

# THE IMMEDIACY CONCEPT

Treatment Planning  
from Analog to Digital

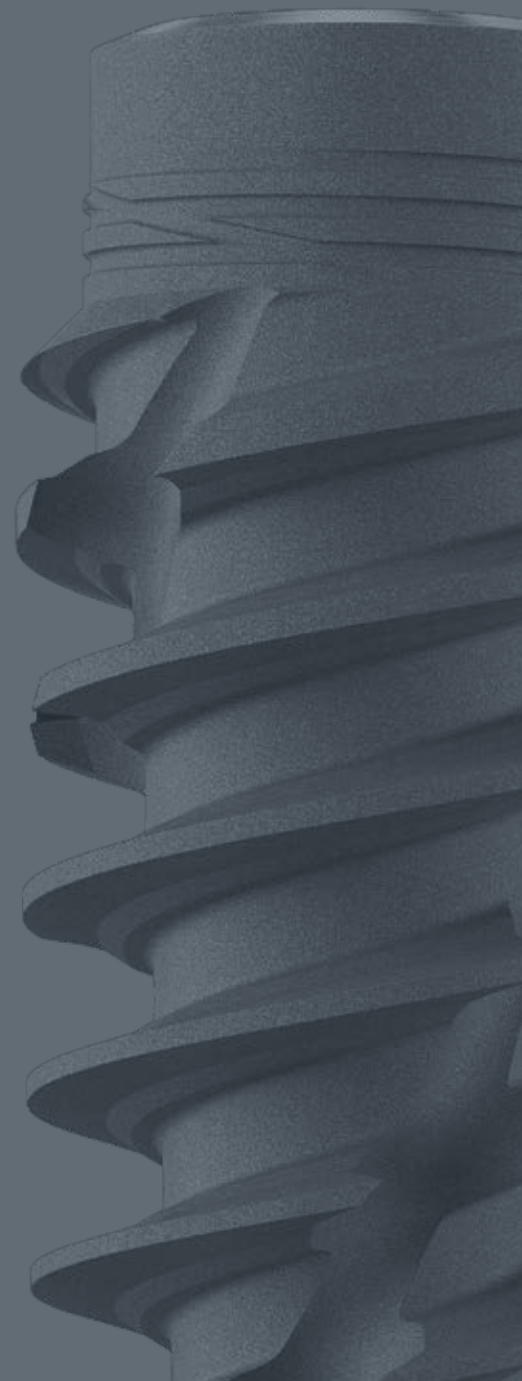
Edited by

Edmond Bedrossian, DDS

E. Armand Bedrossian, DDS, MSD

Lawrence E. Brecht, DDS

with foreword by Daniel Buser, DDS, Dr med dent



The Immediacy Concept: *Treatment Planning from Analog to Digital*



One book, one tree: In support of reforestation worldwide and to address the climate crisis, for every book sold Quintessence Publishing will plant a tree (<https://onetreepanted.org/>).

#### Library of Congress Cataloging-in-Publication Data

Names: Bedrossian, Edmond, editor. | Bedrossian, E. Armand (Edmond Armand), editor. | Brecht, Lawrence, editor.

Title: The immediacy concept : treatment planning from analog to digital / edited by Edmond Bedrossian, E. Armand Bedrossian, Lawrence Brecht.

Description: Batavia, IL : Quintessence Publishing, Co, Inc, [2022] |

Includes bibliographical references and index. | Summary: "Clinical manual for immediate implant treatment planning in the digital age, including the fundamentals of analog treatment planning that clinicians must master before moving to the digital realm"-- Provided by publisher.

Identifiers: LCCN 2021046221 (print) | LCCN 2021046222 (ebook) | ISBN 9781647240424 (hardcover) | ISBN 9781647241193 (ebook)

Subjects: MESH: Dental Implantation | Dental Implants | Digital Technology | Osseointegration | Case Reports

Classification: LCC RK667.I45 (print) | LCC RK667.I45 (ebook) | NLM WU 640 | DDC 617.6/93--dc23

LC record available at <https://lccn.loc.gov/2021046221>

LC ebook record available at <https://lccn.loc.gov/2021046222>

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

ISBN: 978-1-64724-042-4



© 2022 Quintessence Publishing Co, Inc

Quintessence Publishing Co, Inc  
411 N Raddant Road  
Batavia, IL 60510  
[www.quintpub.com](http://www.quintpub.com)

5 4 3 2 1

All rights reserved. This book or any part thereof may not be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, or otherwise, without prior written permission of the publisher.

Editor: Marieke Z. Swerski  
Design: Sue Zubek  
Production: Angelina Schmelter

Printed in Croatia

# THE IMMEDIACY CONCEPT

Treatment Planning from  
Analog to Digital

Edited by

**Edmond Bedrossian, DDS**

Professor  
Department of Oral & Maxillofacial Surgery  
Dugoni School of Dentistry  
University of the Pacific

Private Practice  
San Francisco, California

**E. Armand Bedrossian, DDS, MSD**

Affiliate Associate Professor  
Graduate Prosthodontics Department  
University of Washington School of Dentistry  
Seattle, Washington

Private Practice  
San Francisco, California

**Lawrence E. Brecht, DDS**

Clinical Associate Professor  
Director of Maxillofacial Prosthetics  
New York University College of Dentistry

Director of Maxillofacial Prosthetics  
Northwell Health

Private Practice Limited to Prosthodontics  
and Maxillofacial Prosthetics  
New York, New York

 **QUINTESSENCE PUBLISHING**

Berlin | Chicago | Tokyo  
Barcelona | London | Milan | Mexico City | Paris | Prague | Seoul | Warsaw  
*Beijing | Istanbul | Sao Paulo | Zagreb*

# Contents

*Foreword vi*

*Preface vii*

*Acknowledgments viii*

*Contributors ix*

## **SECTION I** **The Immediacy** **Concept**

1. Osseointegration Demystified 3  
Peter Schupbach, Roland Glauser
2. Biologic Principles and the Immediacy Concept 19  
Tara Aghaloo, Danny Hadaya, Delaney Islip
3. Implant Design for the Immediacy Concept 29  
Edmond Bedrossian, Eirik Aasland Salvesen
4. Biomechanical Principles for Immediate Loading 39  
Edmond Bedrossian
5. The Tissue-Level Implant 51  
Edmond Bedrossian, Edgard El Chaar, Benjamin E. Pippenger, Eik Schiegnitz

## **SECTION II** **The Digital** **Workflow**

6. Digital Workflow and the Immediacy Concept 69  
Sonia Leziy, Brahm Miller
7. Digital Workflow Step by Step 95  
E. Armand Bedrossian, Edmond Bedrossian
8. Complete Digital Workflow for Full-Arch Rehabilitation 121  
Panos Papaspyridakos
9. Analog to Digital Workflow in Immediacy 133  
Edmond Bedrossian, E. Armand Bedrossian

**SECTION III**  
**Treating Fully**  
**Edentulous Arches**

10. Loading Protocols for Full-Arch Rehabilitation 153  
Waldemar Polido, Dean Morton, Wei-Shao Lin
11. Systematic Treatment Planning Protocol for the Maxilla 165  
Edmond Bedrossian
12. The Tilted Implant Concept in the Maxilla 179  
Edmond Bedrossian
13. Systematic Treatment Planning Protocol for the Mandible 195  
Edmond Bedrossian, E. Armand Bedrossian

**SECTION IV**  
**Prosthetics for Full-**  
**Arch Rehabilitation**

14. Chairside Analog Conversion for a Fixed Provisional Prosthesis 217  
Lawrence E. Brecht
15. Workflow and Material Choice for the Full-Arch Prosthesis 227  
E. Armand Bedrossian
16. Managing Structural Complications of Full-Arch Restorations 247  
Ricardo Mitrani, E. Armand Bedrossian, Jack Goldberg

**SECTION V**  
**Zygomatic Implants**

17. Biomechanical Principles for Zygomatic Implants 265  
Edmond Bedrossian
18. New Zygomatic Implant Design 287  
Edmond Bedrossian, Sepehr Zarrine
19. Prevention and Management of Zygomatic Implant  
Complications 297  
Edmond Bedrossian

**SECTION VI**  
**Case Presentations**

20. Case Presentations 317  
Edmond Bedrossian, E. Armand Bedrossian

*Index* 391

# Foreword

In the past 50 years, modern implant dentistry—based on the concept of osseointegration—has made tremendous and constant progress to the benefit of patients. Osseointegration was first described by the two research groups of Prof P-I Brånemark from the University of Gothenburg and Prof André Schroeder from the University of Bern. In the 1980s and 1990s, the basic surgical principles were defined, the clinical indications expanded from fully edentulous to partially edentulous patients, the submerged versus nonsubmerged healing modalities were examined, and new microrough implant surfaces were tested, which initiated a paradigm shift in the dental implant market.

Since the millennium change, we have been in a phase of routine application of dental implants. In the past 20 years, many efforts have been made to improve the attractiveness of implant therapy for patients by reducing the surgical invasiveness, pain and morbidity, and healing and treatment periods required. Various placement protocols with immediate, early, and late implant placement postextraction were defined at an ITI Consensus Conference in 2003. In addition, the different loading protocols with immediate, early, and conventional loading and restoration were defined 5 years later.

The present textbook is edited by Dr Edmond Bedrossian, a gifted oral and maxillofacial surgeon and very experienced implant specialist. He was able to invite additional talented authors for contributions to the book, resulting in an excellent and very comprehensive textbook on the concept of immediacy. The first two chapters present the biologic basis of this concept, followed by relevant implant design aspects and biomechanical principles in chapters 3 and 4. Chapter 5 discusses the concept of nonsubmerged tissue-level implants, including the latest development with the TLX implant (Straumann). Chapters 6 to 9 then present the latest developments of the digital workflow in various clinical situations, which has had a tremendous positive impact for these implant treatments. The second half of the book deals with the treatment of fully edentulous patients, in particular the edentulous maxilla, where the immediate loading protocol is a tremendous service for patients for obvious reasons. The book then concludes with case presentations on all clinical situations described throughout to showcase everything that has been learned and how it can be applied.

The clinical chapters clearly show not only the great progress made with these treatment modalities, but also that these treatments are challenging for the clinician and complex in nature. Therefore, these procedures should only be carried out by skilled and experienced implant surgeons. Besides that, case selection based on well-defined selection criteria is very important to select the most appropriate treatment option in a given situation.

In conclusion, this is an excellent, clinically oriented textbook about the concept of immediacy in implant dentistry, and the reader will highly profit from the content. I congratulate Dr Edmond Bedrossian and the other authors. This book can be highly recommended to colleagues with an interest in this topic.

**Daniel Buser, DMD, Dr med dent  
Prof Emeritus, University of Bern**

# Preface

The emphasis of this book is that the preservation of alveolar hard and soft tissues is more predictable using the immediacy concept than is the reconstruction of the hard and soft tissues using the traditional delayed approach. Implant treatment is the most physiologic treatment offered to patients missing a single tooth, several teeth, and even their entire dentition. Internal loading of the alveolar bone with an implant-supported prosthesis maintains the alveolar bone volume after loss of teeth.

Treatment of patients with missing teeth has evolved over the past three decades from two-stage delayed loading of implants placed in healed extraction sites to immediate implant placement with immediate provisional restoration placement at the time the teeth are removed. On the other hand, the rehabilitations of the terminal dentition patient and the existing fully edentulous patient have also evolved from delayed placement and delayed loading to immediate placement, which can be performed both in the maxilla and the mandible. What was the motivation for this dramatic change?

- Improved patient comfort and satisfaction
- Shortened treatment time
- Greater treatment acceptance

The vast body of published literature on this subject has allowed for many systematic reviews that clearly support immediate implant placement, fabrication of immediate provisionals, and immediate loading in appropriate clinical settings. Even in extreme cases of alveolar resorption, immediate implant placement with the use of tilted and/or zygomatic implants for the rehabilitation of the edentulous maxilla with a fixed prosthesis has also demonstrated success rates of over 97%. These published success rates are consistent with the 97% to 98% success rate expected with the traditional two-stage delayed loading protocols.

This book presents up-to-date information from discussion of the fundamental (analog) prosthetic and surgical treatment planning protocols to the integration and use of available digital workflows that complement everyday clinical practice. I am confident that readers will appreciate the journey through this book. The authors of every chapter underscore the fundamental scientific facts essential for predictable treatment planning with the practical presentation of clinical protocols for positive short- and long-term outcomes. This patient-centric approach results in the most contemporary and up-to-date information for our colleagues and their patients in every single chapter. The first chapter begins with a comprehensive discussion of distance and contact osteogenesis. Later chapters present the implant micro and macro design features necessary for achieving immediacy. Fundamental analog surgical as well as prosthetic protocols are presented in subsequent chapters. The role of the digital workflow is comprehensively discussed, and its use for the treatment of missing single to fully edentulous cases is presented through the remaining chapters. The final chapters illustrate multiple case reports utilizing and executing the information learned in previous chapters.

*“Preservation  
is more  
predictable than  
reconstruction.”*

**Prof P-I  
Brånemark's  
sentiment stands  
true today as it  
did the day he  
stated it:**

***"No one should  
die with their teeth  
in a glass of water."***

The chapters written by leaders in the field of implant dentistry intend to follow the simple but powerful objectives set by Prof Brånemark, which include interdisciplinary collaboration, simplification, and following science with well-established treatment planning and protocols. The messages from each of Prof Brånemark's objectives are as follows:

*Interdisciplinary collaboration* between the implant team, the restorative dentist, the surgeon, and the laboratory technician is critical in proper treatment planning, execution of plans, and the long-term maintenance of implant reconstructions. In cases of patients with congenital and/or acquired maxillofacial defects, collaboration with our medical colleagues is also vital.

*Simplification* refers to the comprehensive understanding of a subject or a procedure. In order to discuss a subject or to execute a procedure and have others respond by saying, "You make it look simple," the complete command of the subject or the procedure is necessary. Knowing the level of predictable outcomes by proper preoperative clinical evaluation and treatment planning leads to practical and predictable prognosis. Therefore, realistic appreciation of the difference between "optimal" and "adequate" treatment outcomes is critical.

*Following science* and having a comprehensive knowledge of well-established protocols are essential to prevent complications. Following these objectives will lead to treating our patients in the most predictable manner with predictable long-term prognoses. After all, the patient is paramount.

Enjoy the content of this textbook; I am confident that you will find the comprehensive and contemporary information as essential for your daily practice as I do in mine.

## ***Acknowledgments***

This textbook was made possible by collaboration between global leaders of implant dentistry, and this collaboration has been a privilege and the highlight of my career. Without their unselfish sharing of their years of experience and knowledge, this project would not have been possible. I am extremely thankful for Drs Larry Brecht and Armand Bedrossian, who have been invaluable as coeditors as well as contributors to various chapters in this book.

Dr Danny Buser, an icon in the field of dental implants and ITI, has graciously written the foreword for this textbook, further confirming that the authors have provided implant teams with the most current and contemporary scientific information to treat our patients in the best possible manner.

I would also like to thank Elizabeth Murdoch Titcomb of Iolite Biomedical Communications for the creative illustrations throughout this textbook, allowing comprehensive and clear communications of many anatomical and technical concepts.

I am humbled by the collaboration of so many of the globally renowned authors of this textbook and am confident that we have honored the objectives set forth by my mentor, friend, and the father of osseointegration, Prof P-I Brånemark.

# Contributors

**Tara Aghaloo, DDS, MD, PhD**

Professor

Division of Diagnostic and Surgical Sciences

Section of Oral and Maxillofacial Surgery

UCLA School of Dentistry

Los Angeles, California

**Edmond Bedrossian, DDS**

Professor

Department of Oral & Maxillofacial Surgery

Dugoni School of Dentistry

University of the Pacific

Private Practice

San Francisco, California

**E. Armand Bedrossian, DDS, MSD**

Affiliate Associate Professor

Graduate Prosthodontics Department

University of Washington School of Dentistry

Seattle, Washington

Private Practice

San Francisco, California

**Lawrence E. Brecht, DDS**

Clinical Associate Professor

Director of Maxillofacial Prosthetics

New York University College of Dentistry

Director of Maxillofacial Prosthetics

Department of Oral and Maxillofacial Surgery/

Dental Medicine

Department of Otolaryngology

Northwell Health

Private Practice Limited to Prosthodontics

and Maxillofacial Prosthetics

New York, New York

**Edgard El Chaar, DDS, MS**

Director, Advanced Education Program

in Periodontics

New York University College of Dentistry

New York, New York

**Jack Goldberg, DDS, MS**

Private Practice

Mexico City, Mexico

**Roland Glauser, DMD**

Private Practice

Zürich, Switzerland

**Danny Hadaya, DDS, PhD**

Resident

Division of Diagnostic and Surgical Sciences

Section of Oral and Maxillofacial Surgery

UCLA School of Dentistry

Los Angeles, California

**Delaney Islip, BS**

Dental Student, Class of 2022

UCLA School of Dentistry

Los Angeles, California

**Sonia Leziy, DDS, Dipl Perio**

Private Practice

Nanaimo, British Columbia

Clinical Associate Professor

University of British Columbia

Vancouver, British Columbia

Canada

**Wei-Shao Lin, DDS, PhD**

Associate Professor

Program Director, Advanced Education Program

Department of Prosthodontics

Co-Director, Center for Implant, Esthetic,

and Innovative Dentistry

Indiana University School of Dentistry

Indianapolis, Indiana

**Brahm Miller, DDS, Dipl Pros**

Private Practice

Nanaimo, British Columbia

Clinical Associate Professor

University of British Columbia

Vancouver, British Columbia

Canada

**Ricardo Mitrani, DDS, MSD**

Private Practice  
Mexico City, Mexico

Affiliate Associate Professor  
Department of Restorative Dentistry  
University of Washington School of Dentistry  
Seattle, Washington

Resident Faculty  
Spear Education  
Scottsdale, Arizona

**Dean Morton, BDS, MS**

Professor  
Department of Prosthodontics  
Director, Center for Implant, Esthetic,  
and Innovative Dentistry  
Indiana University School of Dentistry  
Indianapolis, Indiana

**Panos Papaspyridakos, DDS, MS, PhD**

Associate Professor  
Department of Prosthodontics  
Tufts University School of Dental Medicine  
Boston, Massachusetts

**Benjamin E. Pippenger, PhD**

Senior Scientist  
Department of Periodontology  
University of Bern  
Bern, Switzerland

**Waldemar Polido, DDS, MS, PhD**

Clinical Professor  
Department of Oral and Maxillofacial Surgery  
Co-Director, Center for Implant, Esthetic,  
and Innovative Dentistry  
Indiana University School of Dentistry  
Indianapolis, Indiana

**Eirik Aasland Salvesen, DDS**

Private Practice  
Stavanger, Norway

Private Practice  
Trondheim, Norway

**Eik Schiegnitz, PD, Dr med dent, MSc**

Head of the Division of Implantology  
Department of Oral and Maxillofacial Surgery  
University Medical Center  
Johannes Gutenberg-University  
Mainz, Germany

**Peter Schupbach, PD, ScD, PhD**

Owner  
Schupbach Histology and Imaging  
Thawil, Switzerland

**Sepehr Zarrine, DDS**

Private Practice  
Saint Dié, France

# SECTION I

## THE IMMEDIACY CONCEPT

### Included topics:

- Osseointegration Demystified
- Biologic Principles and the Immediacy Concept
- Implant Design for the Immediacy Concept
- Biomechanical Principles for Immediate Loading
- The Tissue-Level Implant





---

# Osseointegration Demystified

---

Peter Schupbach, PD, ScD, PhD  
Roland Glauser, DMD

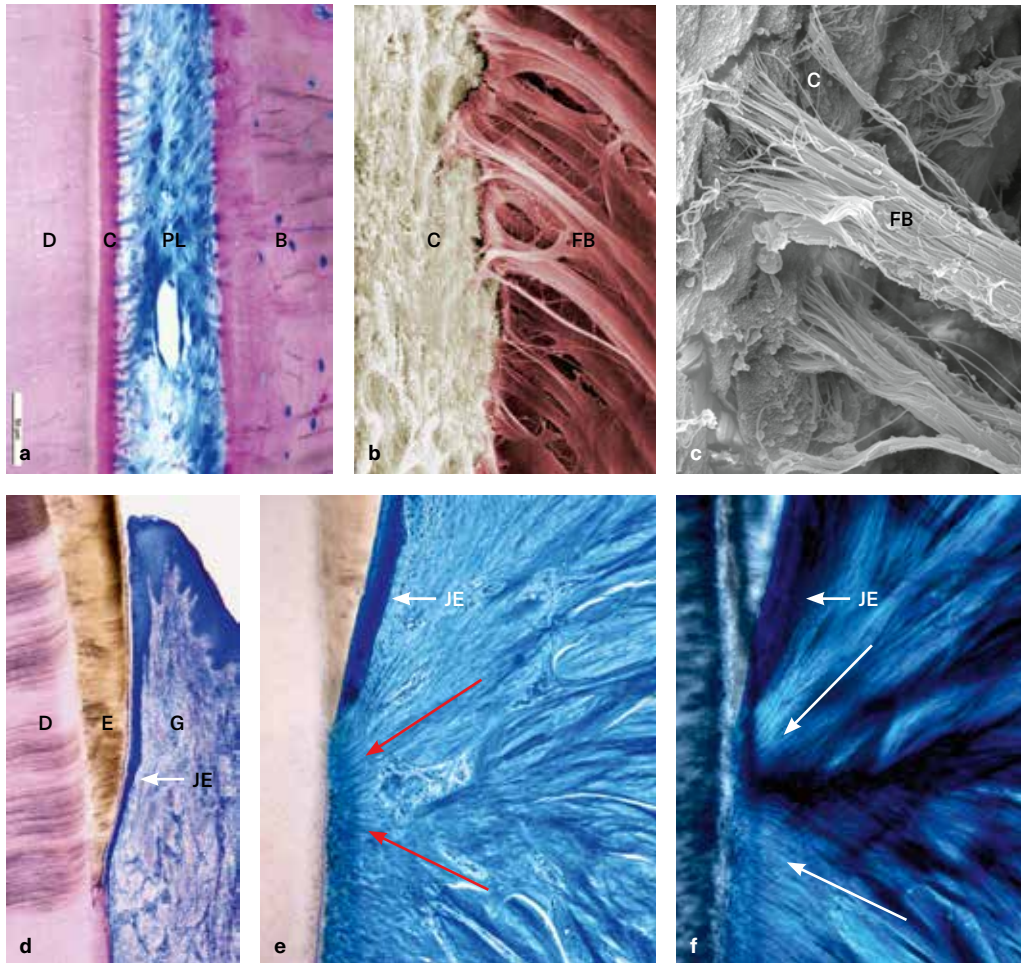
For decades now, dental implants have been successfully used to replace lost teeth, thereby restoring masticatory function, compromised esthetics, discomfort, and low self-confidence. Original surgical and restorative protocols focused on edentulous patients and included a strictly staged approach as the standard *modus operandi*. Over the decades, a myriad of developments has been introduced, including implant treatment of partial edentulism and aiming at simplification without jeopardizing predictability of dental implants. A main focus was on a reduction of the number of interventions, the invasiveness of the surgery, and the overall duration of the treatment. Moreover, changing patient demands have obviously stimulated a shortening of the entire treatment approach. Over the years, additional indications presenting with more advanced tissue conditions such as immediate implants have been included for treatments using dental implants.

## Tooth-Supporting Tissues

The way our teeth are attached to the alveolar bone by the periodontal ligament (PDL) and protected by the marginal periodontium against foreign intruders is a masterpiece of tissue architecture and function. The cementum, PDL, alveolar bone, and gingiva form an evolutionary, structural, and functional unit called the *dental attachment apparatus*.<sup>1</sup> This unit serves several functions: it anchors the individual teeth to their bony alveoli and binds together one jaw's teeth into a dental arch. The PDL is a dense connective tissue composed of collagenous fibers and cells, blood vessels, and nerves. It is interposed in the space between the root surface of a tooth and the alveolar bone. Collagen fiber bundles called *Sharpey fibers* cross the space and are anchored in the root cementum at one end and in the alveolar bone at the other. Sharpey fibers are composed of hundreds of single collagen fibers. Every single fiber is deeply buried and anchored in the mineralized matrix of cementum and in the periosteum of the alveolar bone, respectively. On average, 28,000 collagen fiber bundles insert per 1 mm<sup>2</sup> area of cementum on a functioning tooth. The PDL works like a flexible suspension that allows resisting displacing forces and protects the teeth against an excessive occlusal load.

The primary functions of the gingiva around natural teeth are protection and stability; that is, to defend the interface between the teeth and the soft tissues against foreign invaders and to stabilize the position of the tooth in the alveolar bone. The structural framework that allows these tasks to be accomplished offers various spectacular details provided by evolution. Among them are how the gingiva and the underlying bone are protected by the highly specialized junctional epithelium and the way the collagen fibers of the connective tissue are attached to the tooth (Fig 1-1).

The junctional epithelium extends from the sulcular epithelium to the enamel/cementum junction and forms an epithelial, nonkeratinized sleeve around the tooth collar, thereby preserving the continuity of the epithelial coating of the oral cavity.<sup>2</sup> It is commonly accepted that the junctional epithelium is attached to enamel by the epithelial attachment apparatus, which comprises hemidesmosomes attached to the internal basal lamina. The unique structure and antibacterial peripheral defense mechanisms also allow for control of the lifelong constant microbiologic challenge. While the junctional epithelium forms the coronal part of the dentogingival junction, the apical portion is characterized by dentogingival collagenous fiber bundles extending in oblique angles into the root cementum. The resulting robust tissue attachment thereby supports the junctional epithelium and its rather fragile attachment mechanism by hemidesmosomes.



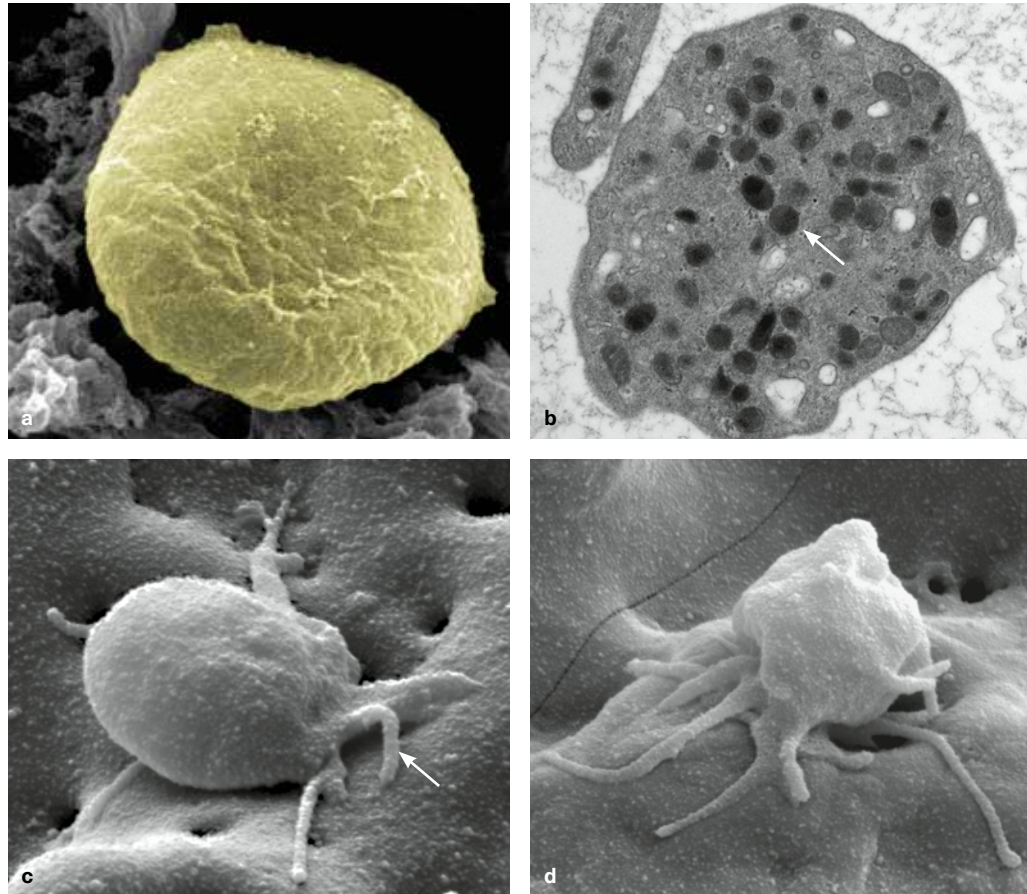
**FIG 1-1** Dental attachment apparatus. (a) Longitudinal section through the periodontal ligament (PL). B: alveolar bone; D: dentin; C: cementum. (b and c) Sharpey collagen fiber bundles (FB) attached to root cementum (C). (d) Gingiva (G) attached to enamel (E); JE: junctional epithelium. (e) Functionally oriented collagen fibers (red arrows) viewed in transmitted light and (f) viewed in polarized light (white arrows).

## Wound Healing Cascade and Bone Healing Mechanism

Both general wound healing and peri-implant wound healing of both soft and hard tissues are well-understood mechanisms.<sup>3-5</sup> Several reviews have been published that focus on dental peri-implant healing.<sup>6-8</sup> Placement of an implant into the alveolar bone is followed by a sequence of healing phases and bone formation, resulting in osseointegration. A temporal sequence of peri-implant wound healing is given in Fig 1-2. This sequence is based on a dog study, and the reader must consider that the healing in this model is five times faster than in humans.

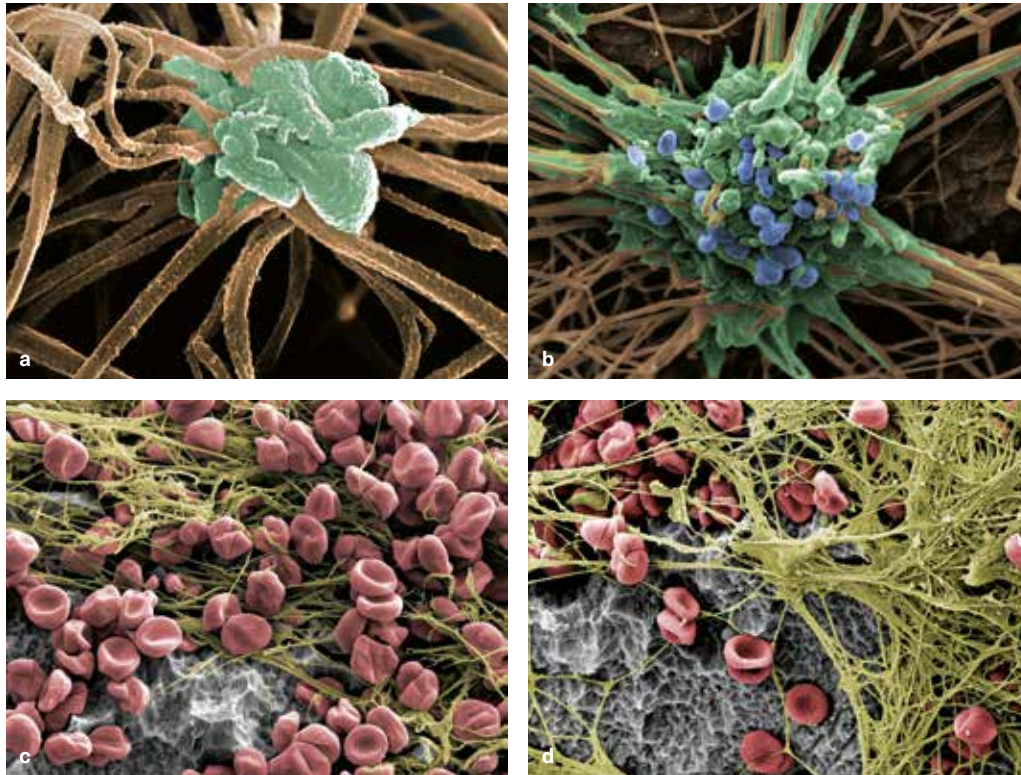
Hemostasis represents the first phase of peri-implant healing around implants. Hemostasis is begun by blood platelets, which are the first cells that interact with the implant surface. Inactive platelets have a discoid shape and are the smallest of the many types of cells in circulating blood, averaging only 2.0 to 5.0  $\mu\text{m}$  in diameter and 0.5  $\mu\text{m}$  in thickness. Sections in the equatorial plane reveal that platelets contain granules filled with growth factors and enzymes, such as platelet-derived growth factor (PDGF) and transforming growth factor  $\beta$  (TGF- $\beta$ ), together with vasoactive factors such as serotonin and histamine. These factors play a crucial role in regulating the following wound-healing cascade.<sup>9</sup> After leaving an injured blood vessel, the platelets are activated immediately by injured collagen fibers and tissues. Besides the latter, biomaterials placed in the body can activate platelets. It takes only 2 minutes to initiate the fibrin formation on titanium surfaces.<sup>10</sup>

**FIG 1-2** Platelet activation. (a) Scanning electron micrograph (SEM) of an inactive platelet. (b) SEM view of a section through an inactive platelet. Note the presence of numerous granules (arrow) containing growth factors and enzymes. (c) SEM of an initial stage of platelet activation. Note the outgrowth of pseudopodia (arrow). (d) Activated platelet.

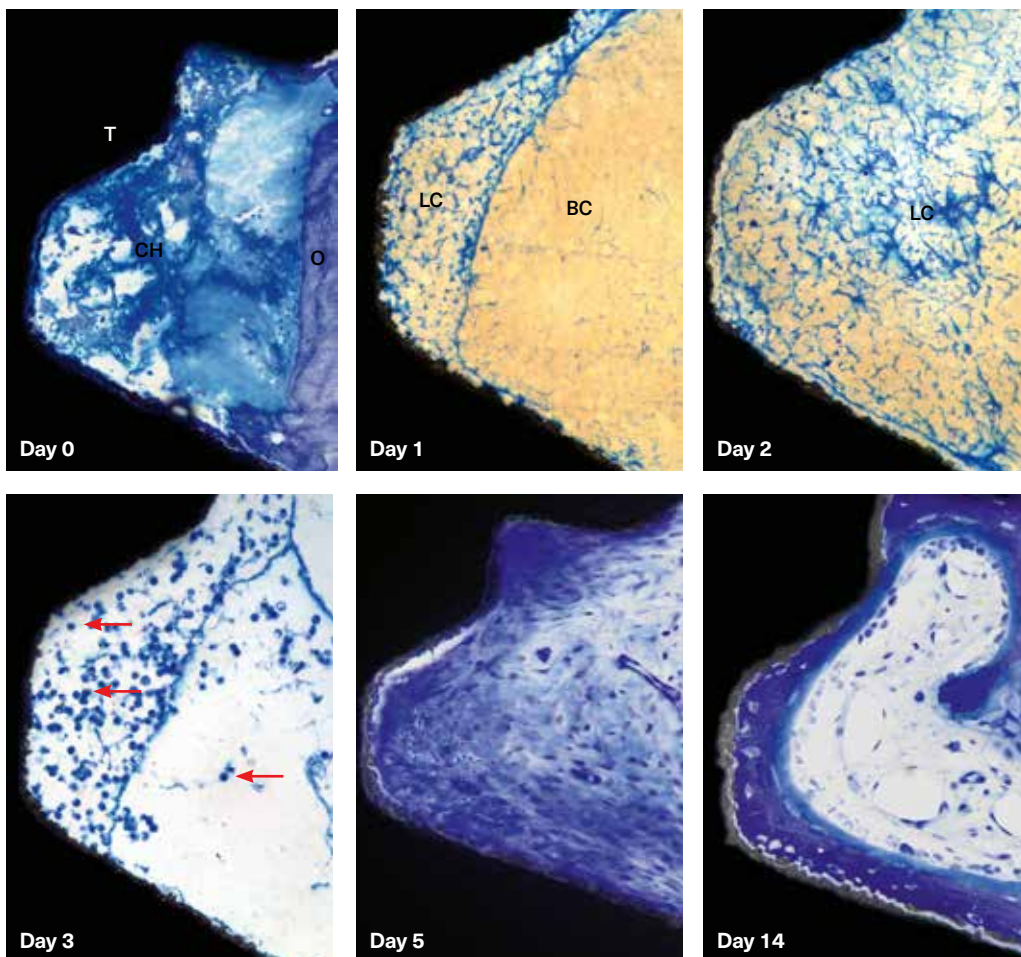


When activated, platelets change in shape to become more spherical, and pseudopods form on their surface (Fig 1-3). As a result, they assume a stellate shape with a considerably enlarged surface. Chemical reactions change the surface of the platelet to make it sticky. The platelets clump together to form aggregates. Such aggregates will plug small blood vessels in the periphery of the wound, and bleeding will be slowed and finally stopped. Clotting proteins form out of fibrinogen, long sticky strands called *fibrin*. Only 10 to 20 minutes after implant placement, a blood clot composed of blood cells, activated platelets, and fibrin strands is adherent to the implant surface. Simultaneously, the platelet envelope collapses, and the granules are released. These factors will regulate early wound healing by attracting the cells needed during the next phase of wound healing, the inflammatory phase.

Once bleeding is controlled, inflammatory cells are attracted and migrate to the wound area to promote the inflammatory phase (Fig 1-4). Initially, leukocytes are the most numerous cells, peaking at 48 hours following implant placement. The critical function of the leukocytes is the degradation of the fibrin clot as indicated by the *red arrows* in Fig 1-4d and clearance of invading bacteria and debris in the wound area. Macrophages rapidly follow neutrophils. Macrophages play multiple roles in wound healing. One of them is removing the leukocytes, thus paving the way for the resolution of the inflammation. They also attract stem cells and fibroblasts to the wound area and start angiogenesis. In this way, macrophages promote the transition to the now following proliferative phase.<sup>11</sup>



**FIG 1-3** Hemostasis. (a) Colored SEM of a platelet (green) entrapped in the fibrin mesh (brown). (b) Colored SEM showing the release of granules. (c and d) SEM of the blood coagulum attached to an SLActive implant surface.



**FIG 1-4** Temporal sequence of early wound healing in a dog model. Day 0: Border wall of the osteotomy (O) and bone debris between the threads (T). Day 1: A blood coagulum (BC), and partially and area of lysed coagulum (LC). Day 2: Advanced lysis of the coagulum. Day 3: Removal of the fibrin remnants removed by neutrophils (arrows). Day 5: Provisional matrix between the threads. Day 14: Initial bone formation by contact osteogenesis.

The proliferative phase (see Fig 1-4) is characterized by the replacement formation of granulation tissue, angiogenesis, collagen deposition, and wound contraction by myofibroblasts. In granulation tissue formation, fibroblast-like cells invade the wound and form a provisional extracellular matrix by secreting collagen and fibronectin. New capillaries are formed by vascular endothelial cells. They derive from endothelial cells of the original capillaries but also from the circulating endothelial progenitors.<sup>12</sup> Simultaneously, fibroblast-like mesenchymal cells differentiate into osteogenic cells and finally to osteoblasts. The latter will deposit a layer of collagen fibers, the so-called osteoid, which becomes mineralized, and by that, woven bone is formed. During this process, some osteoblasts will become entrapped in the osteoid layer and surrounded by the mineralized matrix and form the osteocytes in living bone.<sup>13</sup>

## The Event of Osseointegration

The surgical preparation of an osteotomy into native or regenerated bone and subsequent implant insertion will lead to a sequence of healing steps at the tissue interface that results mostly in the event classified as osseointegration.<sup>14</sup> We should notice that this implant-bone relationship is a very intimate one, but obviously it is an osseoadaptation rather than a real osseointegration. Nevertheless, the terminology of osseointegration has been established and has been used consistently for more than six decades.

One of the prerequisites for proper osseointegration is a stable implant anchorage and no relative movement (also described as *micromotion* or *micromovement*) to surrounding tissue (Fig 1-5). It is mandatory to understand the importance of implant stability over time and the sequence of bone healing, and likewise important to know that implant surfaces, implant designs, and surgical approaches influence the interactions between tissues, cells, and the dental implant.

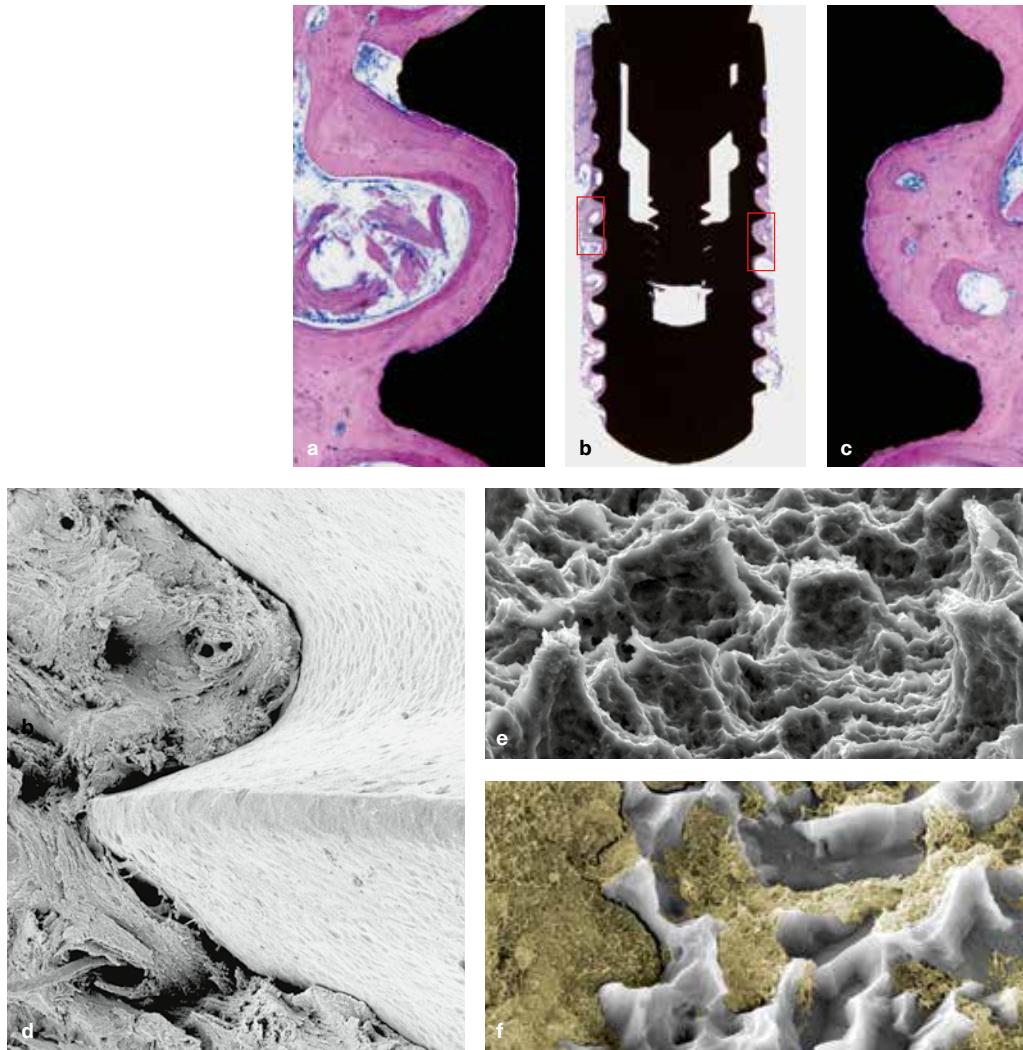
*Osseointegration* refers to a direct structural and functional connection between ordered, living bone and the surface of a load-carrying implant.<sup>15</sup> Therefore, an implant is considered as osseointegrated when there is no relative movement between the implant and the anchoring bone.

A direct bone-to-implant contact as observed histologically may be indicative of the lack of a local or systemic biologic response to that surface. It could be concluded that osseointegration is not the result of an advantageous biologic tissue response but rather the lack of a negative tissue response.<sup>16</sup> Hence, with a successful osseointegration, a beneficial foreign-body reaction has been established.<sup>17</sup>

## Different Patterns of Bone Healing Around Implants

Two completely different mechanisms of bone formation are present around dental implants: distance and contact osteogenesis.<sup>18</sup> In distance osteogenesis (Fig 1-6a), osteogenic cells, such as pericytes, become differentiated to osteoblasts that secrete the collagen-containing matrix of bone in the provisional matrix. Eventually, the matrix becomes mineralized by hydroxyapatite (HA) crystals also deposited by osteoblasts.

Bone formation by distance osteogenesis always starts away from the implant at the osteotomy wall and involves an ordinary sequence of bone wound healing as present in the

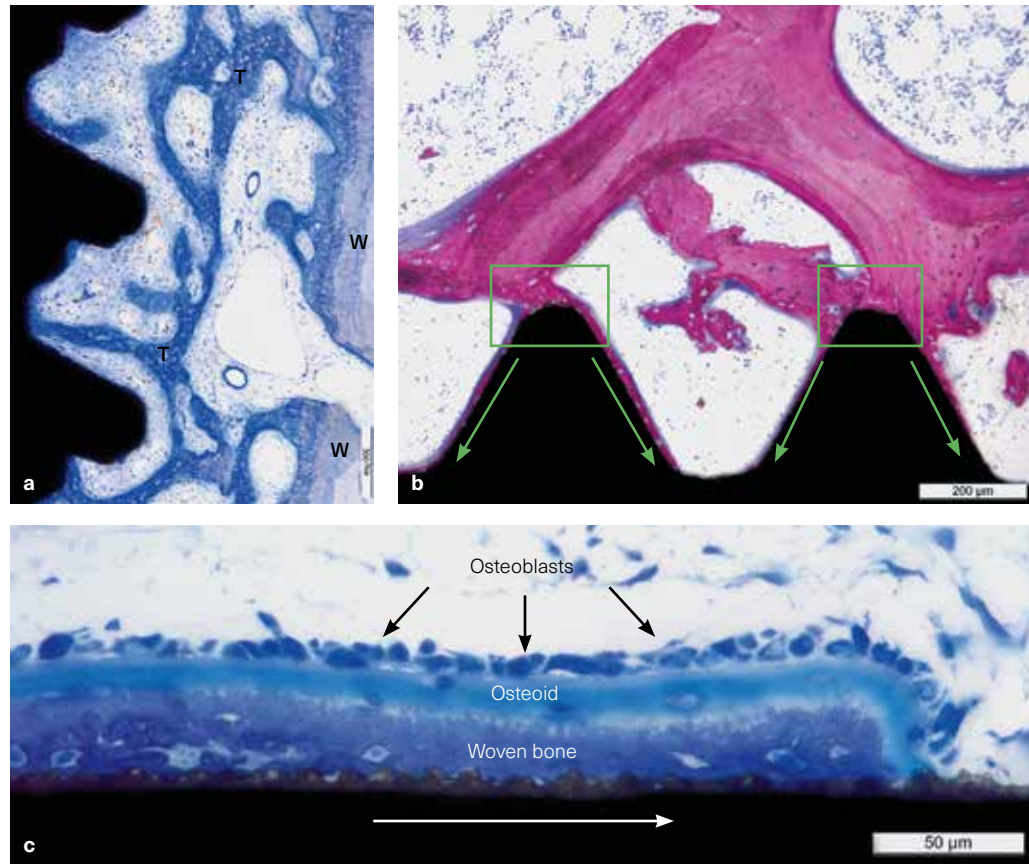


**FIG 1-5** Final osseointegration. (a to c) Human histology of a Straumann Bone Level implant trephined out following 3 years in place. (d) SEM illustrating the intimate adaption of bone to an implant surface. (e) SEM view of an SLActive surface. (f) SEM view of bone anchorage in an SLActive surface.

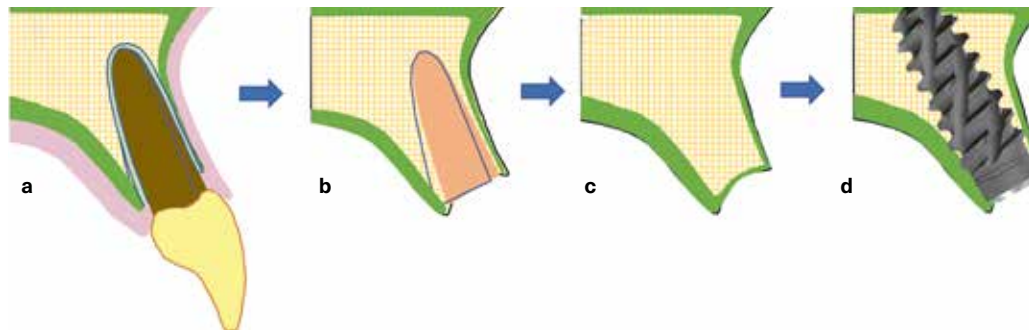
tooth extraction socket or the bone marrow ablation site (see Fig 1-6a). The front of newly formed bone advances by distance osteogenesis radially to the implant surface. Only when newly formed bone reaches the implant surface does the implant's secondary stability, a biologic stabilization of the implant, take place.

Bone formation by contact osteogenesis (Figs 1-6b and 1-6c) needs contact points between local bone with the implant surface, either between the implant thread tips with dense bone or between the implant surface with bone trabecula of soft bone. Outgoing from these contact points, bone formation occurs directly on the implant surface and is spreading around the implant.<sup>19</sup> In detail, osteoblasts deposit the collagen matrix directly on the surface, and the matrix becomes mineralized. By that, initially, a thin band of newly formed woven bone will be deposited directly on the surface, and along the surface, as continuously osteoblasts are streaming to the front of bone formation. Simultaneously, osteoblasts also line the layer of newly formed bone. By that, the thin band of newly formed immature woven bone gains in thickness by appositional bone growth.

**FIG 1-6** Bone healing mechanisms. (a) Woven bone formation by distance osteogenesis outgoing from the osteotomy wall (W). The first newly formed woven bone trabeculae (T) already crossed the gap to the implant and reached its surface. (b) Woven bone formation by contact osteogenesis outgoing from contact points between local trabecular bone (*green rectangles*) and extending as a thin band toward the valley between the threads. (c) Contact osteogenesis. Osteoblasts deposit a layer of collagen fibers, called *osteoid*, which becomes mineralized, and by that, woven bone is formed.



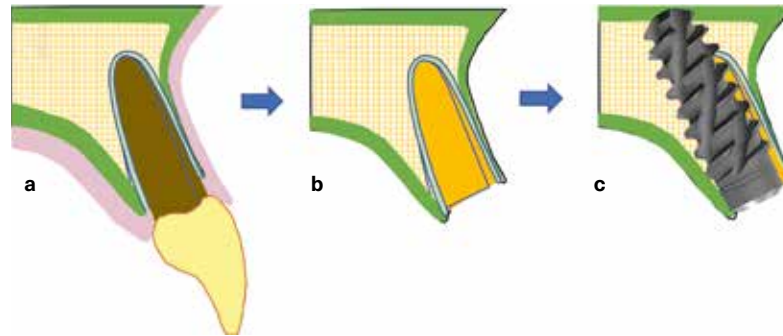
**FIG 1-7** Bone conditions in a healed site in the incisor region. (a) Anatomy before tooth removal. (b) Socket configuration after tooth removal. (c) Bone contours following healing with cortical zones in *green*. (d) Bone-to-implant relation after implant placement.



Woven bone, formed by both distance and contact osteogenesis, is gradually remodeled and replaced during a time period of 1 to 3 months by lamellar bone containing bone marrow adipocytes, blood vessels, and collagen fibers. In many respects, this process is similar to the bone healing occurring at a fracture site.

## Implants Placed in a Healed Site

When you are aiming for a stable implant anchorage during the early wound healing phase, there should be a well-balanced mix between (1) dense host bone areas (Fig 1-7; *green zone* with slower turnover) with primary implant contacts enabling high primary implant stability and (2) soft bone areas (with faster turnover) facilitating new bone formation.



**FIG 1-8** Bone conditions in an immediate site in the incisor region. (a) Anatomy before tooth removal. (b) Socket configuration after tooth removal. (c) Bone-to-implant relation after implant placement with cortical zones in *green*. Remaining socket (bone defect) in *orange*.

## Immediate Implant Placement

Aside from surgical skills, there are three factors that primarily influence successful immediate implant placement and subsequent osseointegration:

1. Local bone quality and quantity
2. Number of primary bone-to-implant contacts established with implant placement
3. Speed of new bone formation at the bone-implant interface

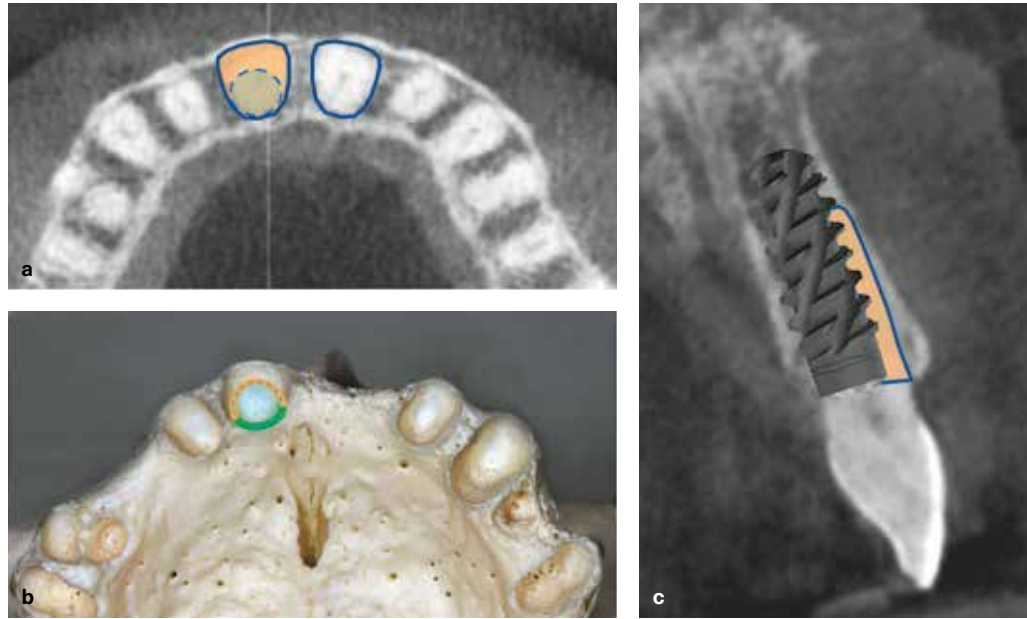
Implants placed immediately following tooth removal are usually inserted toward the palatal or lingual aspect of the alveolar socket in order to engage sufficient local bone and to improve initial implant anchorage. In addition, working length during surgical site preparation also intends to reach periapical host bone (if anatomically possible) so that the implant can achieve even more stabilization.

Referring to an intact socket configuration, this insertion strategy creates two distinct peri-implant environments: (1) on the palatal and apical aspect, the implant is in direct contact with host bone (*green zone* in Fig 1-8), while (2) on the buccal and to some extent on the interproximal aspect, a gap exists between implant and socket wall (*orange zone* in Fig 1-8).

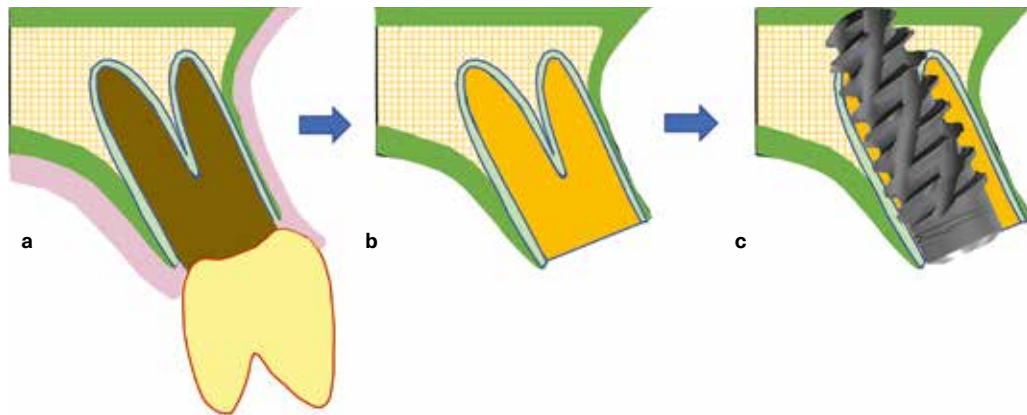
Hence, from a biologic point of view, it is important to understand different bone healing patterns when dealing with these unequal starting conditions (Figs 1-9 to 1-11). Moreover, it is important to understand that an implant surface is a nonvital counterpart that slows down revascularization in adjacent wound areas, but the surface may speed up bone healing with particular surface characteristics (eg, morphology, chemistry).

In general, when placing an implant into an extraction socket, a wider implant diameter would proportionally reduce remaining defect volume to the socket when compared with a narrower diameter. This simple geometric effect would favor selection of wider implants when dealing with extraction sockets. However, with regard to long-term peri-implant tissue stability, implant diameter selection has changed over the last few decades from rather wide diameter implants in the 1990s toward a more narrower neck diameter. Whereas in early years, a wider implant was intended to fill up more of the resulting socket defect, today, a slim neck portion leaves more space for hard and soft tissue formation and thereby allows for a reliable long-term marginal tissue maintenance.

**FIG 1-9** Socket morphology in relation to implant geometry in the incisor region. (a) Alveolar cross section (*orange*) in CBCT diagnostics. (b) Cross section illustrated on maxillary skull model. Exemplary implant will be stabilized on palatal area (*green*) with remaining buccal defect area (*orange*). (c) Sagittal view in CBCT with implant and remaining defect morphology (*orange*).



**FIG 1-10** Bone conditions in an immediate site in the premolar region. (a) Anatomy before tooth removal. (b) Socket configuration after tooth removal. (c) Bone-to-implant relation after implant placement with cortical zones in *green*. Remaining socket (bone defect) in *orange*.



**FIG 1-11** Bone conditions in an immediate site in the premolar region. (a) Socket configuration after tooth removal. (b) Bone-to-implant relation after implant placement with orientation to the palatal aspect. Remaining socket (bone defect) in buccal area.

