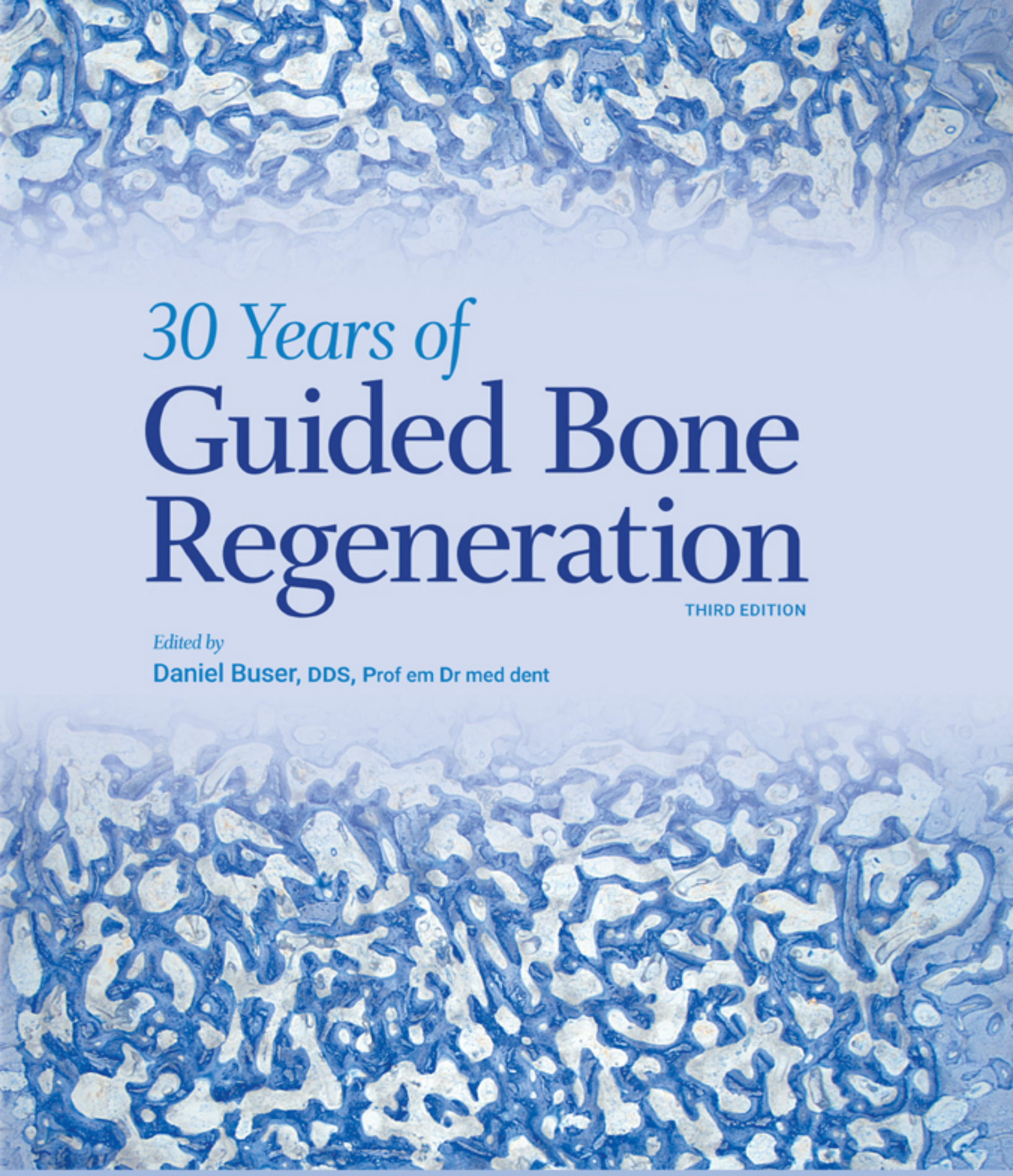

30 Years of Guided Bone Regeneration

THIRD EDITION

Edited by

Daniel Buser, DDS, Prof em Dr med dent

QUINTESSENCE PUBLISHING

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Third Edition

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Contents

Foreword

There have already been three decades of scientific documentation and successful clinical experience in the field of GBR—a truly impressive accomplishment! In this third edition of an already well-established textbook, authored and edited under the judicious leadership of Professor Danny Buser, a carefully selected international panel of experts has updated and shed light from all relevant angles on one of the most significant recent achievements of contemporary dental medicine. The text not only surveys 30 years of progress made; it also comprehensively defines the current state of the art in GBR and its tremendous impact, namely on implant dentistry. Clinical protocols aimed at reducing overall treatment complexity and time, as well as diminishing patient morbidity, have been developed and refined during recent years. In addition, based on the remarkable levels of reliability and predictability of GBR, numerous new avenues for clinical application have been opened.

In fact, the knowledge of which techniques and associated biomaterials are recommended today, linked to the indispensable robust scientific documentation, provide the clinician with the basis for target-oriented clinical decision making in view of the subsequent treatment. This includes the consideration of the practitioner's individual state of education and competence. Namely, the SAC concept—which objectively differentiates straightforward, advanced, and complex cases in relation to the difficulty level of a given clinical situation—is of particular importance and has been strongly promoted by the main author for many years.

The current third edition of a textbook that has twice already previously reached the status of a true standard of

reference has clearly outperformed its two predecessor issues. Beyond any doubt, oral surgeons, periodontists, prosthodontists, and general practitioners, as well as dental students, will find all the detailed information relevant to successful implementation of GBR in daily practice, ultimately to the benefit of countless patients.

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Dedication

This textbook is dedicated to Robert K. Schenk, Prof Dr med, who was Professor of Anatomy at the University of Bern, Switzerland. He was a world-renowned scientist in the field of bone physiology and bone healing. His instruction on the basics of bone healing was what allowed for the tremendous progress with GBR we made in the 1990s. Dr Schenk's chapter on the basics of bone healing in the first GBR book was a sensation at that time. He was able to illustrate his knowledge with fantastic histologic pictures produced by his lab. Besides his generosity to share his knowledge and wisdom, he was a true friend and mentor.

Robert K. Schenk, Prof Dr med (1923–2011)

Preface

The utilization of barrier membranes for the regeneration of bone defects has significantly changed implant dentistry in the past 30 years and clearly expanded the utilization of dental implants in patients. This principle is called guided bone regeneration (GBR or GBR technique), and was first described in 1959 by Hurley and colleagues for the treatment of experimental spinal fusion. In the 1960s, the research teams of Bassett and Boyne tested Millipore filters for the healing of cortical defects in long bones and osseous facial reconstruction, respectively. The authors utilized these filters to establish a suitable environment for osteogenesis by excluding fibrous connective tissue cells from bone defects. However, these studies did not lead to a clinical application of barrier membranes in patients at that time.

The clinical potential of barrier membranes was picked up in the early 1980s in the field of periodontology by the research team of Nyman and Karring, who systematically examined barrier membranes for periodontal regeneration. A few years later, barrier membranes were also tested for the regeneration of bone defects in experimental studies. The first three studies were done in Gothenburg by Dahlin and Nyman. Based on promising results in these studies, clinical testing of barrier membranes began in implant patients in the late 1980s. After 5 years of intensive experimental and clinical work, the first edition of the textbook *Guided Bone Regeneration in Implant Dentistry* was published in 1994, and it received a high interest by readers in the field of implant dentistry. In 2009, the second edition of the GBR book was published with an update of the

scientific knowledge and the surgical techniques being utilized after 20 years of a wide clinical application of GBR.

In the past 12 years, the scientific knowledge and the clinical experience have evolved further. During these years, many fine-tuning efforts have been made for the various surgical techniques to improve the regenerative outcomes, or to reduce the surgical invasiveness for patients. Therefore, it was time to make a new effort to once again analyze the scientific basis of the GBR technique and its clinical applications. The result is in your hands, the third edition of the GBR book, called *30 Years of Guided Bone Regeneration in Implant Dentistry*. This book is again written for the surgical clinician with an interest and experience in implant dentistry.

As an introduction to the topic of the book, chapter 1 discusses the development and fine-tuning phase of the GBR technique over the past 30 years. Chapter 2 covers the biologic basis of bone regeneration and presents a scientific update on bone formation and bone remodeling. The excellent histology utilizing nondecalcified sections is based on more than 30 years of experimental research, and it presents the details of bone regeneration in general and the details of bone formation in membrane-protected defects with bone grafts or bone substitutes in particular. Chapter 3 is completely new and describes the molecular and cellular characteristics of autogenous bone chips, and how they release various growth factors when put in a mixture of blood and physiologic and sterile saline. Chapter 4 is also completely new and describes the hard and soft tissue alterations following tooth extraction. Clinicians need to understand these biologic mechanisms for proper selection of the most suitable treatment option in postextraction implant placement. Chapter 5 is also new and systematically describes the surgical and anatomical factors influencing the regenerative outcome of GBR procedures,

including the interesting classifications of defect morphology.

In the clinical section of the book, chapters 6 to 14, clinical procedures associated with different indications of the GBR technique are presented in detail. Each chapter deals with specific indications and describes the criteria for patient selection, the step-by-step surgical procedure, and aspects of postoperative treatment. Emphasis is given to incision technique and flap design; the selection, handling, and placement of barrier membranes; the combination of membranes with autogenous bone grafts and low-substitution bone fillers; and aspects of wound closure. These chapters of the book reflect the immense progress and excellent documentation of GBR in the past 10 to 15 years, and its outstanding importance in daily practice of implant therapy.

Acknowledgments

As editor, I cordially thank all authors and coauthors for their great effort and time to realize this textbook. It has been very intensive work during a pandemic crisis, but a satisfying experience to collaborate with colleagues of such international reputation and high quality. Some of them are long-term personal friends, which makes the pleasure even greater. I also want to share that all authors, including myself, agreed to have the authors' royalties entirely paid into the Buser Implant Foundation, a foundation established in August 2019 right after my retirement as Professor and Chairman at the Department of Oral Surgery and Stomatology, University of Bern, after 20 years of service. The foundation's objectives are the promotion of education and research in the field of implant dentistry by providing personal stipends and junior investigator grants to young colleagues of our profession. The first Buser Foundation

Scholarship in Implant Dentistry has been awarded in spring 2021.

I also thank Bernadette Rawyler, who created all the beautiful digital artwork in my chapters. These illustrations have made it much easier to communicate the correct messages and necessary information from the authors to the reader.

Last but not least, I also cordially thank Bryn Grisham and Marieke Zaffron of Quintessence Publishing for their excellent collaboration to realize this book. The quality work and the quality printing of Quintessence was again superb and is highly appreciated. It reflects almost 30 years of close collaboration with Quintessence Publishing, both in Berlin and in Chicago. I thank Horst Wolfgang Haase, Christian W. Haase, as well as Alexander Ammann for this excellent collaboration over so many years, which was based on trust, respect, and friendship.

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1

The Development of Guided Bone Regeneration Over the Past 30 Years

Daniel Buser, DDS, Dr med dent

Modern implant dentistry based on the concept of osseointegration recently celebrated its 50th birthday.[1] The tremendous progress made in the rehabilitation of fully and partially edentulous patients is based on fundamental experimental studies performed by two research teams. One team was located in Sweden and headed by Prof P-I Brånemark from the University of Gothenburg; the other was located in Switzerland and headed by Prof André Schroeder from the University of Bern. In the late 1960s and 1970s, the two research groups independently published landmark papers describing the phenomenon of osseointegrated titanium implants.[2–4] An *osseointegrated implant* was characterized by direct apposition of living bone to the implant surface.[5–7]

In the early phase of this development, several prerequisites were identified for osseointegration to be achieved.[2,3] Some of these have been revised over the past 50 years; others are still considered important. In order to achieve osseointegration, the implant must be placed using a low-trauma surgical technique to avoid overheating the bone during preparation of a precise implant bed, and the implant must be inserted with sufficient primary stability.[5,8]

When these clinical guidelines are followed, successful osseointegration will predictably occur for nonsubmerged titanium implants (single-stage procedure) as well as for submerged titanium implants (two-stage procedure), as demonstrated in comparative experimental studies.[9,10]

When clinical testing of osseointegrated implants first began, the majority of treated patients were fully edentulous. Promising results were reported in retrospective studies.[11–13] Encouraged, clinicians increasingly began using osseointegrated implants in partially edentulous patients, and the first reports on this utilization were published in the late 1980s and early 1990s with promising short-term results by various groups.[14–18] As a consequence, single-tooth gaps and distal extension situations have become more and more common indications for implant therapy in daily practice. Today, these practices dominate in many clinical centers.[19–21]

One of the most important prerequisites for achieving and maintaining successful osseointegration is the presence of a sufficient volume of healthy bone at the recipient site. This includes not only sufficient bone height to allow the placement of an implant of adequate length, but also a ridge with sufficient crest width. Clinical studies in the 1980s and 1990s showed that osseointegrated implants lacking a buccal bone wall at the time of implant placement had an increased rate of soft tissue complications and/or a compromised long-term prognosis.[22,23] To avoid increased rates of implant complications and failures, these studies suggested that potential implant recipient sites with insufficient bone volume should either be considered local contraindications for implant placement or should be locally augmented with an appropriate surgical procedure to regenerate the local bone deficiency.

During these early decades, several attempts were made to develop new surgical techniques to augment local bone deficiencies in the alveolar ridge in order to overcome these

local contraindications for implant therapy. The proposed techniques included vertical ridge augmentation using autogenous block grafts from the iliac crest in extremely atrophic arches,[24,25] sinus floor elevation procedures in the maxilla,[26–28] the application of autogenous onlay grafts for lateral ridge augmentation,[29–31] or split-crest techniques such as alveolar extension plasty.[32–34]

During the same period, in addition to these new surgical techniques, the concept of guided bone regeneration (GBR) with barrier membranes was introduced. Based on case reports and short-term clinical studies, various authors reported first results with this membrane technique for the regeneration of localized bone defects in implant patients.[35–40]

This textbook will provide an update on the biologic basis of the GBR technique and its various clinical applications for implant patients. Clinical experience with GBR in daily practice now spans 30 years. These 30 years can be divided into a development phase and a phase of routine application with extensive efforts to fine-tune the surgical procedure (Fig 1-1). The focus was on improving the surgical technique, expanding the range of applications, improving the predictability for successful outcomes, and reducing morbidity and pain for the patients.

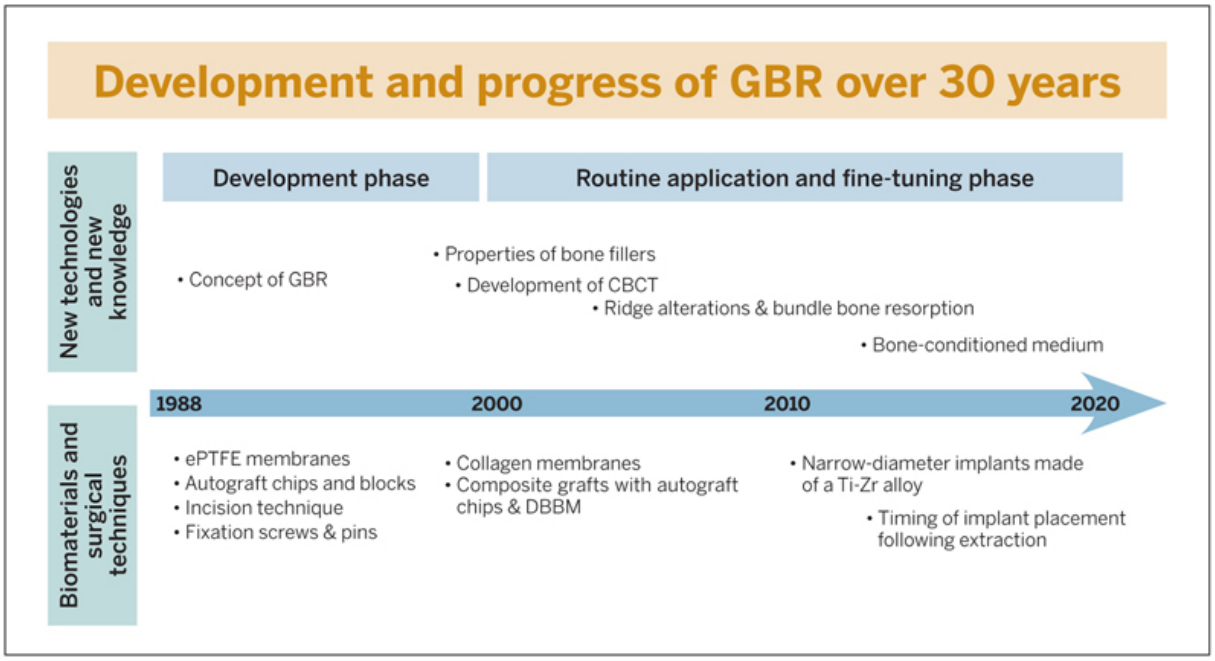


Fig 1-1 Development of GBR over 30 years since the late 1980s. ePTFE, expanded polytetrafluoroethylene; DBBM, deproteinized bovine bone mineral; Ti-Zr, titanium-zirconia

Development Phase of GBR

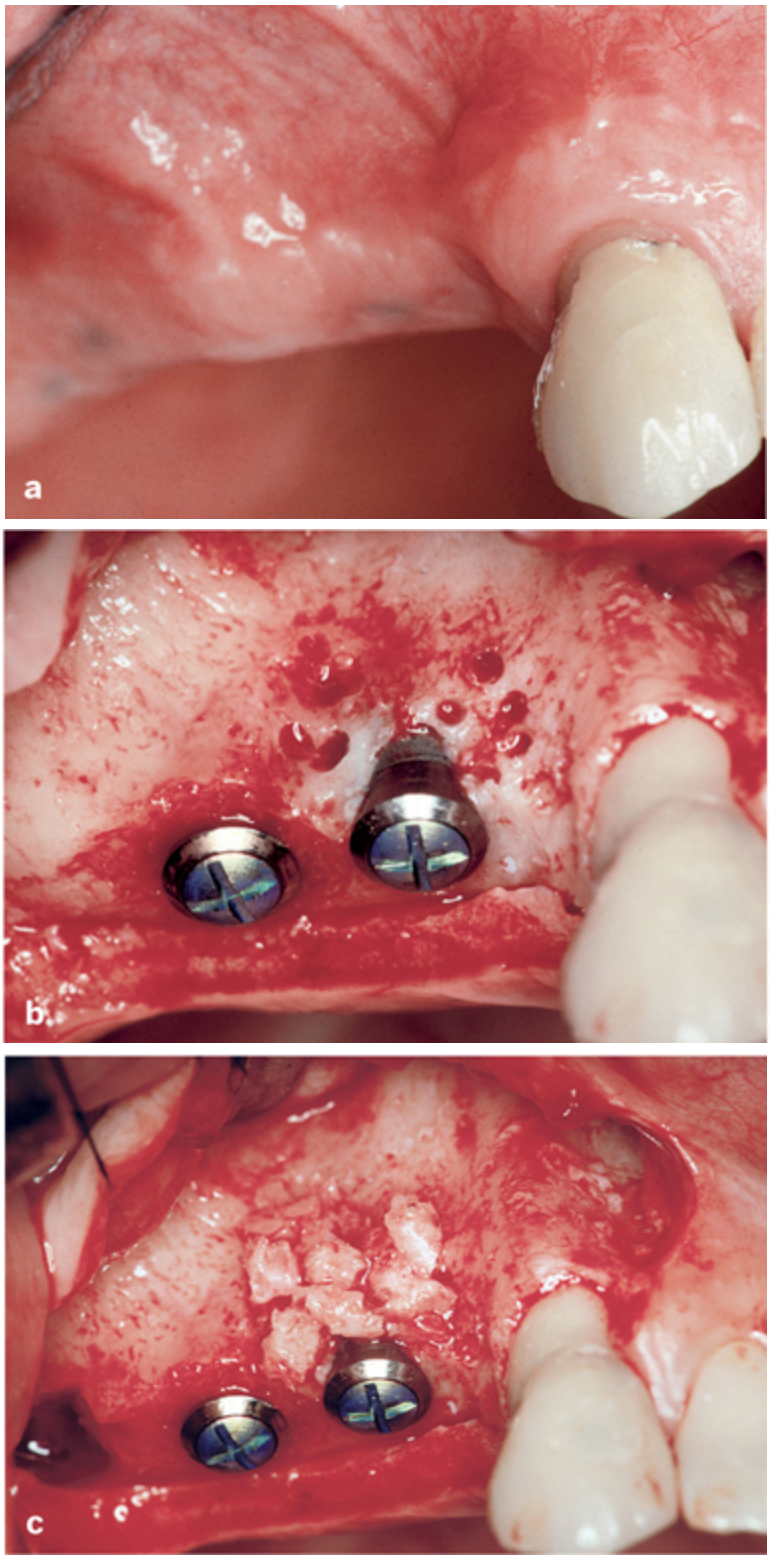
The use of barrier membranes for implant patients was certainly triggered by the clinical application of barrier membranes for periodontal regeneration, called *guided tissue regeneration* (GTR). GTR was first developed in the early 1980s by the group led by Nyman et al.[41,42] The initial studies were performed with Millipore filters, which had already been used in experimental studies in the late 1950s and 1960s for the regeneration of bone defects.[43–45] However, these studies had no impact on the development of new surgical techniques to regenerate localized defects in the jaws, since the potential of this membrane application was probably not recognized at that time.

The two papers by Nyman et al[41,42] in the field of GTR, both of which demonstrated successful treatment outcomes of GTR procedures, were received with great interest and led

to increased research activities in the mid to late 1980s.[46–49] These studies were already being performed with expanded polytetrafluoroethylene (ePTFE), which is a bioinert membrane and became the standard membrane for GTR and GBR procedures during the development phase of both techniques. The use of ePTFE membranes for bone regeneration was initiated in the mid 1980s by the group of Dahlin et al, who performed a series of preclinical studies.[50–52] These studies confirmed the concept that the application of an ePTFE membrane established a physical barrier that separated the tissues and cells that could potentially participate in the wound healing events inside the secluded space. The barrier membrane promoted the proliferation of angiogenic and osteogenic cells from the marrow space into the bone defect without interference by fibroblasts. These events were nicely demonstrated by Schenk et al[53] in a landmark experimental study in foxhounds. The current biologic understanding of wound healing events in membrane-protected bone defects is presented in detail in chapter 2 of this textbook.

The use of ePTFE membranes for GBR procedures started in the late 1980s. The main objective was to achieve regeneration in peri-implant bone defects in implant sites with local bone deficiencies. The GBR technique has been used with both simultaneous and staged approaches. Implant placement with simultaneous GBR was predominantly used for immediate implant placement in postextraction sites to regenerate peri-implant bone defects[35,36,38] or for implants in sites with crestal dehiscence defects.[40] The staged approach was used in clinical situations with healed ridges but an insufficient crest width. The membrane technique was used to enlarge the crest width with a first surgery, and implant placement took place after 6 to 9 months of healing in a second surgical procedure.[37]

Early on, several complications were observed with both approaches, and modifications of the surgical techniques were proposed to improve the predictability of successful treatment outcomes. One frequent complication was the collapse of the ePTFE membranes, which reduced the volume of the regenerated tissue underneath the membrane. In addition, some of the regenerated sites demonstrated insufficient bone formation and the formation of a periosteum-like tissue underneath the membrane.[37,40] Therefore, bone fillers such as autografts or allografts were recommended by various groups, primarily to support the membrane and reduce the risk of membrane collapse.[54–56] The combination of ePTFE membranes and autogenous bone grafts provided good clinical outcomes for both approaches. Some of these patients are still being followed and documented up to 25 years after surgery (Figs 1-2 to 1-4).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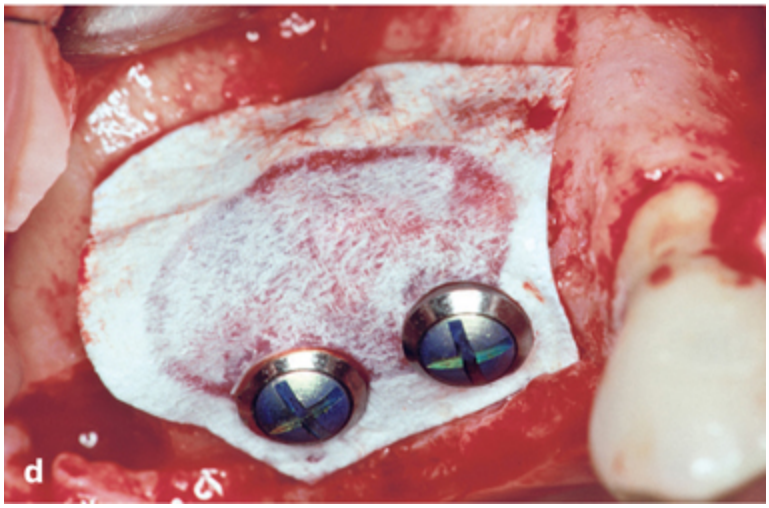
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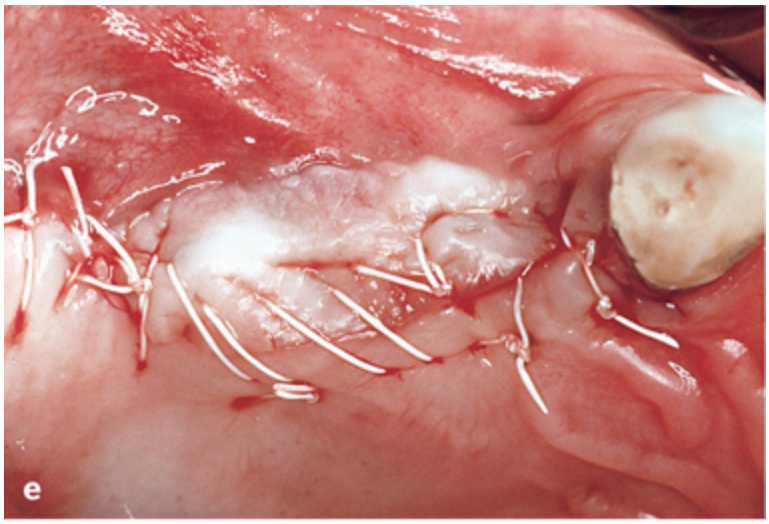
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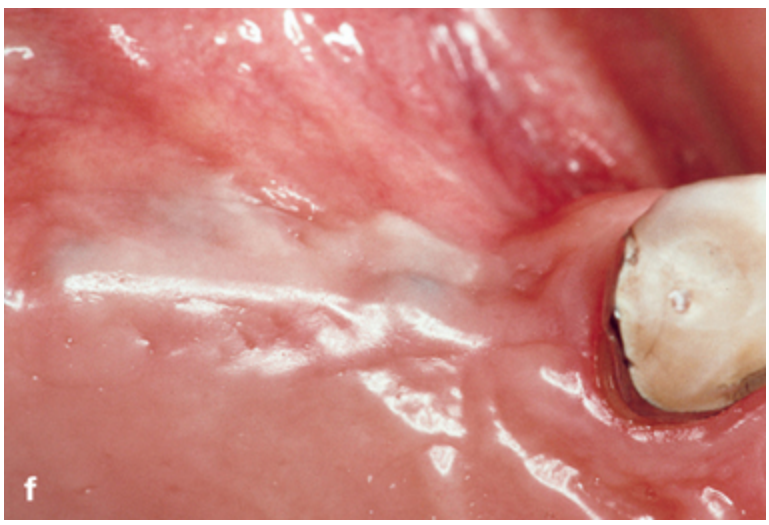
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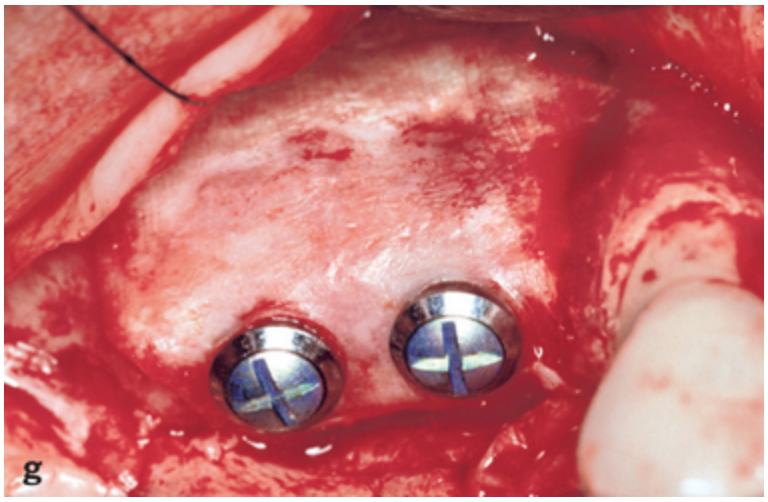
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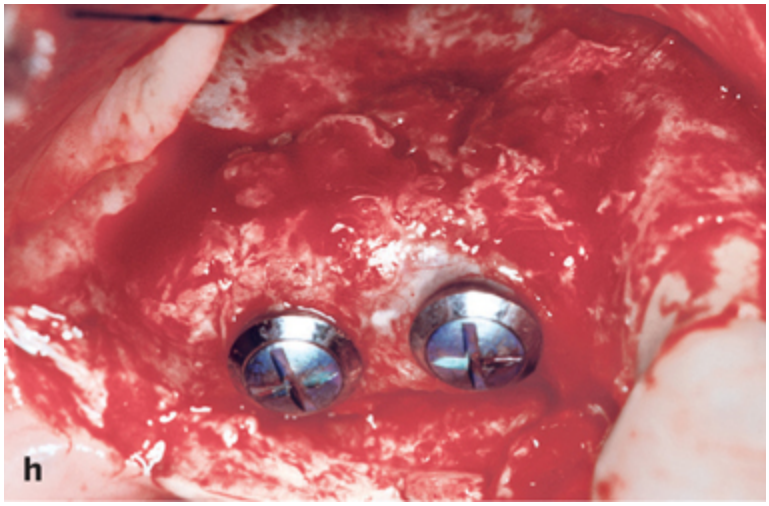
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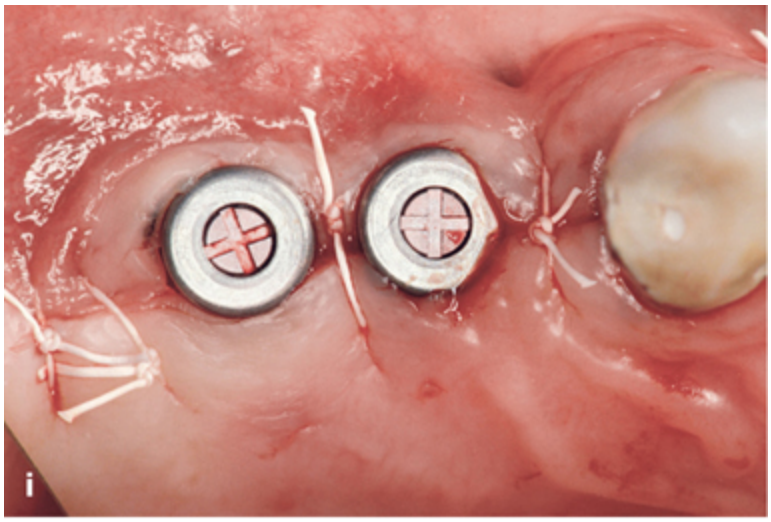
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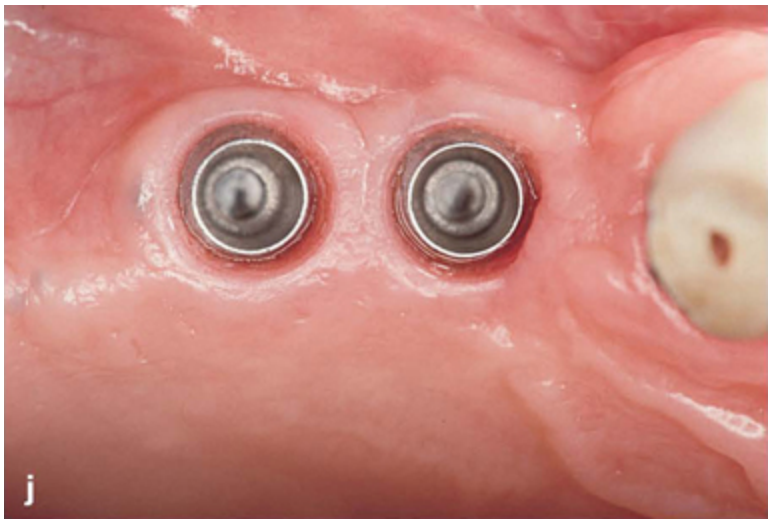
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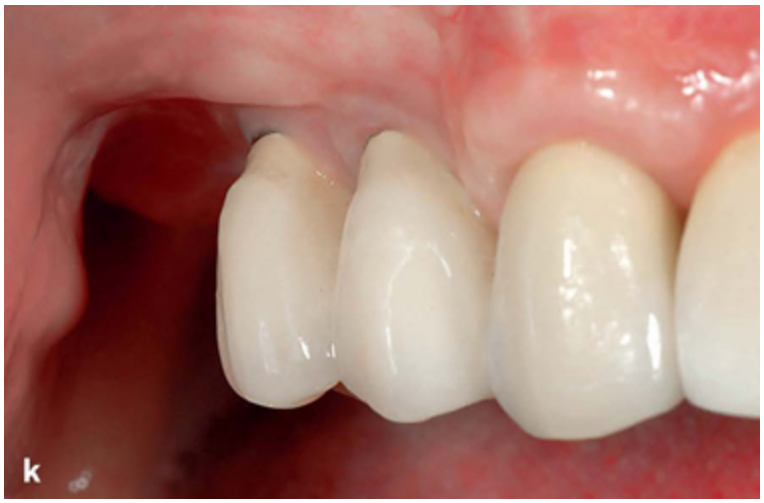
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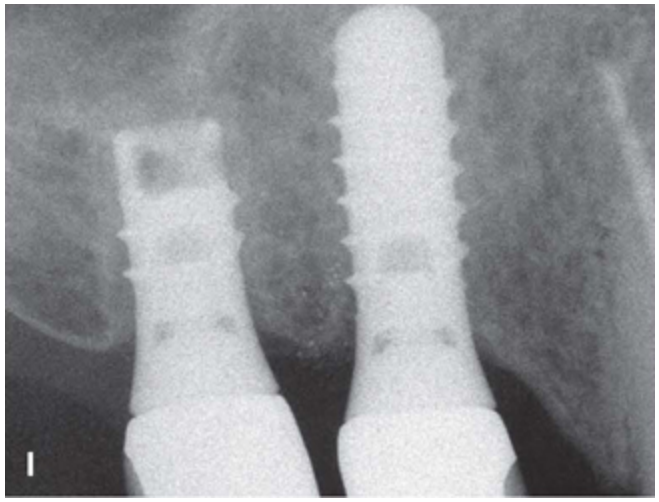
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