1023
 - Correction of ridge defects by the use of soft tissue grafts, 1025
 - Surgical procedures for ridge augmentation, 1025
- ### 47 Periodontal Plastic Microsurgery, 1043
- Rino Burkhardt and Niklaus P. Lang*
- Microsurgical techniques in dentistry: development of concepts, 1043
 - Concepts in microsurgery, 1044
 - Magnification, 1044
 - Instruments, 1049
 - Suture materials, 1049
 - Training concepts: Surgeons and assistants, 1052
 - Clinical indications and limitations, 1053
 - Comparison to conventional mucogingival interventions, 1055

Part 14: Surgery for Implant Installation

48 Piezoelectric Surgery for Precise and Selective Bone Cutting, 1063

Stefan Stübinger and Niklaus P. Lang

- Background and physical principles, 1063
- Technical characteristics of piezoelectric bone surgery, 1064
- Application of piezosurgery, 1064
- Clinical and biologic advantages of piezosurgery, 1065
 - Piezoelectric implant site preparation, 1067
- Clinical applications of piezoelectric surgery, 1067
 - Sinus floor elevation, 1068
 - Bone grafting, 1069
 - Lateralization of the inferior alveolar nerve, 1069
 - Edentulous ridge splitting, 1070
 - Orthodontic microsurgery, 1070
- Conclusion, 1071

49 Timing of Implant Placement, 1073

Christoph H.F. Hämmerle, Mauricio Araújo, and Jan Lindhe

- Introduction, 1073
- Type 1 placement as part of the same surgical procedure as and immediately following tooth extraction, 1075
 - Ridge alterations in conjunction with implant placement, 1075
 - Stability of implant, 1081
- Type 2 placement: Completed soft tissue coverage of the tooth socket, 1082
- Type 3 placement: Substantial bone fill has occurred in the extraction socket, 1083
- Type 4 placement: Alveolar process is healed following tooth loss, 1083

Clinical concepts, 1084
 Aim of therapy, 1084
 Success of treatment and long-term outcomes, 1086
 Conclusion, 1086

Part 15: Reconstructive Ridge Therapy

50 Ridge Augmentation Procedures, 1091

*Hector F. Rios, Fabio Vignoletti,
 William V. Giannobile, and Mariano Sanz*

Introduction: Principles in alveolar bone regeneration, 1091
 Promoting primary wound closure, 1093
 Enhancing cell proliferation and differentiation, 1093
 Protecting initial wound stability and integrity, 1093
 Treatment objectives, 1093
 Diagnosis and treatment planning, 1094
 Patient, 1094
 Defect classification, 1094
 Bone augmentation therapies, 1096
 Biologic principles of guided bone regeneration, 1096
 Regenerative materials, 1096
 Barrier membranes, 1096
 Bone grafts and bone substitutes, 1097
 Evidence-based results for ridge augmentation procedures, 1099
 Ridge preservation, 1099
 Bone regeneration in fresh extraction sockets, 1099
 Horizontal ridge augmentation, 1101
 Ridge splitting/expansion, 1103
 Vertical ridge augmentation, 1103
 Emerging technologies, 1105
 Growth factors, 1105
 Cell therapy, 1106
 Scaffolding matrices to deliver cells and genes, 1106
 Future perspective, 1108
 Conclusion, 1109
 Acknowledgments, 1109

51 Elevation of the Maxillary Sinus Floor, 1115

Bjarni E. Pjetursson and Niklaus P. Lang

Introduction, 1115
 Treatment options in the posterior maxilla, 1116
 Sinus floor elevation with a lateral approach, 1117
 Anatomy of the maxillary sinus, 1117
 Presurgical examination, 1118
 Indications and contraindications, 1118
 Surgical techniques, 1118
 Post-surgical care, 1122
 Complications, 1122
 Grafting materials, 1123
 Success and implant survival, 1125
 Sinus floor elevation with the transalveolar approach (osteotome technique), 1128
 Indications and contraindications, 1128
 Surgical technique, 1128
 Post-surgical care, 1132
 Complications, 1133
 Grafting material, 1133
 Success and implant survival, 1134
 Short implants, 1134
 Conclusion and clinical suggestions, 1136

Part 16: Occlusal and Prosthetic Therapy

52 Tooth-Supported Fixed Dental Prostheses, 1143

Jan Lindhe and Sture Nyman

Clinical symptoms of trauma from occlusion, 1143
 Angular bony defects, 1143
 Increased tooth mobility, 1143
 Progressive (increasing) tooth mobility, 1143
 Tooth mobility crown excursion/root displacement, 1143
 Initial and secondary tooth mobility, 1143
 Clinical assessment of tooth mobility (physiologic and pathologic tooth mobility), 1145
 Treatment of increased tooth mobility, 1146
 Situation 1, 1146
 Situation 2, 1147
 Situation 3, 1147
 Situation 4, 1150
 Situation 5, 1152

53 Implants in Restorative Dentistry, 1156

Niklaus P. Lang and Giovanni E. Salvi

Introduction, 1156
 Treatment concepts, 1156
 Limited treatment goals, 1157
 Shortened dental arch concept, 1157
 Indications for implants, 1158
 Increase of subjective chewing comfort, 1158
 Preservation of intact teeth or reconstructions, 1159
 Replacement of strategically important missing teeth, 1160
 Conclusion, 1163

54 Implants in the Zone of Esthetic Priority, 1165

Ronald E. Jung and Rino Burkhardt

Introduction, 1165
 Importance of esthetics in implantology and its impact on patient quality of life, 1165
 Decision-making process and informed consent, 1166
 Preoperative diagnostics and risk analysis, 1167
 Clinical measurements, 1167
 Image-guided diagnostics, 1168
 Visualization of prospective results for diagnostics and to inform patients, 1168
 Checklists and risk assessment (indications and contraindications), 1169
 Provisional restorations and timing of the treatment sequences, 1172
 Phase 1: From tooth extraction to implant placement, 1172
 Phase 2: From implant placement to abutment connection, 1175
 Phase 3: From abutment connection to final crown/bridge placement, 1177
 Surgical considerations when dealing with implants in the zone of esthetic priority, 1179
 Surgical aspects for an undisturbed wound healing, 1179
 Incisions and flap designs, 1180
 Clinical concepts for a single missing tooth, 1182
 Sites with no or minor tissue deficiencies, 1182
 Sites with extended or severe tissue deficiencies, 1182
 Clinical concepts for multiple missing teeth, 1185
 Sites with minor tissue deficiencies, 1190

Sites with extended tissue deficiencies, 1190
 Sites with severe tissue deficiencies, 1196
 Prosthetic reconstruction in the zone of esthetic priority, 1201
 Screw-retained versus cemented reconstructions, 1201
 Standardized prefabricated versus customized abutments, 1207
 Porcelain-fused-to-metal versus all-ceramic abutments, 1208
 Esthetic failures, 1209
 Classification of esthetic failures, 1210
 Recommendations for retreatment of esthetic failures, 1210
 Concluding remarks and perspectives, 1213

55 Implants in the Posterior Dentition, 1218
Ronald E. Jung, Daniel S. Thoma, and Urs C. Belser
 Introduction, 1218
 Indications for implants in the posterior dentition, 1219
 Controversial issues, 1221
 General considerations and decision-making for implants in the posterior dentition, 1221
 Decision-making between implant-supported reconstruction and tooth-supported fixed dental prostheses, 1221
 Implant restorations with cantilever units, 1223
 Combination of implant and natural tooth support, 1224
 Splinted versus single-unit restorations of multiple adjacent posterior implants, 1225
 Longest possible versus shorter implants, including impact of crown-to-implant ratio, 1226
 Implants in sites with extended vertical bone volume deficiencies, 1227
 Preoperative diagnostics and provisional reconstructions in the posterior dentition, 1233
 Preoperative prosthetic diagnostics, 1233
 Three-dimensional radiographic diagnostics and planning, 1233
 Clinical concepts for the restoration of free-end situations with fixed implant-supported prostheses, 1235
 Number, size, and distribution of implants, 1235
 Clinical concepts for multiunit tooth-bound posterior implant restorations, 1238
 Number, size, and distribution of implants, 1238
 Clinical concepts for posterior single-tooth replacement, 1241
 Premolar-size single-tooth restorations, 1241
 Molar-size single-tooth restorations, 1244
 Prosthetic reconstructions in the posterior dentition, 1245
 Loading concepts for the posterior dentition, 1245
 Screw-retained versus cemented reconstructions, 1247
 Selection criteria for choice of restorative materials (abutments/crowns), 1248
 Concluding remarks and perspectives, 1254
 Acknowledgments, 1254

56 Role of Implant–Implant- and Tooth–Implant-Supported Fixed Partial Dentures, 1262
Clark M. Stanford and Lyndon F. Cooper
 Introduction, 1262
 Patient assessment, 1262
 Implant treatment planning for the edentulous arch, 1264

Prosthesis design and full-arch tooth replacement therapy, 1264
 Complete-arch fixed complete dentures, 1264
 Prosthesis design and partially edentulous tooth replacement therapy, 1265
 Cantilever pontics, 1267
 Immediate provisionalization, 1269
 Disadvantages of implant–implant fixed partial dentures, 1269
 Tooth–implant fixed partial dentures, 1270
 Conclusion, 1272

57 Complications Related to Implant-Supported Restorations, 1276

Clark M. Stanford, Lyndon F. Cooper, and Y. Joon Coe
 Introduction, 1276
 Clinical complications in conventional fixed restorations, 1276
 Clinical complications in implant-supported restorations, 1278
 Biologic complications, 1278
 Mechanical complications, 1281
 Other issues related to prosthetic complications, 1286
 Implant angulation and prosthetic complications, 1286
 Screw-retained versus cement-retained restorations, 1287
 Ceramic abutments, 1288
 Esthetic complications, 1288
 Success/survival rate of implant-supported prostheses, 1290
 Conclusion, 1290

Part 17: Orthodontics and Periodontics

58 Tooth Movement in the Periodontally Compromised Patient, 1297

Mariano Sanz and Conchita Martin
 Introduction: Biologic principles of orthodontic tooth movement, 1297
 Periodontal and orthodontic diagnosis, 1298
 Treatment planning, 1300
 Periodontal considerations, 1300
 Orthodontic considerations, 1301
 Orthodontic treatment, 1305
 Specific orthodontic tooth movements, 1305
 Extrusion movements, 1305
 Molar uprighting, 1308
 Orthodontic tooth movements through cortical bone, 1308
 Intrusive tooth movements, 1311
 Orthodontic tooth movements and periodontal regeneration, 1316
 Pathologic tooth migration, 1320
 Multidisciplinary treatment of esthetic problems, 1321

59 Implants Used for Orthodontic Anchorage, 1325

Marc A. Schätzle and Niklaus P. Lang
 Introduction, 1325
 Evolution of implants for orthodontic anchorage, 1326
 Prosthetic implants for orthodontic anchorage, 1326
 Bone reaction to orthodontic implant loading, 1327

Indications for prosthetic oral implants for orthodontic anchorage, 1329
Prosthetic oral implant anchorage in growing orthodontic patients, 1329
Orthodontic implants as temporary anchorage devices, 1332
Implant designs and dimensions, 1332
Insertion sites for palatal implants, 1333
Palatal implants and their possible effects in growing patients, 1334
Clinical procedures and loading time schedule for palatal implant installation, 1336
Direct or indirect orthodontic implant anchorage, 1338
Stability and success rates, 1339
Implant removal, 1339
Advantages and disadvantages, 1340
Conclusion, 1341

Part 18: Supportive Care

60 Supportive Periodontal Therapy, 1347

Niklaus P. Lang, Giedrė Matulienė,

Giovanni E. Salvi, and Maurizio S. Tonetti

Definition, 1347

Basic paradigms for the prevention of periodontal disease, 1348

Patients at risk for periodontitis without supportive periodontal therapy, 1350
Supportive periodontal therapy for patients with gingivitis, 1351
Supportive periodontal therapy for patients with periodontitis, 1352
Continuous multilevel risk assessment, 1353
Subject periodontal risk assessment, 1354
Calculating the patient's individual periodontal risk assessment, 1359
Tooth risk assessment, 1359
Site risk assessment, 1361
Radiographic evaluation of periodontal disease progression, 1362
Clinical implementation, 1362
Objectives for supportive periodontal therapy, 1363
Supportive periodontal therapy in daily practice, 1364
Examination, re-evaluation, and diagnosis, 1364
Motivation, re-instruction, and instrumentation, 1365
Treatment of re-infected sites, 1366
Polishing, fluorides, and determination of recall interval, 1366

Index, i1

Contributors

Maurício Araújo

Department of Dentistry
State University of Maringá
Maringá
Paraná
Brazil

Jill D. Bashutski

Department of Biomedical Engineering
College of Engineering
Ann Arbor
MI
USA

Hans-Rudolf Baur

Department of Cardiology
Medical School
University of Berne
Berne
Switzerland

Urs C. Belser

Department of Prosthetic Dentistry
School of Dental Medicine
University of Geneva
Geneva
Switzerland

Gunnar Bergenholtz

Department of Endodontology
Institute of Odontology
The Sahlgrenska Academy at
University of Gothenburg
Gothenburg
Sweden

Tord Berglundh

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

Dieter D. Bosshardt

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

Rino Burkhardt

Private Practice
Zurich
Switzerland
and
Faculty of Dentistry
The University of Hong Kong
Hong Kong
China

Gianfranco Carnevale

Private Practice
Rome
Italy

Delwyn Catley

Department of Psychology
University of Missouri – Kansas City
Kansas
MO
USA

Y. Joon Coe

Department of Prosthodontics
University of Maryland
Baltimore
MD
USA

Lyndon F. Cooper

Department of Prosthodontics
University of North Carolina
Chapel Hill
NC
USA

Pierpaolo Cortellini

Private Practice
Florence
Italy

Mike Curtis

Institute of Dentistry
Barts and The London School of
Medicine and Dentistry
Queen Mary University of London
London
UK

José J. Echeverría

Department of Peridontology
School of Dentistry
University of Barcelona
Barcelona
Spain

Ingvar Ericsson

Department of Prosthodontic Dentistry
Faculty of Odontology
Malmo University
Malmo
Sweden

William V. Giannobile

Michigan Center for Oral Health Research
University of Michigan Clinical Center
Ann Arbor
MI
USA
and
Department of Biomedical Engineering
College of Engineering
Ann Arbor
MI
USA

Christoph H.F. Hämmeler

Clinic for Fixed and Removable Prosthodontics
and Dental Material Science
Center of Dental Medicine
University of Zurich
Zurich
Switzerland

Lisa Heitz-Mayfield

International Research Collaborative – Oral
Health and Equity
School of Anatomy, Physiology and Human Biology
The University of Western Australia
Crawley
WA
Australia

David Herrera

ETEP (Etiology and Therapy of Periodontal Diseases)
Research Group
Faculty of Odontology
University of Complutense
Madrid
Spain

Palle Holmstrup

Department of Periodontology
School of Dentistry
University of Copenhagen
Copenhagen
Denmark

Reinhilde Jacobs

Laboratory of Oral Physiology
Department of Periodontology
Oral Imaging Center
Faculty of Medicine
Catholic University of Leuven
Leuven
Belgium

Mats Jontell

Oral Medicine and Pathology
Institute of Odontology
The Sahlgrenska Academy at University
of Gothenburg
Gothenburg
Sweden

Ronald E. Jung

Clinic of Fixed and Removable Prosthodontics
Center of Dental and Oral Medicine and
Cranio-Maxillofacial Surgery
University of Zurich
Zurich
Switzerland

D. Kaigler

Michigan Center for Oral Health Research
Department of Periodontics and Oral Medicine
University of Michigan School of Dentistry
Ann Arbor
MI
USA

Thorkild Karring

Department of Periodontology and Oral
Gerontology
Royal Dental College
University of Aarhus
Aarhus
Denmark

Denis Kinane

Departments of Pathology and Periodontology
School of Dental Medicine
University of Pennsylvania
Philadelphia
PA
USA

Bernard Koong

School of Dentistry
Faculty of Medicine, Dentistry and Health Sciences
University of Western Australia
Perth
Australia

Marja L. Laine

Department of Periodontology
Academic Center for Dentistry Amsterdam (ACTA)
University of Amsterdam and VU University
Amsterdam
The Netherlands

Evanthia Lalla

Division of Periodontics
Section of Oral and Diagnostic Sciences
Columbia University College of Dental Medicine
New York
NY
USA

Niklaus P. Lang

Department of Periodontology
 School of Dental Medicine
 University of Berne
 Berne
 Switzerland
 and
 Center of Dental Medicine
 University of Zurich
 Zurich
 Switzerland

Jan Lindhe

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

Bruno G. Loos

Department of Periodontology
 Academic Center for Dentistry Amsterdam (ACTA)
 University of Amsterdam and VU University
 Amsterdam
 The Netherlands

Angelo Mariotti

Division of Periodontology
 Ohio State University
 College of Dentistry
 Columbus
 OH
 USA

Philip David Marsh

Department of Oral Biology
 School of Dentistry
 University of Leeds
 Leeds
 UK

Conchita Martin

Faculty of Odontology
 University of Complutense
 Madrid
 Spain

Giedrė Matulienė

Private Practice
 Zurich
 Switzerland

Andrea Mombelli

Department of Periodontology
 School of Dental Medicine
 University of Genoa
 Geneva
 Switzerland

Sture Nyman (deceased)

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

Panos N. Papapanou

Division of Periodontics
 Section of Oral and Diagnostic Sciences
 Columbia University College of
 Dental Medicine
 New York
 NY
 USA

Bjarni E. Pjetursson

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

Roberto Pontoriero

Private Practice
 Milan
 Italy

Christoph A. Ramseier

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

G. Rasperini

Department of Biomedical, Surgical
 and Dental Sciences
 Foundation IRCCS Ca' Granda Polyclinic
 University of Milan
 Milan
 Italy

Domenico Ricucci

Private Practice
 Cetraro
 Italy

Hector F. Rios

Department of Periodontology
 and Oral Medicine
 University of Michigan
 School of Dentistry
 Ann Arbor
 MI
 USA

Giovanni E. Salvi

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

Mariano Sanz

Faculty of Odontology
University of Complutense
Madrid
Spain

Arne S. Schäfer

Center of Dento-Maxillo-Facial Medicine
Charité – Universitätsmedizin
Berlin
Germany

Marc A. Schätzle

Clinic of Orthodontics and Pediatric Dentistry
Center of Dental Medicine
University of Zurich
Zurich
Switzerland

Jorge Serrano

ETEP (Etiology and Therapy of Periodontal Diseases)
Research Group
Faculty of Odontology
University of Complutense
Madrid
Spain

Gregory J. Seymour

Faculty of Dentistry
University of Otago
Dunedin
New Zealand

Beatrice Siegrist-Guldener

Department of Periodontology
University of Berne Dental School
Berne
Switzerland

José F. Siqueira, Jr

Department of Endodontics
Faculty of Dentistry
Estácio de Sá University
Rio de Janeiro
Brazil

Dagmar Else Slot

Department of Periodontology
Academic Centre for Dentistry Amsterdam (ACTA)
University of Amsterdam and VU
University Amsterdam
Amsterdam
The Netherlands

Clark M. Stanford

Dental Administration,
University of Illinois at Chicago
College of Dentistry
Chicago
IL
USA

Stefan Stübinger

Center for Applied Biotechnology and Molecular
Medicine (CABMM)
Vetsuisse Faculty
University of Zurich
Zurich
Switzerland

Jeanie E. Suvan

Unit of Periodontology
UCL Eastman Dental Institute
London
UK

Ricardo P. Teles

Department of Periodontology
The Forsyth Institute
Boston
MA
USA

Daniel S. Thoma

Clinic of Fixed and Removable Prosthodontics
Center of Dental and Oral Medicine and
Cranio-Maxillofacial Surgery
University of Zurich
Zurich
Switzerland

Cristiano Tomasi

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

Maurizio S. Tonetti

European Research Group on Periodontology
(ERGOPerio)
Genoa
Italy

Leonardo Trombelli

Research Centre for the Study of Periodontal
and Peri-implant Diseases
University Hospital
University of Ferrara
Ferrara
Italy

Ubele van der Velden

Department of Periodontology
Academic Center for Dentistry Amsterdam (ACTA)
University of Amsterdam and VU University
Amsterdam
The Netherlands

Fridus van der Wijden

Department of Periodontology
Academic Centre for Dentistry Amsterdam (ACTA)
University of Amsterdam and VU
University Amsterdam
Amsterdam
The Netherlands

Arie J. van Winkelhoff

Faculty of Medical Sciences
Center for Dentistry and Oral Hygiene
University of Groningen
Groningen
The Netherlands

Fabio Vignoletti

Faculty of Odontology
University of Complutense
Madrid
Spain

Jan L. Wennström

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

Matthias Zehnder

Clinic of Preventive Dentistry, Periodontology,
and Cariology
University of Zurich
Zurich
Switzerland

Giovanni Zucchelli

Department of Biomedical and Neuromotor Sciences
Bologna University
Bologna
Italy

Preface

In an age when the internet is providing numerous options of treatment based on not always properly validated concepts presented by clinicians of sometimes unclear background, the practitioner is left with a confusing image of the profession. The questions of what is right and what is a professional error are becoming increasingly difficult to determine. It is evident that such online education – while occasionally having its undisputed benefits – bears the danger of distributing treatment philosophies that are most likely not scientifically scrutinized and, hence, may even be detrimental to the patient.

Given these facts, one may wonder what the role of a textbook becomes, when everything is so easily accessible through electronic media. Obviously, a textbook still represents a unique source of professional information containing a treatment philosophy that must be based on scientific evidence rather than on trial and error or personal preference. *Clinical Periodontology and Implant Dentistry* has always emphasized the evidence-based treatment approach.

The textbook originated from Scandinavia and documented various treatment procedures with clinical research data. In later years, the authorship became more international, which led to the success of the text throughout the world. In the fourth edition some aspects of implant dentistry were incorporated, and by the time that fifth edition was prepared implant dentistry had become an important part of clinical periodontology. Owing to the increased content, the first of the now two volumes presented the basic aspects, applying biological principles to both periodontal and peri-implant tissues, whereas the second volume was devoted to treatment aspects. It had become evident that periodontology also affects the biology of implants.

Consequently, these two fields of dentistry have become merged and married to each other. The new sixth edition of this textbook incorporates the

important topic of the strictly prosthetic aspects of treating mutilated dentition. An essential part of comprehensive therapy is treatment planning according to biological principles, to which special attention has been given. The installation of oral implants and their healing are covered in detail, and novel concepts of tissue integration are also addressed. Last, but not least, clinical experience from latter years has revealed that biological complications occur with oral implants. The sixth edition gives special attention to coping with such adverse events and also to issues related to the maintenance of periodontal and peri-implant health. All in all, the sixth edition represents a thoroughly revised syllabus of contemporary periodontology and implant dentistry.

If a textbook is to maintain its role as a reference source and guide for clinical activities it has to be updated at regular intervals. The sixth edition follows the fifth edition by 7 years, and 90% of the content has been revised in the last 2 years. Several chapters have been reconceived or completely rewritten by a new generation of internationally recognized researchers and master clinicians. As we thank our contributors to this new masterpiece for their enormous effort in keeping the text updated, we hope that the sixth edition of *Clinical Periodontology and Implant Dentistry* will maintain its status as the master text of periodontology and implant dentistry for the entire profession worldwide.

We express our gratitude to the numerous coworkers at Wiley, our publisher, who contributed to the realization of the project, and special thanks go to Nik Prowse (freelance project manager), Lucy Gardner (freelance copy-editor) and Susan Boobis (freelance indexer).

However, most of our thanks go to you, as reader, student, colleague, specialist clinician or researcher in clinical periodontology and implant dentistry. We hope that you enjoy this new edition, with its new clothes and new outline.



Niklaus P. Lang

February 2015



Jan Lindhe

Part 1: Anatomy

- 1** Anatomy of Periodontal Tissues, 3
Jan Lindhe, Thorkild Karring, and Maurício Araújo
- 2** Bone as a Living Organ, 48
Hector F. Rios, Jill D. Bashutski, and William V. Giannobile
- 3** The Edentulous Ridge, 65
Maurício Araújo and Jan Lindhe
- 4** The Mucosa at Teeth and Implants, 83
Jan Lindhe, Jan L. Wennström, and Tord Berglundh
- 5** Osseointegration, 100
Jan Lindhe, Tord Berglundh, and Niklaus P. Lang
- 6** From Periodontal Tactile Function to Peri-implant Osseoperception, 112
Reinhilde Jacobs

Chapter 1

Anatomy of Periodontal Tissues

Jan Lindhe,¹ Thorkild Karring,² and Maurício Araújo³

¹Department of Periodontology, Institute of Odontology, The Sahlgrenska Academy at University of Gothenburg, Gothenburg, Sweden

²Department of Periodontology and Oral Gerontology, Royal Dental College, University of Aarhus, Aarhus, Denmark

³Department of Dentistry, State University of Maringá, Maringá, Paraná, Brazil

Introduction, 3

Gingiva, 5

 Macroscopic anatomy, 5

 Microscopic anatomy, 8

Periodontal ligament, 25

Root cementum, 29

Bone of the alveolar process, 34

Macroscopic anatomy, 34

Microscopic anatomy, 36

Blood supply of the periodontium, 41

Lymphatic system of the periodontium, 45

Nerves of the periodontium, 45

Acknowledgment, 46

Introduction

This chapter provides a brief description of the characteristics of the normal periodontium. It is assumed that the reader has prior knowledge of oral embryology and histology.

The periodontium (peri = around, odontos = tooth) comprises the following tissues: (1) *gingiva* (G), (2) *periodontal ligament* (PL), (3) *root cementum* (RC), and (4) *alveolar bone proper* (ABP) (Fig. 1-1). ABP lines the alveolus of the tooth and is continuous with the alveolar bone; on a radiograph it may appear as *lamina dura*. The *alveolar process* that extends from the basal bone of the maxilla and mandible consists of the alveolar bone and the *alveolar bone proper*.

The main function of the periodontium is to attach the tooth to the bone tissue of the jaws and to maintain the integrity of the surface of the masticatory mucosa of the oral cavity. The periodontium, also called “the attachment apparatus” or “the supporting tissues of the teeth”, constitutes a developmental, biologic, and functional unit which undergoes certain changes with age and is, in addition, subjected to morphologic changes related to functional alterations and alterations in the oral environment.

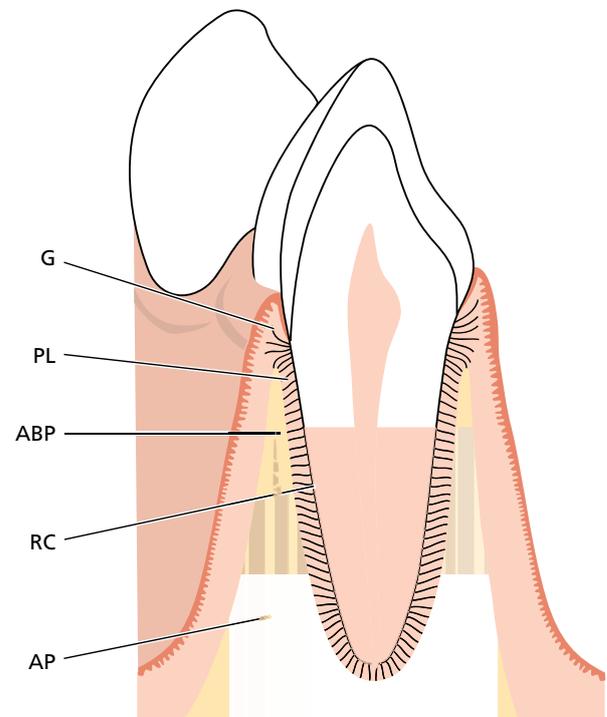


Fig. 1-1

The development of the periodontal tissues occurs during the development and formation of teeth. This process starts early in the embryonic phase when cells from the neural crest (from the neural tube of the embryo) migrate into the first branchial arch. In this position, the neural crest cells form a band of *ectomesenchyme* beneath the epithelium of the stomatodeum (the primitive oral cavity). After the uncommitted neural crest cells have reached their location in the jaw space, the epithelium of the stomatodeum releases factors which initiate epithelial–ectomesenchymal interactions. Once these interactions have occurred, the ectomesenchyme takes the dominant role in the further development. Following the formation of the *dental lamina*, a series of processes are initiated (bud stage, cap stage, bell stage with root development) which result in the formation of a tooth and its surrounding periodontal tissues, including the alveolar bone proper. During the cap stage, condensation of ectomesenchymal cells appears in relation to the dental epithelium (the dental organ [DO]), forming the *dental papilla* (DP) that gives rise to the dentin and the pulp, and the *dental follicle* (DF) that gives rise to the periodontal supporting tissues (Fig. 1-2). The decisive role played by the ectomesenchyme in this process is further established by the fact that the tissue of the dental papilla apparently also determines the shape and form of the tooth.

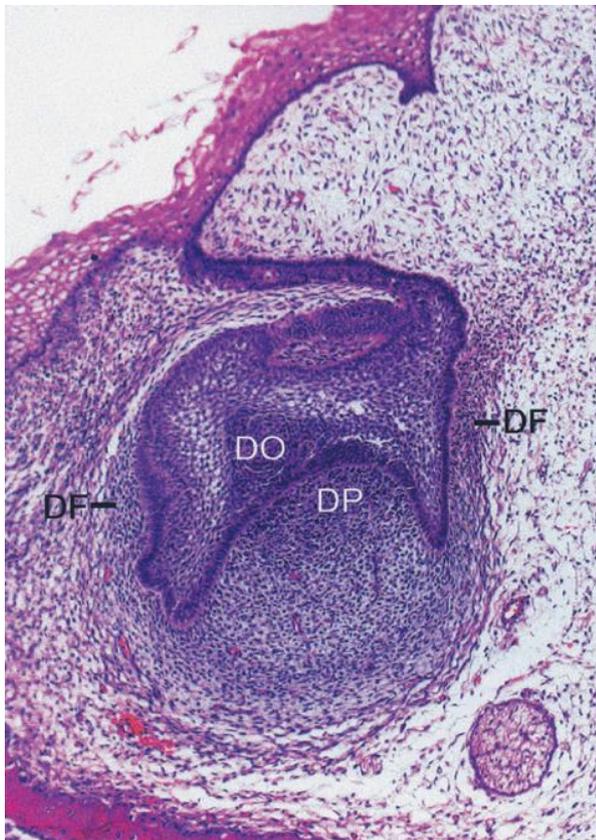


Fig. 1-2

If a tooth germ in the bell stage of development is dissected and transplanted to an ectopic site (e.g. the connective tissue or the anterior chamber of the eye), the tooth formation process continues. The crown and the root are formed, and the supporting structures (i.e. cementum, periodontal ligament, and a thin lamina of alveolar bone proper) also develop. Such experiments document that all information necessary for the formation of a tooth and its attachment apparatus resides within the tissues of the dental organ and the surrounding ectomesenchyme. The dental organ is the formative organ of enamel, the dental papilla is the formative organ of the dentin–pulp complex, and the dental follicle is the formative organ of the attachment apparatus (cementum, periodontal ligament, and alveolar bone proper).

The development of the root and the periodontal supporting tissues follows that of the crown. Epithelial cells of the external and internal dental epithelium (the dental organ) proliferate in an apical direction, forming a double layer of cells called *Hertwig's epithelial root sheath* (RS). The odontoblasts (OBs) forming the dentin of the root differentiate from ectomesenchymal cells in the dental papilla under the inductive influence of the inner epithelial cells (Fig. 1-3). The dentin (D) continues to form in an apical direction, producing the framework of the root. During formation of the root, the periodontal supporting tissues, including the acellular cementum, develop. Some of the events in cementogenesis are still unclear, but the following concept is gradually emerging.

At the start of dentin formation, the inner cells of Hertwig's epithelial root sheath synthesize and secrete enamel-related proteins, probably belonging to the amelogenin family. At the end of this period, the epithelial root sheath becomes fenestrated and ectomesenchymal cells from the dental follicle penetrate through these fenestrations and contact the root surface. The ectomesenchymal cells in contact with the enamel-related proteins differentiate into cementoblasts and start to form cementoid. This cementoid represents the organic matrix of the cementum and consists of a ground substance and collagen fibers, which intermingle with collagen fibers in the not yet fully mineralized outer layer of the dentin. It is assumed that the cementum becomes firmly attached to the dentin through these fiber interactions. The formation of the cellular cementum, which often covers the apical third of the dental roots, differs from that of acellular cementum in that some of the cementoblasts become embedded in the cementum.

The remaining parts of the periodontium are formed by ectomesenchymal cells from the dental follicle lateral to the cementum. Some of them differentiate into periodontal fibroblasts and form the fibers of the periodontal ligament, while

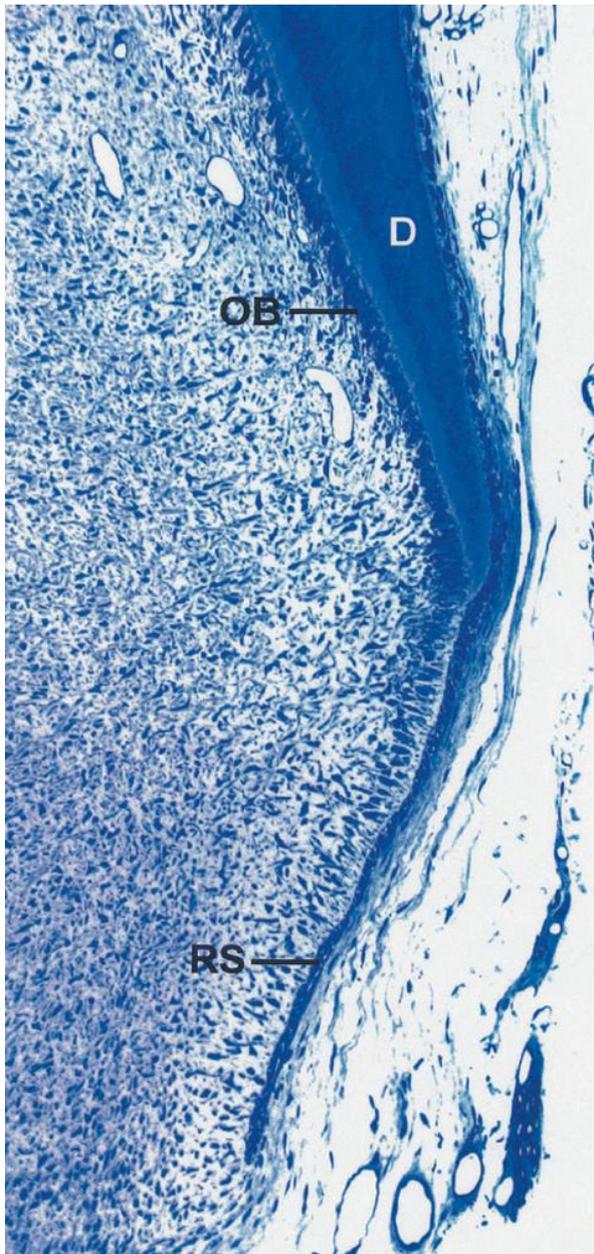


Fig. 1-3

others become osteoblasts and form the alveolar bone proper in which the periodontal fibers are anchored. In other words, the primary alveolar wall is also an ectomesenchymal product. It is likely, but still not conclusively documented, that ectomesenchymal cells remain in the mature periodontium and take part in the turnover of this tissue.

Gingiva

Macroscopic anatomy

The oral mucosa (mucous membrane) is continuous with the skin of the lips and the mucosa of the soft palate and pharynx. The oral mucosa consists

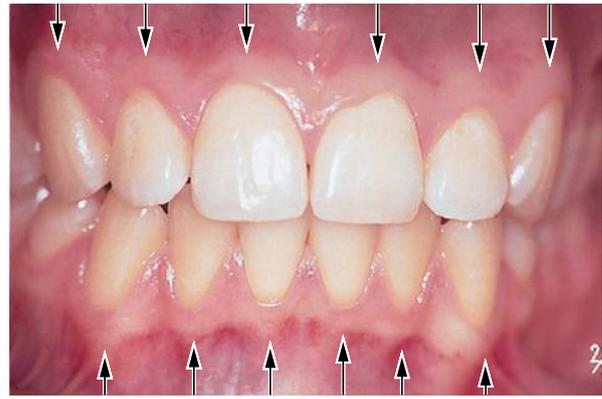


Fig. 1-4



Fig. 1-5

of (1) the *masticatory mucosa*, which includes the gingiva and the covering of the hard palate; (2) the *specialized mucosa*, which covers the dorsum of the tongue; and (3) the remaining part, called the *lining mucosa*.

Figure 1-4 The gingiva is that part of the masticatory mucosa which covers the alveolar process and surrounds the cervical portion of the teeth. It consists of an epithelial layer and an underlying connective tissue layer called the *lamina propria*. The gingiva obtains its final shape and texture in conjunction with eruption of the teeth.

In the coronal direction, the coral pink gingiva terminates in the *free gingival margin*, which has a scalloped outline. In the apical direction, the gingiva is continuous with the loose, darker red *alveolar mucosa* (lining mucosa) from which the gingiva is separated by a usually easily recognizable border called either the mucogingival junction (arrows) or the mucogingival line.

Figure 1-5 There is no mucogingival line present in the palate since the hard palate and the maxillary alveolar process are covered by the same type of masticatory mucosa.

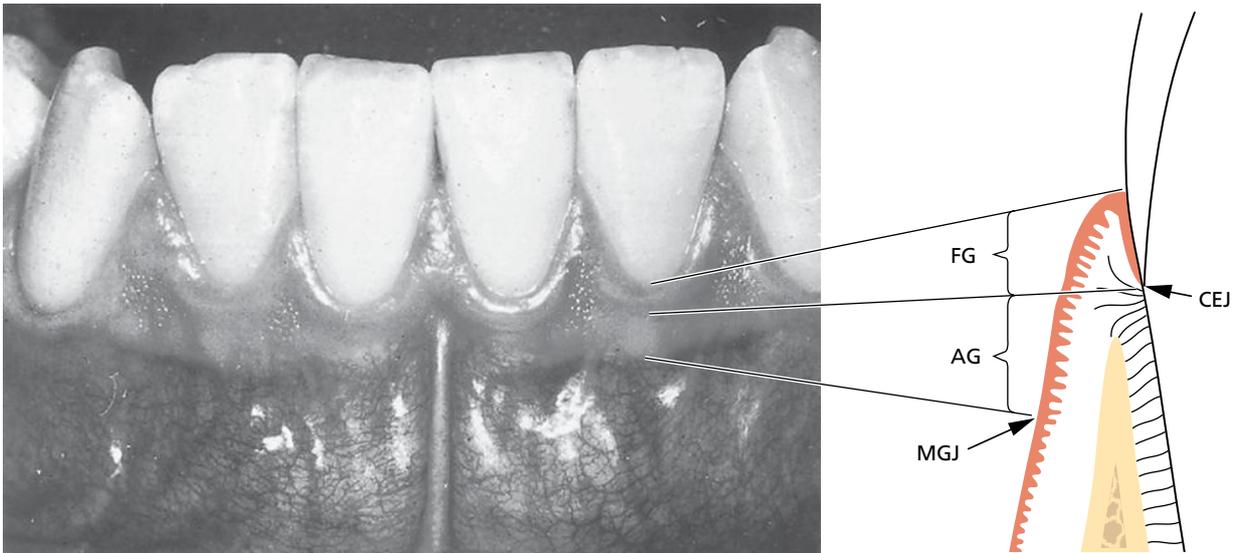


Fig. 1-6

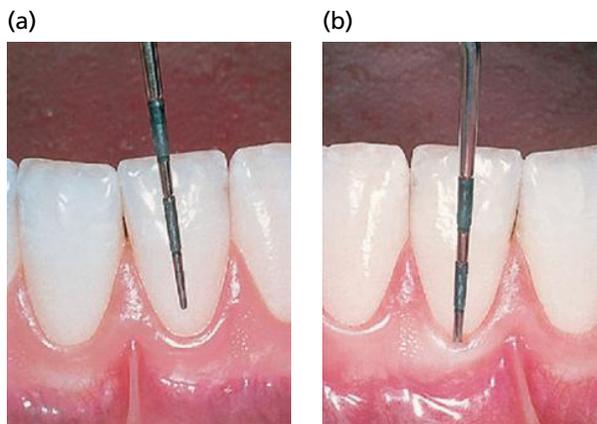


Fig. 1-7

Figure 1-6 Three parts of the gingiva can be identified:

1. Free gingiva (FG)
2. Interdental gingiva
3. Attached gingiva (AG).

The free gingiva is coral pink, has a dull surface and a firm consistency. It comprises the gingival tissue at the vestibular and lingual/palatal aspects of the teeth. On the vestibular and lingual sides of the teeth, the free gingiva extends from the gingival margin in an apical direction to the *free gingival groove*, which is positioned at a level corresponding to the level of the *cemento-enamel junction* (CEJ). The attached gingiva is demarcated by the *mucogingival junction* (MGJ) in the apical direction.

Figure 1-7 The free gingival margin is often rounded in such a way that a small invagination or sulcus is formed between the tooth and the gingiva (Fig. 1-7a).

When a periodontal probe is inserted into this invagination and, further apically, towards the CEJ, the gingival tissue is separated from the tooth and a “*gingival pocket*” or “*gingival crevice*” is artificially opened. Thus,

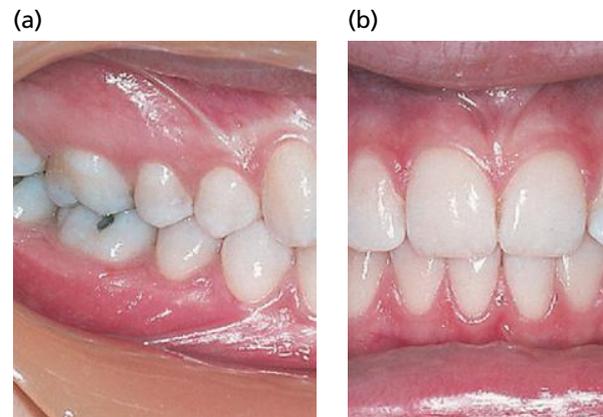


Fig. 1-8

in normal or clinically healthy gingiva there is in fact no “*gingival pocket*” or “*gingival crevice*” present, but the gingiva is in close contact with the enamel surface. In Fig. 1-7b, a periodontal probe has been inserted into the tooth–gingiva interface and a “*gingival crevice*” artificially opened approximately to the level of the CEJ.

After complete tooth eruption, the free gingival margin is located on the enamel surface approximately 1.5–2 mm coronal to the CEJ.

Figure 1-8 The shape of the *interdental gingiva* (the *interdental papilla*) is determined by the contact relationships between the teeth, the width of the approximal tooth surfaces, and the course of the CEJ. In anterior regions of the dentition, the interdental papilla is of pyramidal form (Fig. 1-8b), while in the molar regions, the papillae are flatter in the buccolingual direction (Fig. 1-8a). Due to the presence of interdental papillae, the free gingival margin follows a more or less accentuated, scalloped course through the dentition.

Figure 1-9 In the premolar/molar regions of the dentition, the teeth have approximal contact surfaces (Fig. 1-9a) rather than contact points. Since the shape of

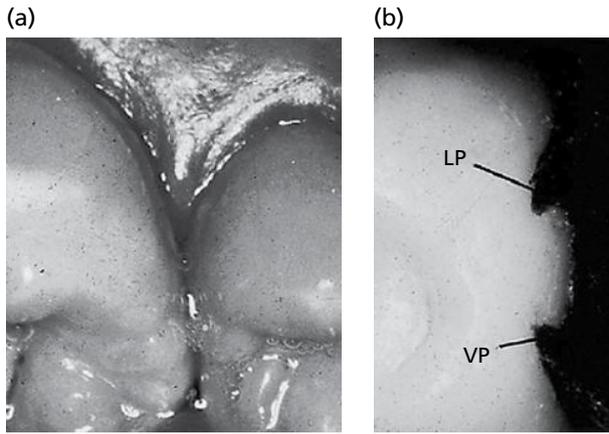


Fig. 1-9

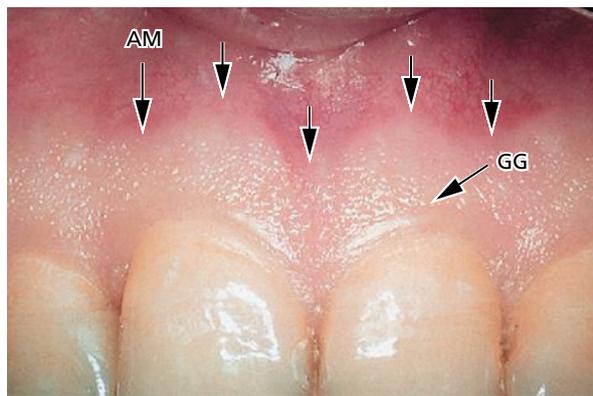
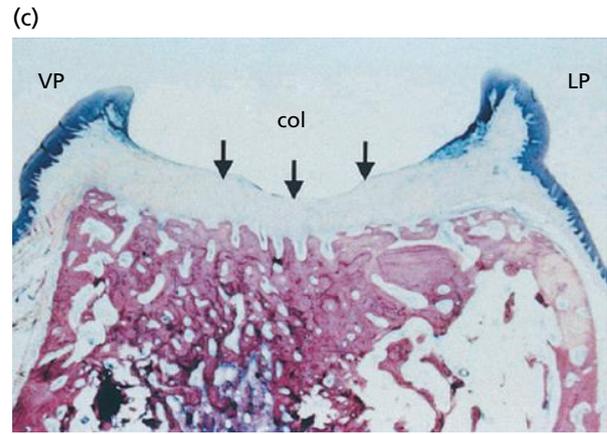


Fig. 1-10

the interdental papilla conforms with the outline of the interdental contact surfaces, a concavity – *a col* – is established in the premolar and molar regions, as demonstrated in Fig. 1-9b, where the distal tooth has been removed. Thus, the interdental papillae in these areas often have one vestibular (VP) and one lingual/palatal portion (LP) separated by the col region. The col region, as demonstrated in the histologic section (Fig. 1-9c), is covered by a thin non-keratinized epithelium (arrows). This epithelium has many features in common with the junctional epithelium (see Fig. 1-34).

Figure 1-10 The attached gingiva is demarcated in the coronal direction by the free gingival groove (GG) or, when such a groove is not present, by a horizontal plane placed at the level of the CEJ. In clinical examinations, it was observed that a free gingival groove is only present in about 30–40% of adults.

The free gingival groove is often most pronounced on the vestibular aspect of the teeth, occurring most frequently in the incisor and premolar regions of the mandible, and least frequently in the mandibular molar and maxillary premolar regions.

The attached gingiva extends in the apical direction to the mucogingival junction (arrows), where it becomes continuous with the alveolar (lining) mucosa (AM). It is of firm texture, coral pink in color, and often shows small depressions on the surface. The depressions, called “stippling”, give the appearance of orange peel. The

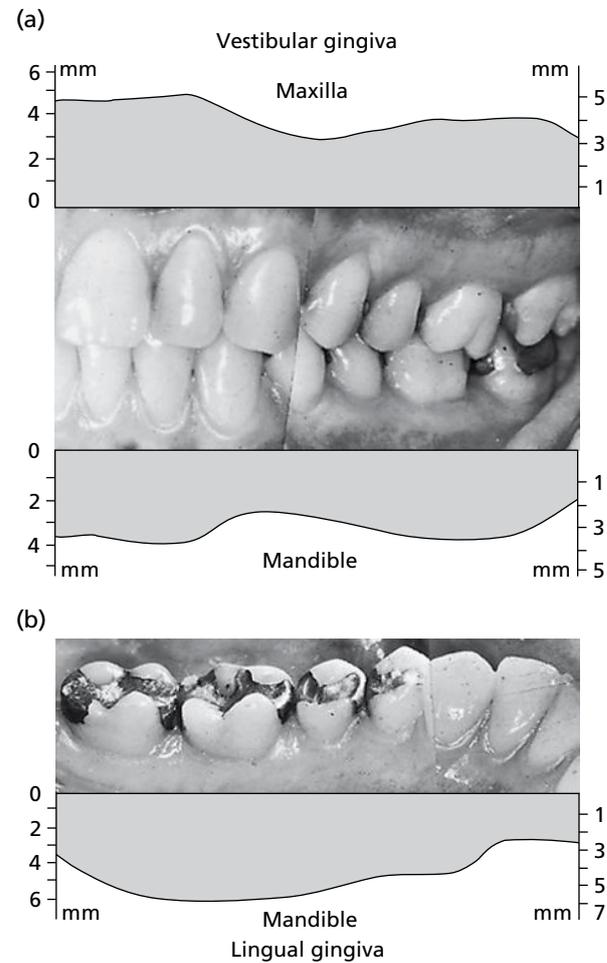


Fig. 1-11

gingiva is firmly attached to the underlying alveolar bone and cementum by connective tissue fibers, and is, therefore, comparatively immobile in relation to the underlying tissue. The darker red alveolar mucosa (AM) located apical to the mucogingival junction, on the other hand, is loosely bound to the underlying bone. Therefore, in contrast to the attached gingiva, the alveolar mucosa is mobile in relation to the underlying tissue.

Figure 1-11 shows how the width of the gingiva varies in different parts of the dentition. In the maxilla

(Fig. 1-11a), the vestibular gingiva is generally widest in the area of the incisors and narrowest adjacent to the premolars. In the mandible (Fig. 1-11b), the gingiva on the lingual aspect is particularly narrow in the area of the incisors and wide in the molar region. The range of variation is 1–9 mm.



Fig. 1-12

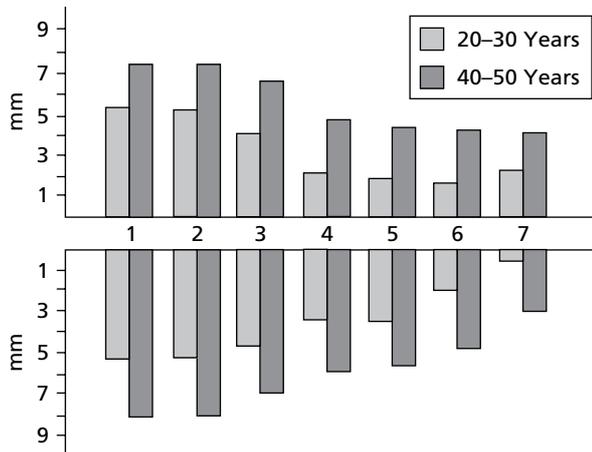


Fig. 1-13

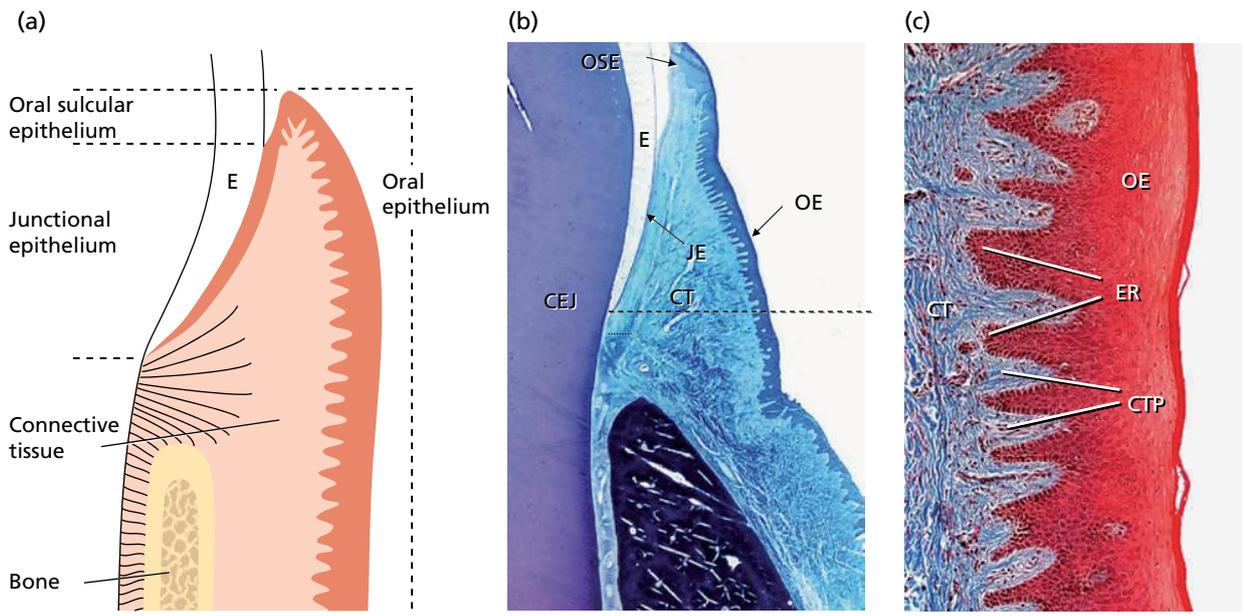


Fig. 1-14

Figure 1-12 illustrates an area in the mandibular premolar region where the gingiva is extremely narrow. The arrows indicate the location of the mucogingival junction. The mucosa has been stained with an iodine solution in order to distinguish more accurately between the gingiva and the alveolar mucosa.

Figure 1-13 depicts the result of a study in which the width of the attached gingiva was assessed and related to the age of the patients examined. It was found that the gingiva in 40–50-year olds was significantly wider than that in 20–30-year olds. This observation indicates that the width of the gingiva tends to increase with age. Since the mucogingival junction remains stable throughout life in relation to the lower border of the mandible, the increasing width of the gingiva may suggest that the teeth, as a result of occlusal wear, erupt slowly throughout life.

Microscopic anatomy

Oral epithelium

Figure 1-14a A schematic drawing of a histologic section (see Fig. 1-14b) describing the composition of the gingiva and the contact area between the gingiva and the enamel (E).

Figure 1-14b The free gingiva comprises all epithelial and connective tissue structures (CT) located coronal to a horizontal line placed at the level of the cemento enamel junction (CEJ). The epithelium covering the free gingiva may be differentiated as follows:

- *Oral epithelium (OE)*, which faces the oral cavity
- *Oral sulcular epithelium (OSE)*, which faces the tooth without being in contact with the tooth surface

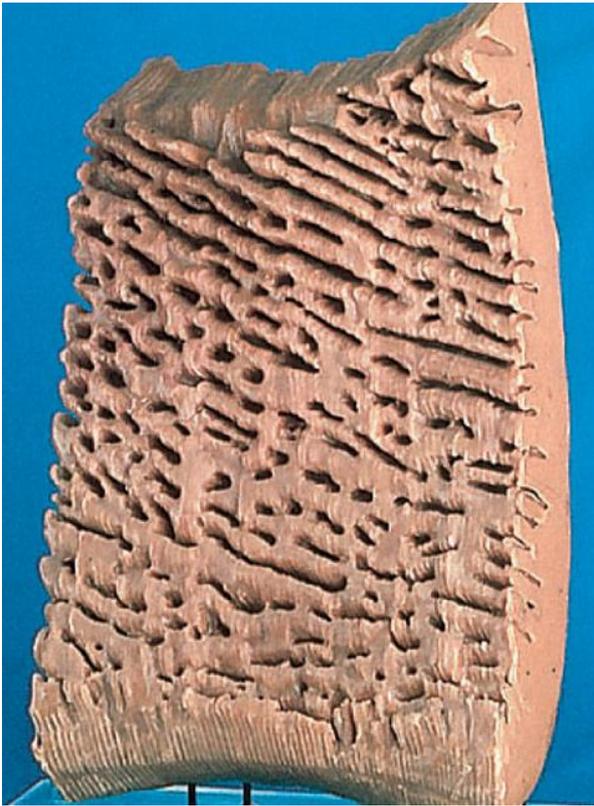


Fig. 1-15

- *Junctional epithelium (JE)*, which provides the contact between the gingiva and the tooth.

Figure 1-14c The boundary between the oral epithelium (OE) and underlying connective tissue (CT) has a wavy course. The connective tissue portions which project into the epithelium are called *connective tissue papillae (CTP)* and are separated from each other by *epithelial ridges* – so-called *rete pegs (ER)*. In normal, non-inflamed gingiva, rete pegs and connective tissue papillae are lacking at the boundary between the junctional epithelium and its underlying connective tissue (Fig. 1-14b). Thus, a characteristic morphologic feature of the oral epithelium and the oral sulcular epithelium is the presence of rete pegs: these structures are lacking in the junctional epithelium.

Figure 1-15 presents a model, constructed on the basis of magnified serial histologic sections, showing the subsurface of the oral epithelium of the gingiva after the connective tissue has been removed. The subsurface of the oral epithelium (i.e. the surface of the epithelium facing the connective tissue) exhibits several depressions corresponding to the connective tissue papillae (see Fig. 1-16) which project into the epithelium. It can be seen that the epithelial projections, which in histologic sections separate the connective tissue papillae, constitute a continuous system of epithelial ridges.

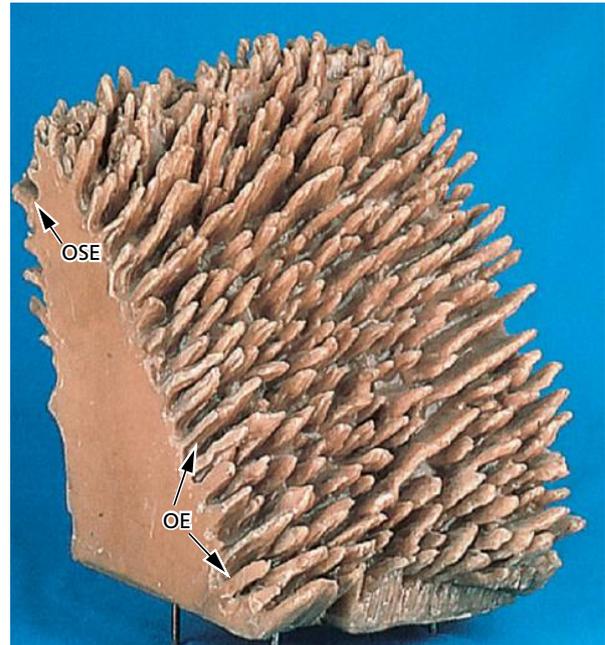


Fig. 1-16

Figure 1-16 presents a model of the connective tissue, corresponding to the model of the epithelium shown in Fig. 1-15. The epithelium has been removed, thereby making the vestibular aspect of the gingival connective tissue visible. Note the connective tissue papillae which project into the space that was occupied by the oral epithelium (OE) in Fig. 1-15 and by the oral sulcular epithelium (OSE) at the back of the model.

Figure 1-17a In most adults the attached gingiva shows a stippling on the surface. The photograph shows a case where this stippling is conspicuous (see also Fig. 1-10).

Figure 1-17b presents a magnified model of the outer surface of the oral epithelium of the attached gingiva. The surface exhibits the minute depressions (1–3) which give the gingiva its characteristic stippled appearance.

Figure 1-17c shows a photograph of the subsurface (i.e. the surface of the epithelium facing the connective tissue) of the model shown in Fig. 1-17b. The subsurface of the epithelium is characterized by the presence of epithelial ridges which merge at various locations (1–3). The depressions seen on the outer surface of the epithelium (1–3 in Fig. 1-17b) correspond to these fusion sites (1–3) between the epithelial ridges. Thus, the depressions on the surface of the gingiva occur in the areas of fusion between various epithelial ridges.

Figure 1-18 (a) A portion of the oral epithelium covering the free gingiva is illustrated in this photomicrograph. The oral epithelium is a *keratinized, stratified,*

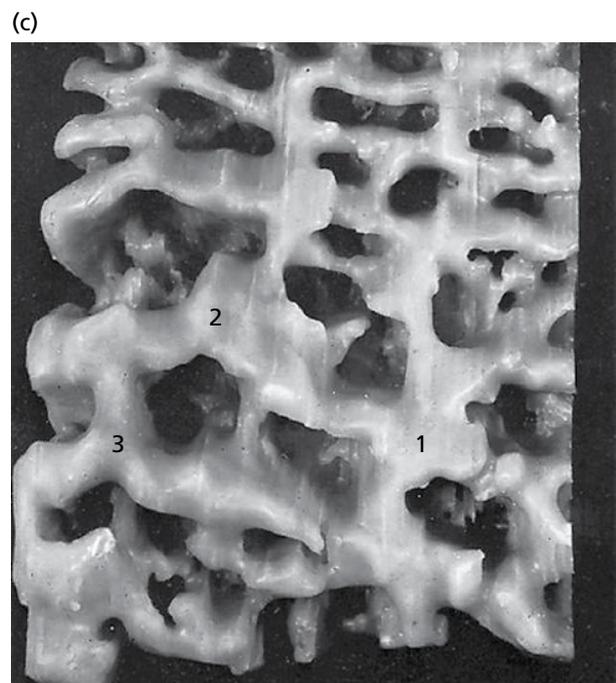
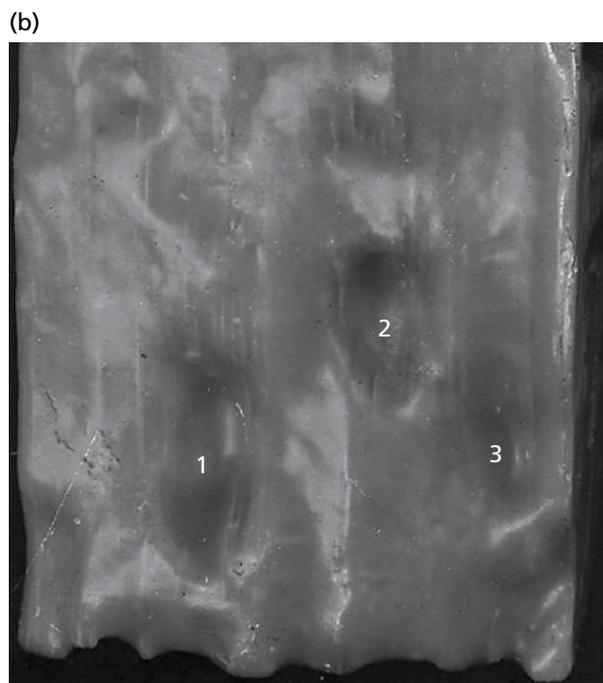
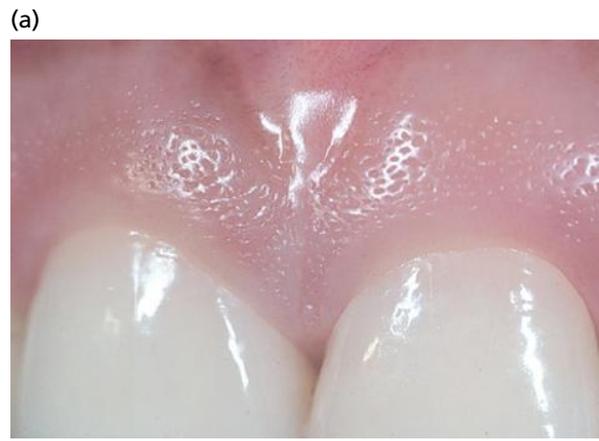


Fig. 1-17

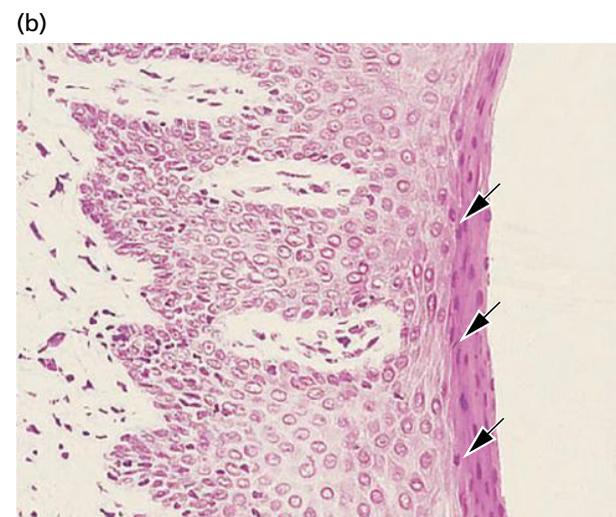
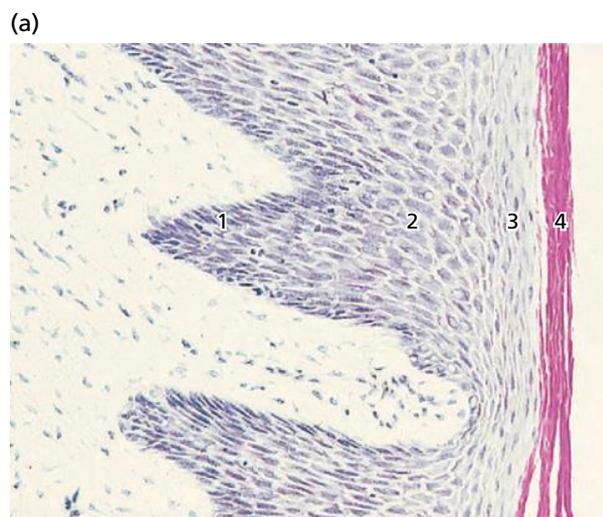


Fig. 1-18

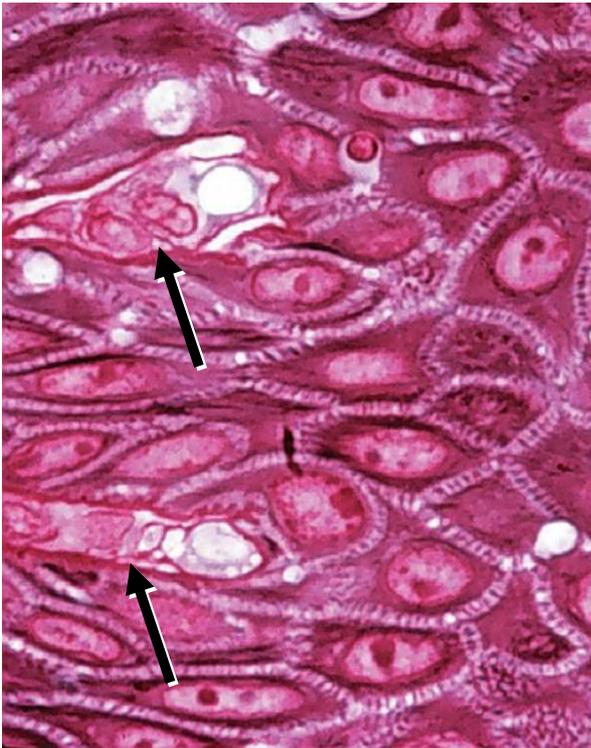


Fig. 1-19

squamous epithelium which, on the basis of the degree to which the keratin-producing cells are differentiated, can be divided into the following cell layers:

1. *Basal layer* (stratum basale or stratum germinativum)
2. *Prickle cell layer* (stratum spinosum)
3. *Granular cell layer* (stratum granulosum)
4. *Keratinized cell layer* (stratum corneum).

It should be observed that in this section, cell nuclei are lacking in the outer cell layers. Such an epithelium is denoted *orthokeratinized*. Often, however, the cells of the stratum corneum of the epithelium of human gingiva contain remnants of the nuclei as seen in Fig. 1-18b (arrows). In such a case, the epithelium is denoted *parakeratinized*.

Figure 1-19 In addition to the keratin-producing cells, which comprise about 90% of the total cell population, the oral epithelium contains the following types of cell:

- *Melanocytes*
- *Langerhans cells*
- *Merkel's cells*
- *Inflammatory cells.*

These cell types are often stellate and have cytoplasmic extensions of various size and appearance. They are also called "clear cells" since in histologic sections, the zone around their nuclei appears lighter than that in the surrounding keratin-producing cells.



Fig. 1-20

The photomicrograph shows "clear cells" (arrows) located in or near the stratum basale of the oral epithelium. With the exception of the Merkel's cells, these "clear cells", which do not produce keratin, lack desmosomal attachment to adjacent cells. The melanocytes are pigment-synthesizing cells and are responsible for the melanin pigmentation occasionally seen on the gingiva. However, both lightly and darkly pigmented individuals have melanocytes in the epithelium.

The Langerhans cells are believed to play a role in the defense mechanism of the oral mucosa. It has been suggested that the Langerhans cells react with antigens which are in the process of penetrating the epithelium. An early immunologic response is thereby initiated, inhibiting or preventing further antigen penetration of the tissue. The Merkel's cells have been suggested to have a sensory function.

Figure 1-20 The cells in the basal layer are either cylindrical or cuboid, and are in contact with the *basement membrane* that separates the epithelium and the connective tissue. The basal cells possess the ability to divide, that is undergo mitotic cell division. The cells marked with arrows in the photomicrograph are in the process of dividing. It is in the basal layer that the epithelium is renewed. Therefore, this layer is also termed *stratum germinativum*, and can be considered the *progenitor cell compartment* of the epithelium.

Figure 1-21 When two daughter cells (D) have been formed by cell division, an adjacent "older" basal cell (OB) is pushed into the spinous cell layer and starts, as a *keratinocyte*, to traverse the epithelium. It takes approximately 1 month for a keratinocyte to reach the outer epithelial surface, where it is shed from the stratum corneum. Within a given time, the

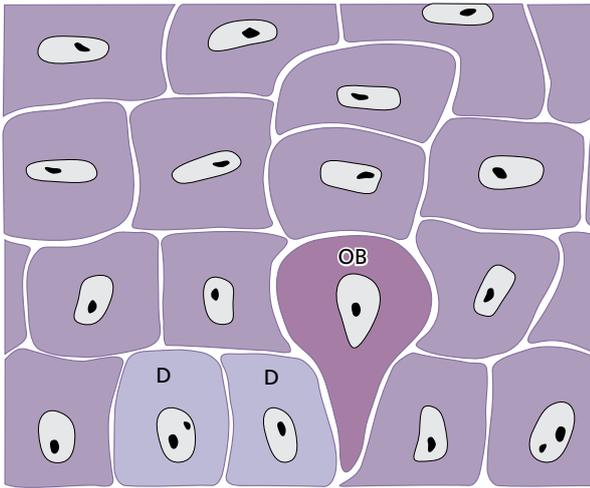


Fig. 1-21



Fig. 1-22

number of cells which divide in the basal layer equals the number of cells which are shed from the surface. Thus, under normal conditions there is equilibrium between cell renewal and cell loss so that the epithelium maintains a constant thickness. As the basal cell migrates through the epithelium, it becomes flattened with its long axis parallel to the epithelial surface.

Figure 1-22 The basal cells are found immediately adjacent to the connective tissue and are separated from this tissue by the basement membrane, probably produced by the basal cells. Under the light microscope this membrane appears as a structureless zone approximately $1\text{--}2\mu\text{m}$ wide (arrows) and reacts positively to a periodic acid-Schiff (PAS) stain. This positive reaction demonstrates that the basement membrane contains carbohydrate (glycoproteins). The epithelial cells are surrounded by an extracellular substance which also contains protein-polysaccharide complexes. At the ultrastructural level, the basement membrane has a complex composition.

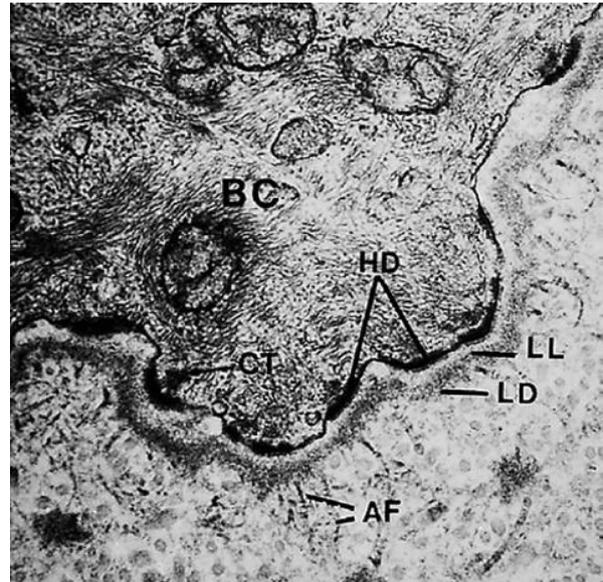


Fig. 1-23

Figure 1-23 is an electron micrograph (magnification $\times 70000$) of an area including part of a basal cell, the basement membrane, and part of the adjacent connective tissue. The basal cell (BC) occupies the upper portion of the micrograph. Immediately beneath the basal cell, an approximately $400\text{-}\text{\AA}$ wide electron-lucent zone can be seen, which is called the *lamina lucida* (LL). Beneath the lamina lucida, an electron-dense zone of approximately the same thickness can be observed. This zone is called *lamina densa* (LD). From the lamina densa so-called *anchoring fibers* (AF) project in a fan-shaped fashion into the connective tissue. The anchoring fibers are approximately $1\mu\text{m}$ in length and terminate freely in the connective tissue. The basement membrane, which under the light microscope appears as an entity, thus, in the electron micrograph, appears to comprise one lamina lucida and one lamina densa with adjacent connective tissue fibers (anchoring fibers). The cell membrane of the epithelial cells facing the lamina lucida harbors a number of electron-dense, thicker zones appearing at various intervals along the cell membrane. These structures are called *hemidesmosomes* (HD). The cytoplasmic *tonofilaments* (CT) in the cell converge towards the hemidesmosomes. The hemidesmosomes are involved in the attachment of the epithelium to the underlying basement membrane.

Figure 1-24 illustrates an area of stratum spinosum in the gingival oral epithelium. Stratum spinosum consists of $10\text{--}20$ layers of relatively large, polyhedral cells, equipped with short cytoplasmic processes resembling spines. The cytoplasmic processes (arrows) occur at regular intervals and give the cells a prickly appearance. Together with intercellular protein-carbohydrate complexes, cohesion between the cells is provided by numerous "desmosomes" (pairs of hemidesmosomes) which are located between the cytoplasmic processes of adjacent cells.