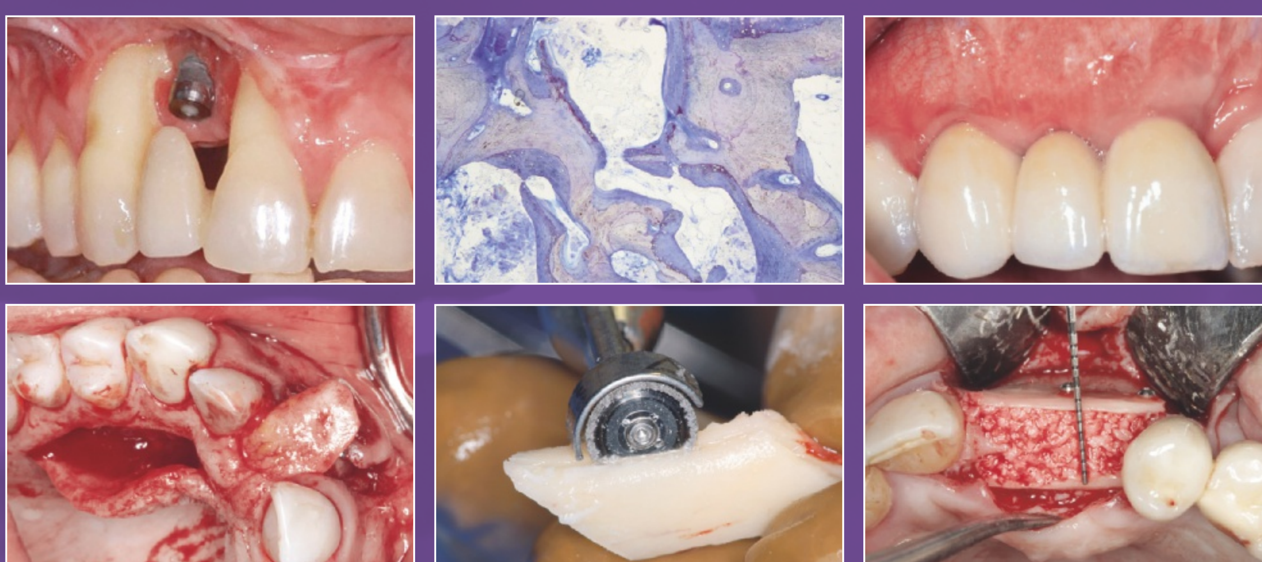
Fouad Khoury

Bone and Soft Tissue Augmentation in Implantology



With contributions from:
R. Gruber, Th. Hanser, Ph. Keeve, Ch. Khoury, J. Neugebauer, J. E. Zöller

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QUINTESSENCE PUBLISHING

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

A CIP record for this book is available from the British Library.
ISBN: 978-1-78698-104-2

QUINTESSENCE PUBLISHING
DEUTSCHLAND

Quintessenz Verlags-GmbH
Ifenpfad 2–4
12107 Berlin
Germany
www.quintessence-publishing.com

Quintessence Publishing Co Ltd
Grafton Road, New Malden
Surrey KT3 3AB
United Kingdom
www.quintessence-publishing.com

Editing: Avril du Plessis,
Quintessenz Verlags-GmbH, Berlin, Germany
Layout and Production:
Quintessenz Verlags-GmbH, Berlin, Germany

Printed and bound in Croatia by GZH

Foreword

The replacement of failed and missing teeth with dental implants is a common and well-accepted treatment modality. The success and long-term stability of dental implants is directly related to the quantity and quality of the supporting bone and surrounding soft tissue. When there is a lack of adequate bone volume for implant placement, a variety of bone augmentation procedures and materials have been proposed to develop the site. Although no single technique or biomaterial is optimal for every clinical situation, autogenous bone continues to be considered the gold standard of graft materials, and this text exemplifies this mantra.

Prof. Dr. Fouad Khoury is a world-renowned authority in the fields of oral surgery and dental implantology. He is a unique blend of gifted clinician and inspiring teacher. Prof. Khoury is Chairman and Director of the Privatklinik Schloss Schellenstein in Olsberg, Germany, and Professor in the Department of Oral and Maxillofacial Surgery at the University of Muenster.

Prof. Khoury is a skilled and exceptional surgeon who has dedicated his career to developing innovative techniques using autogenous bone for augmentation of the deficient ridge. His knowledge of bone biology spurred the development of the split cortical bone block protocol, often referred to as the ‘Khoury bone plate’ technique. This novel approach has been well proven as a very predictable method for the three-dimensional reconstruction of the maxilla and mandible. Prof. Khoury’s perspective on the importance of autogenous bone led to his development of other bone grafting procedures such as the bone core technique and the bony lid approach. His clinical philosophy has also stressed that successful bone augmentation requires impeccable soft tissue management.

This outstanding new book presents techniques for more routine treatment as well as some of the most challenging cases a clinician might encounter.

Prof. Khoury has assembled a team of respected academicians and expert clinicians to complete the text. A comprehensive understanding of bone biology is fundamental to developing a rationale for clinical decisions. Prof. Reinhard Gruber has done a wonderful job laying the foundation by explaining the biology of bone regeneration and the unique characteristics of autogenous bone. The book continues with clinical topics written by Dr. Thomas Hanser, Dr. Philip Keeve, Prof. Charles Khoury, Prof. Joerg Neugebauer, and Prof. Joachim Zoeller, including diagnosis and treatment planning, soft tissue management, autogenous bone harvesting, complex implant-supported rehabilitation, risk factors, and complications. The procedures are well documented in a clear and precise manner with high-quality photographs and extensive references. Many of the chapters address the interdisciplinary aspects of treatment, which is critical in managing more complex cases.

Prof. Khoury is one of the most generous and humble teachers I have encountered in dentistry. For decades he has not only thoughtfully treated patients but shared his vast knowledge and experience with students and clinicians around the world in classrooms and conferences.

He has also been devoted to documentation and long-term follow up of his cases to scientifically support his philosophy of treatment. This text is just one example of his lifetime commitment and dedication to teaching.

It is been a distinct honor to get to know Prof. Khoury over the years as an esteemed colleague and friend. We have shared a similar perspective on the importance of autologous tissue for predictable augmentation and long-term outcomes.

I would like to thank and congratulate Prof. Khoury and his co-authors for their contributions and this achievement. This superb text will serve as an invaluable reference for students and faculty as well as clinicians in the treatment of their implant patients. We are indeed fortunate that Prof. Khoury and his team have shared their expertise in this new third edition.

Craig M. Misch, DDS, MDS
May 2021

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Foreword of the first edition

Implant dentistry has evolved into a highly predictable clinical procedure in routine cases where the available bone is of adequate height and width. However, this condition is not met by all of our patients. Yet even patients with an inadequate bone supply to support implants now want – even expect – improved function and better esthetics.

This superb textbook presents treatment techniques both for routine cases and for some of the most difficult cases a dentist is likely to encounter. Dr. Fouad Khoury is one of the elite clinicians in oral and maxillofacial surgery. He is a true talent. He is supremely knowledgeable about every clinical aspect of transplantation, and his approach is impeccably scientific. He is a rare blend of superb clinician and gifted teacher.

For this book, Dr. Khoury was able to enlist the assistance of a wonderful group of teachers and academics. They have done an excellent job of sharing their knowledge and experience. They have described their treatment procedures in a clear and precise manner, including extensive references at the end of each chapter. In addition, many of the chapters address the interdisciplinary aspects of treatment – which deserves particular praise, since too many clinicians tend to be locked into their own specialist's approach to their patients' problems. We should remember to take a step back now and then and look at a therapy as a unified whole, not just at a sequence of treatment steps, important as they may be.

Dr. Khoury is one of the most innovative surgeons that I know. For decades, he has been at the forefront of new and creative ideas to help his patients. He has also been kind enough to share these innovations with the rest of the world. This book is just one example of his lifetime commitment to teaching.

He and his co-authors are to be congratulated for this outstanding effort. It is the work of a lifetime put down on paper for all of us to look at, think about, and – most importantly – use in the treatment of our patients. By sharing with us their thoughts about what works and what does not, Dr. Khoury and his team have truly advanced the cause of dentistry. We are grateful and thank them for all of their hard work.

Dennis P. Tarnow, DDS
2006

Professor and Chairman
Department of Periodontology and
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Preface

Oral rehabilitation supported by dental implants is today an important column of restorative dentistry. Since the first scientific-based publications in the early 1960s, many improvements in materials and techniques, especially in the augmentative field, have occurred. Increasing patient demand for perfect esthetic and functional rehabilitations, even in difficult anatomical situations, has led to the development of different methods that today allow for the fulfillment of almost all patient desires for a restoration that not only mimics the original anatomical situation, but gives an even better long-term result.

During the past 30 years, different techniques and materials have been recommended for the reconstruction of alveolar defects such as autogenous, allogenic or alloplastic bone grafts. Although the actual evolution of allogenic, xenogenic, and alloplastic materials, in combination with guided tissue regeneration techniques, is progressing from day to day, reproducibility and predictable long-term prognoses are still limited in comparison with autogenous bone, which is still the gold standard. The main problem of xenografts and allografts, especially in block form, is their poor ability for revascularization. This leads to several early as well as late complications and failures in the contaminated oral cavity.

Compared with other bone substitutes, the superiority of autogenous bone has been demonstrated on a biologic, immunologic, and even medicolegal basis. Due to graft morphology, autogenous bone has additional mechanical (cortical) and osteogenic (cancellous) properties, allowing early revascularization and functional remodeling, with low complication rates that are unequalled by any allograft, xenograft, or alloplastic material.

Through better understanding of the biologic processes of bone healing, including cell interaction, vascular supply, and bone remodeling, and in combination with some modifications of the surgical procedures, it is possible today to offer an implant-supported restoration to almost all patients. Alveolar bone is reconstructed in a safe and reproducible manner, even in cases of severe bone loss, so that, following prosthetic planning, a secure and correct implant insertion can be performed. Long-term results of such implants inserted in regenerated bone are providing similar success rates to implants inserted in non-grafted bone.

Different techniques and modifications for augmentation with intraorally harvested bone grafts have been developed over the past three decades with predictable long-term results. These techniques cover almost all situations, starting with a minimally invasive approach with locally harvested bone grafts up to the extremely complicated 3D reconstruction of the whole maxilla and/or mandible.

This is the third book I have edited on bone augmentation in oral implantology. The first one was published in 2006 in English, and the second came out in 2009/2010 in more than 10 languages. In this new edition on bone augmentation and soft tissue management in oral implantology, the focus is principally on the techniques that were developed and modified at our hospital over the past three decades and documented long term by our team.

The first chapter deals with the biology of bone healing especially after grafting procedures, and the second with descriptions of diagnostics and treatment planning. Soft tissue management in combination with bone augmentation is a very important topic with a great influence on the success of the grafting procedure. For this reason, the third chapter plays an exceptional role in the new edition, with important step-by-step details of the different techniques. The central topic and most important part of the book is, of course, the fourth chapter on safe bone harvesting and predictable grafting procedures for all kinds of bone deficiencies, starting with minimally invasive techniques for augmentation of small bony defects up to the extensive bone augmentation of severe 3D bone loss. All the techniques are demonstrated step by step with numerous clinical images, allowing a good and easy understanding of the described methods. Documented long-term results of the different techniques, up to 27 years postoperatively, are presented as they appear, with both radiographic and clinical images. The book contains a special chapter with the focus on our restorative concept for the treatment of patients with complex restorations in combination with extensive bone grafting procedures, which also explains the procedures step by step, from the temporary until the definitive restoration. The last chapter discusses the possible risks and complications, in combination with the grafting procedures explaining how to deal with such risks as well as the possibilities of how to prevent or to treat complications.

In this new edition I would like to present our clinical knowledge based on biologic principles as well as our long-term experience, for those interested in extending their clinical skills and scientific background in order to offer their patients the best possible treatment in terms of bone and soft tissue augmentation.

Acknowledgments

Firstly, thank you to all my contributors for their excellent cooperation and the high quality of their work. In addition, I would like to thank all my alumni, not only for their help in the treatment of complex cases but also in the precise documentation of the long-term results, including superb-quality clinical images. In particular, I would like to single out my co-worker, Dr. Thomas Hanser, for his friendship and unwavering loyalty. Over the past 26 years I have had about 38 postgraduate students and residents from different countries following our oral surgery program. These alumni as well as the actual co-workers and residents are: Dr. Friedrich Pape (head of the Restorative Department in Olsberg and responsible for most of the prosthetically treated cases presented in this book), Dr. Frank Spiegelberg, PD Dr. Arndt Happe, Dr. Alessandro Ponte (Turin, Italy & Lugano, Switzerland), Dr. Klaus Engelke, Dr. Stefan Bihl, Dr. Frank Berger, Dr. Jochen Tunkel, Dr. Luca de Stavola (Padova, Italy), Dr. Pierre Keller (Strasbourg, France), Dr. Herman Hidajat, Dr. Jenny Schmidt, Dr Şerif Küçük, Dr. Frank Zastrow, Dr. Joel Nettey-Marbel, Dr. Ayoub Alsifawo (Libya), Dr. Alexander Friedberg, Dr. Ingmar Braun, Dr. Stefano Trasarti (Teramo, Italy), Dr. Romain Doliveux (Lyon, France), Dr. Marco Vuko Tokic (Croatia), Thuy-Duong Do-Quang (Netherlands), Dr. Jan Jansohn, Dr. David Wiss (Vienna, Austria), Dr. Michael Berthold, Dr. Elisabeth Schmidtmayer, Dr. Philip Keeve, Dr. Valentin Loriod (Besançon, France), Dr. Erik Faragó (Budapest, Hungry), Dr. Christopher Schmid, Dr. Andrea Savo (Rome, Italy), Dr. Oliver Dresbach, Dr. Kathrin Spindler, Dr. Alexander Zastera, Dr. Sarah Römer, and Dr. Jan Wildenhof. Special thanks to my previous co-workers, Dr. Carsten Becker, for his help with the digital transformation of analog figures as well as for the excellent illustrations of some surgical techniques (see Chapter 3), and Dr. Tobias Terpelle, for his tremendous support for the chapter on restorative

procedures. In addition, I would like to thank the whole team of the Privatklinik Schloss Schellenstein in Olsberg for their help and loyalty during the past three decades.

Thanks also to the further Director of the Department of Cranio-Maxillofacial Surgery, University Hospital Münster, Prof. Dr. mult. Ulrich Joos, as well as to the actual Director, Prof. Dr. Dr. Johannes Kleinheinz, for their scientific support.

My sincere thanks go to the entire team at Quintessence Publishing, especially Dr. Horst W. Haase, Mr. Christian Haase, Mr. Johannes Wolters, and Mrs. Anita Hattenbach, for their support and patience over the years. Many thanks also to Mrs. Avril du Plessis for the excellent correction and editing as well as to Mrs. Ina Steinbrück for the perfect layout.

Finally, the most important thanks are for my wife, Michaela, and my children, Chantal, Elias, and Chérine, for their love, great support, and endless understanding.

Fouad Khoury
Olsberg, Easter 2021

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3

Soft tissue management and bone augmentation in implantology

Soft tissue management during augmentation, implantation, and second-stage surgery

3.1 Introduction

In addition to purely functional rehabilitation, the esthetic quality of implant treatments is becoming increasingly important in modern implantology. Above all, patients consider the appearance of peri-implant soft tissue and prosthetic superstructures to be decisive.[181]

The care and preservation of existing soft and hard tissue is, of course, essential for esthetically appealing implantology for prosthetic purposes. In many cases where tissue cannot be preserved, functional and esthetic results are not possible without bone augmentation in combination with corresponding soft tissue management. A preoperative esthetic analysis is recommended in almost all cases to ensure that the implant is positioned anatomically correctly and is presented in an optimal manner relative to the adjacent teeth and soft tissue. Soft tissue management is therefore decisive in all surgical interventions for the overall result of augmentative treatment.

According to Rosenquist,[149] there are four factors that fundamentally determine the functional and esthetic appearance of soft tissue: 1) the width and position of the attached keratinized gingiva; 2) the buccal volume and contour of the alveolar process; 3) the height and profile of the gingival margin; and 4) the size and appearance of the interdental and interimplant papillae. However, esthetic results are often poorly documented in the literature and are rarely taken into account as a criterion of treatment success.[16] Notwithstanding, the adequate width of the attached and/or keratinized mucosa was (and is) regularly discussed in the clinical literature. A systematic review found that the amount of plaque accumulation, mucosal inflammation, recessions, and loss of attachment were more expressed to a statistically significant extent around implants where the width of keratinized mucosa was inadequate.[115,147] It has to be noted, however, that parameters such as bleeding on probing (BoP), probing depth, and radiographic bone loss may be worse if the keratinized mucosa is missing.[115] In a study by Keeve and Khoury[94] on a sample of 77 patients with altogether 105 implants over an average observation period of 8 years, a statistically less significant degree of plaque accumulation, recessions, and mucosal inflammation around implants with at least 2 mm of attached mucosa were observed.[94] Due to the structural anatomical differences between teeth and implants, which mostly consist of missing supracrestal fibers attaching to the root in the case of titanium or ceramic surfaces, compromised transmucosal attachment can be expected around implants already after exposure.[158] The best possible fixation of the mucosa surrounding implants can, at the very least, ensure better daily plaque control and reduce the related inflammatory processes.[178] The keratinization of the tissue in visible areas is indispensable for esthetic reasons (e.g. with a view to the formation of recessions), and is essential for the functional and esthetic success of an implant. It is certainly recommended to create keratinized, or at least attached, mucosa of an adequate width during implantation or exposure surgery.

The other important aspect of soft tissue management is the thickness of the peri-implant mucosa. Scientific studies have proven that one should aim for a minimum height of at least 2 mm.[117] A systematic review confirmed that thicker peri-implant soft tissue layers (> 2 to 3 mm) result in significantly less bone loss around implants.[171,178] It is therefore reasonable to prepare not only the width but also the thickness of the attached soft tissue cuff – particularly in esthetic areas – in a manner that enables optimal long-term success rates.

The size and form of the papillae adjacent to implants are determined by anatomical, surgical, and restorative factors. To minimize interimplant bone resorption after prosthetic treatment and prevent a significantly greater degree of bone loss, the distance between two implants should be no less than 3 mm, and that between an implant and a natural tooth no less than 1.5 mm.[65,176]

Interdental papillae are present in 98% of cases if the distance between the *Limbus alveolaris* and the approximal contact point of the prosthesis is less than 5 mm. If the distance is increased to 6 to 7 mm, the stability of the papilla is reduced, and exists in 56% and 27% of cases, respectively.[177]

The formation of papillae between adjacent implants is more problematic. The size of inter-implant papillae can only be predicted up to a distance of 3 mm between the alveolar bone and the contact point.[53] A papilla can probably form between an implant and a tooth at a corresponding vertical distance of 4.5 mm.[152,175]

In the case of pontic solutions, however, papilla height is predictable at a distance of 5.5 to 6 mm between the alveolar bone and the contact point.[152] These anatomical indices are considered indispensable, but they do not guarantee the formation of a papilla after surgical procedures.[190]

Soft tissue management is a very important factor in bone augmentation for the following reasons: 1) for the primary safety of the procedure; 2) for the esthetic result in the anterior area, since bony defects are also combined with poor soft tissue quality; 3) for function, reducing the muscle activity around the grafted bone and the implants; and 4) for the long-term stability of the definitive results. Primary, tension-free wound closure is indispensable in augmentation measures – bone grafts or guided tissue regeneration – and is a decisive prerequisite for the bacteria-free healing of the graft as well as for an eventually successful treatment. Gingiva quantity and quality are important factors, not only for good primary healing of the grafted bone to reduce the risk of tissue necrosis and graft exposure, but also for the long-term stability of the grafted area. In many cases, it is important to improve the quality and quantity of the soft tissue before a bone grafting procedure.

A periosteal incision in line with the Rehrmann technique increases the elasticity of the flap, so that its edges can be closed with external horizontal mattress sutures or simple interrupted sutures without tension in a two-layered procedure. The disadvantage of this procedure is the coronal adaptation of the mucogingival junction during augmentation and implantation, which has to be subsequently corrected for esthetic and functional reasons by a second or third implant-exposure procedure.[97] Soft tissue management therefore plays a decisive role in restoring functional and esthetic soft tissue harmony.

3.1.1 Anatomy and vascularization of the soft tissue

An understanding of the macro- and micro-anatomical structure of periodontal and peri-implant tissue is a prerequisite for understanding the principles of plastic soft tissue surgery and exposure techniques. The different anatomical aspects are briefly presented and explained in the following sub-sections.

3.1.1.1 Gingiva

The gingiva consists of gingival connective tissue and overlying epithelium. With the exception of interdental cols, its surface is keratinized. The gingiva is located between the gingival margin and the mucogingival junction. The thickness of this layer is between 1 and 9 mm,[23] with an average thickness of about 1 mm.[52] It is thickest in the maxillary anterior region and thinnest in the mandibular lingual area.[5] The width of the gingiva is significantly influenced by the position of the teeth,[151] and changes with jaw growth.[9] The orthodontic movement of the teeth in a bucco-oral direction can therefore correspondingly influence the gingival width.[10]

The keratinized, stratified, squamous epithelium reaches up to the cementoenamel junction and goes over into the sulcus epithelium to a physiologic depth of about 0.5 mm in the direction of the periodontal space. The oral sulcus epithelium is histologically similar to the gingival epithelium but is less parakeratinized. It is adjoined at the bottom of the sulcus by the marginal epithelium, with an epithelial attachment of 1 to 2 mm in width on the surface of the enamel. The marginal epithelium is stratified and non-keratinized and has a very high turnover rate.[156] It is completely regenerated every 4 to 6 days by proliferating cell layers. If the marginal epithelia of adjacent teeth or implants adjoin, a non-keratinized col of a papilla is formed.[81] This takes on a saddle-like shape in the interdental area and is dependent on the shape and dimensions of the approximal contact point. The function of the marginal epithelium is to protect the underlying bone from penetrating micro-organisms. This contact and reaction zone ensures that the organism performs immunologic engagement with chemotaxis and humoral defense away from the bones.

This attached gingiva reaching up to the mucogingival junction does not shift relative to the alveolar process, and the connective tissue matrix consists of collagen fibers to about 60%. It forms the supra-alveolar and supracrestal fiber apparatus of the tooth or implant. The collagen fibers are attached to the teeth in three-dimensional (3D) structures. They have a stabilizing function as regards the position of the teeth, and act as a functional unit of the periodontium in the root cementum and the alveolar bone.[66]

The keratinization of the gingival epithelium does not result from functional wear but is rather determined by genetic factors in the underlying connective tissue.[91,92]

3.1.1.2 Peri-implant mucosa

The size, shape, and anatomy of the peri-implant soft tissue depends on wound healing determined by the position of the implant and by the implant system and exposure techniques used. It is comparable to the clinical characteristics of soft tissue around natural teeth.[18,112,155]

It has to be taken into account that instead of a periodontal ligament with physiologic mobility in relation to the anchorage, the implant has an osseointegrative connection with the alveolar bone. As a result, the peri-implant connective tissue fibers around the abutment or the surface of the implant are arranged in a parallel position in the supracrestal area, as opposed to being anchored to the dental root cementum.[1,2,17,18] Peri-implant connective tissue also has a higher ratio of collagen fibers and a lower ratio of fibroblasts, and as such is very similar to scar tissue in histomorphologic terms.[124,157]

While the vascular supply of the gingiva is secured from the three anastomosing areas of the interdental septa, the periodontal ligament, and the oral mucosa, peri-implant connective tissue shows a relatively low level of vascularization. As a result of osseointegration, the vessels from the periodontal ligament no longer exist, which means that the vascular supply of the peri-implant mucosa is almost exclusively ensured through supraperiosteal vessels and a small number of vessels emerging from the bone.[19] External bone surfaces are covered by a thin, inelastic layer of connective tissue that is rich in collagen – the so-called ‘periosteum.’ In addition to osteoblasts, osteoclasts, and the corresponding precursor cells, the periosteum also contains a large number of blood vessels and nerves, which are of particular significance for the regeneration of the freshly augmented bone, and may only be separated during exposure measures above the implant cover screws with the greatest possible care as regards the insertion of the gingiva former.

In particular, during surgical soft tissue management around implants, the scarred histomorphometry of the implant, the lack of anchored fibers, and the comparatively poor vascularization of peri-implant mucosa should in consequence be taken into account. Based on these differences, a reduced resistance to mechanical and microbiologic impacts as well as a compromised healing potential after surgical interventions can be expected due to the poorer vascular supply.[116]

3.1.1.3 Biologic width

The special structure of the gingival tissue around teeth and implants is a unique anatomical situation, where epithelial integrity is interrupted. This involves the formation of a combination of epithelial attachment against microbiological impacts and a connective tissue attachment against mechanical impacts, which is referred to as biologic width.[84]

Around teeth, the biologic width has a vertical dimension of 2.04 mm, of which an average of 1.07 mm consists of connective tissue attachment and 0.97 mm of epithelial attachment.[66] Following exposure, a biologic width also forms around implants. The connective tissue attachment around implants is very constant compared with that of teeth, and has a width of about 1 mm, while the epithelial attachment – also called the long marginal epithelium – is significantly wider.[157] The long marginal epithelium forms a connection to the implant or the abutment surface through hemidesmosomes and internal basal lamina.

Animal experiments have shown that, independent of closed or open healing, a small degree of vertical bone loss can be expected around implants, at an average of 1.1 to 1.3 mm apical to the implant–abutment junction.[54-56] A coronal plaque-related and connection-related inflammatory infiltrate was discovered in the microgap between the abutment and the implant. Despite the topographic proximity of the crestal bone, a physiologic band of connective tissue has always been found. This band shields the bone from the 3D inflammatory infiltrate.[54,55] However, vertical bone loss is still to be expected, in particular in the case of two-part implant systems. It reaches to about 2 mm apical to the junction,[75-77] whereas the material of the abutment also has an influence on the transmucosal soft tissue.[158]

Independent of the design of implants, it has therefore been recommended that peri-implant soft tissue should have a thickness of at least 2 to 3 mm following exposure measures, in the interest of protective immune reactions. Also, a response of the organism can be expected in cases of increased peri-implant bone loss.[30,39]

The goal of placing gingiva formers or abutments during exposure surgery is to change the horizontal dimension of biologic width in line with the platform-switching principle, and thereby ensure the preservation of the peri-implant bone tissue.[36,110] Bone preservation should be further enhanced by replacing gingiva formers and abutments as infrequently as possible, with the least possible trauma to transmucosal soft tissue.[1] Biologic width should therefore always be taken into consideration, also in relation to implants. Without hard tissue support, damage to the biologic width would become visible in the long run and would result in undesirable esthetic phenomena such as recessions and papillae losses.

3.1.1.4 Tissue biotype

From a clinical point of view, periodontal tissue biotypes can be classified in terms of form, profile, and thickness. Normal, thick, and thin biotypes are distinguished.[161] Thick biotypes have a flat bone and gingiva profile with a significant width of keratinized gingiva. Rectangular and quadratic tooth forms co-occur here, and there is a correlation with thicker buccal alveolar walls.[169] For this reason, bone dehiscence or fenestration is less frequently observed with thick biotypes. Thin biotypes can be identified on the basis of a steeper, garland-like gingiva profile, with a tendency for triangular tooth forms and a smaller width of keratinized gingiva. Patients with a thinner biotype are classified as high-risk because they have a significantly greater risk of developing not only buccal but also approximal recessions such as *locus minoris resistentiae*, which can be the result of multiple causes (i.e. trauma).[61,185] Thin biotypes can be converted into thick ones with augmentative techniques, and the related risks can be minimized.

A direct measurement of the tissue biotype and its thickness can be performed by way of a clinical test based on the 'transparency of the periodontal probe.'[49]

3.1.1.5 Attached and keratinized tissue

The formation of keratinized gingiva around teeth is considered a biologic development process due to the genetic determination of basal lamina and is therefore always present, at least in a minimal form. However, this phenomenon has to be created in peri-implant tissue using appropriate exposure techniques.

Since Lang and Loe[106] proved in 1972 that teeth show more significant inflammatory phenomena if the width of the keratinized gingiva is less than 2 mm, this threshold has been regarded as an adequate size for maintaining periodontal health. Wennström and Lindhe[183,184] proved in animal experiments that the size and apical dimension of the inflammatory infiltrate and the incidence of periodontal attachment losses do not differ between patients with an adequate width of keratinized gingiva and those with an inadequate width. A systematic review found that the amount of plaque accumulation, mucosal inflammation, recessions, and loss of attachment were more expressed to a statistically significant extent around implants where the width of keratinized mucosa was inadequate.[115,148] However, it also has to be noted that an inadequate width of keratinized mucosa does not give rise to any noticeable negative effects on parameters such as BoP, probing depth, and radiographic bone loss.[115] Despite the study by Keeve and Khoury[94] referred to above, most scientific studies do not assess success criteria but implant survival rates, based on which it is still difficult to show whether attached mucosa results in any improvement. The present authors strongly recommend the restoration of attached mucosa as an important objective of exposure techniques. The keratinization of tissue and the resulting protective effect – also against the formation of recessions – is indispensable, in particular for esthetic reasons and for the preservation of a pale pink, dimpled, and keratinized surface around implants that is free of inflammation, i.e. appealing 'pink esthetics.'

3.2 The basics of incisions, suturing techniques, and soft tissue healing

The aim of soft tissue healing is a good esthetic and functional final result, which includes complete morphofunctional restoration modeled on original structures. The incision, the formation of the flap, wound margin management, and suturing techniques have to be carefully considered in order to optimize flap healing and transplant receptivity and reduce scarring, especially in the esthetic area.

Principally, there are intraorally – and depending on the indication – two flap designs:

- The full-thickness flap, including mucosa, muscle, and periosteum. This kind of flap, also known as the mucoperiosteal flap, is the most frequently used for intraoral surgeries, including bone augmentation.
- The partial-thickness flap, involving the mucosa alone or including the muscle. This kind of flap requires the surgeon to be more experienced in preparing a mucosal layer over the muscle. It is indicated in some special surgeries, leaving the periosteum on the bone, and is known as the Kazanjian

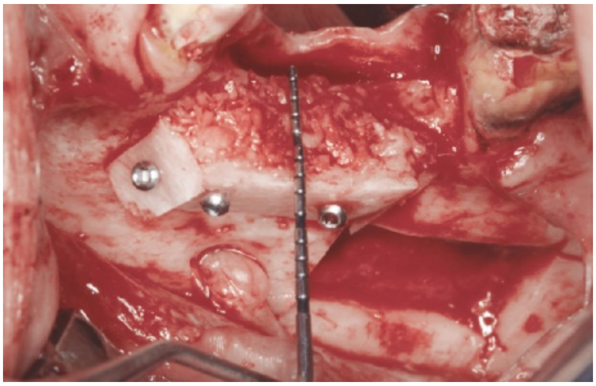

Fig 3-1a Exposure of the mental nerve is a prerequisite in every implant or augmentation surgery in the area of the mandibular premolars/first molar.

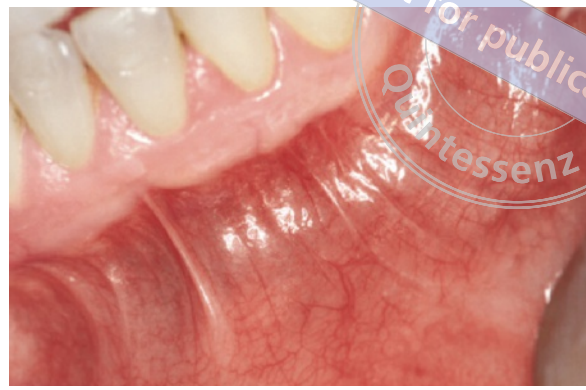

Fig 3-1b Blood vessels running perpendicular to the bone.

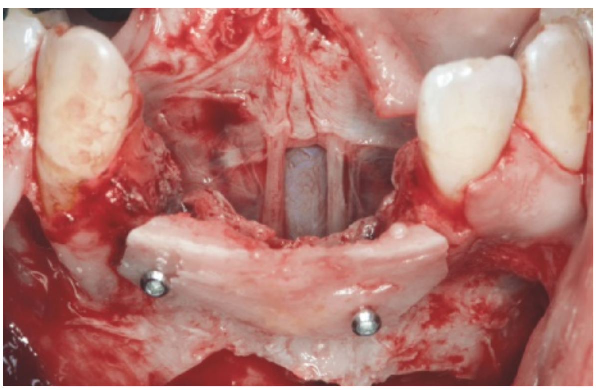

Fig 3-1c Important ramifications of the lingual artery in the mandibular anterior area.

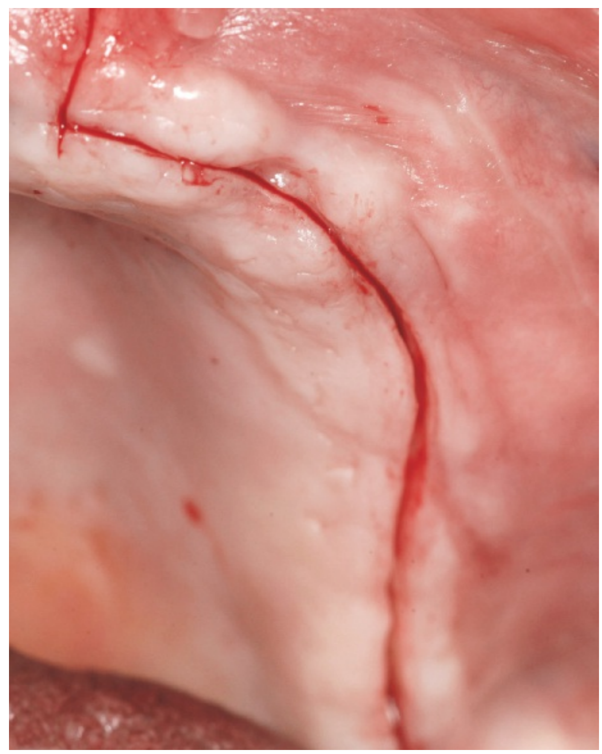

Fig 3-1d Typical incision in the middle of the crest in the edentulous maxilla, with the releasing incision in the frenulum for implant and augmentation surgery, preserving a sufficient vascular supply for good postoperative healing.

vestibuloplasty, the bone extension plasty (see Chapter 4) or the lateral approach for bone augmentation.

Incisions and flap design for bone augmentation and implant insertion must respect the general rules of surgery:

- Incisions have to avoid the injury of important anatomical structures such as nerves or important blood vessels (Fig 3-1a and b).
- Incisions have to take into consideration the course of the blood vessels, on the one hand retaining the maximum vascularization of the flap, and on the other, avoiding heavy bleeding during the surgery (Fig 3-1c and d).
- Incisions and flap design must offer the best possible vision and access for the surgeon.
- Incisions must offer a wide flap basis to reduce the risk of flap necrosis.

Fig 3-1e Intensive scar tissue formation in the maxillary anterior area after horizontal incisions (further apicoectomies).

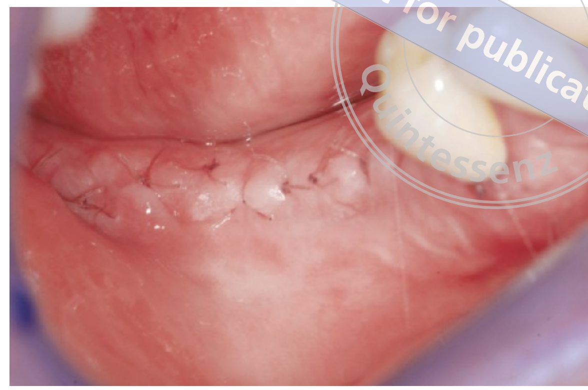

Fig 3-1f Clinical situation in the right mandible 2 weeks postoperatively: incision in the middle of the crest sutured with 6-0 monofilament resorbable sutures.

- Incisions and flap design should reduce the risk of scar tissue, especially in the esthetic area (Fig 3-1e).
- Atraumatic incisions, flap preparation, and sutures without any tension are important factors to reduce the risk of flap necrosis (Fig 3-1f).

Two wound-healing processes are distinguished in the context of exposure measures. In the case of primary wound healing (*per primam intentionem*), the wound margins should be correctly repositioned throughout, which results in the direct closure of the superficial wound layers through the formation of a fibrin network, with optimal fibrinogen synthesis and neoangiogenesis. The tensile strength of the tissue is, however, only restored after the complete healing of the submucosa after about 1 to 3 weeks. In contrast, submucosal granulation tissue grows over tissue continuity defects in the case of secondary wound healing (*per secundam intentionem*), which is determined by neutrophil polymorphonuclear leukocytes and macrophages until the final epithelialization of the wound.

3.2.1 Cellular and molecular healing mechanisms

Wound healing involves both the repair and the regeneration of the damaged tissue. The inflammatory healing process mainly consists of reepithelialization, neoangiogenesis, and the activation of connective tissue cells, which also gives rise to the degradation of the proteins in the extracellular matrix and their resynthesis.[159] The regulation of these processes is determined by interactions between proteins of the matrix and epithelial cells as well as cytokines and growth factors. After these three wound-healing phases are complete, the result is either an area of scar tissue formed by repair healing or an area of exact regeneration by original morphologically functional tissue.

3.2.1.1 Inflammation phase (day 0 to 3)

A brief vasoconstriction and the formation of the blood clot from a plasmatic network of thrombocytes and erythrocytes is followed by increased vascular permeability and the release of cytokines. The fibrinogen synthesis in the blood clot polymerizes fibrin and stimulates the migration and proliferation of marginal epithelial cells. Thrombocytes also release chemotactic cytokines such as TNF-α and IL-1 for neutrophil granulocytes and macrophages.[79] This immune response decontaminates the wound by way of phagocytosis, cell-mediated immune response, and peroxides, before lymphocyte-recruiting macrophages enter the tissue. The lymphocytic reaction follows antigen presentation specific to the molecular patterns of various microorganisms.

3.2.1.2 Proliferative and fibroblastic phase (day 3 to 12)

The proliferation and migration activity of fibroblasts is enhanced by growth factors expressed by macrophages and leads to increased collagen synthesis and to neoangiogenesis triggered by VEGF and β-FGF.[168] The reepithelialization of the wound margins restores the integrity of the anatomical structures. Integrins function as receptors for chemotactic factors, which interact with collagen and fibronectin, and PDGF of thrombocytes and TGF-β of macrophages activate mesenchymal cells and thereby the formation of granulation tissue.[44,79] Glycosaminoglycans, proteoglycans, tenascin, and thrombospondin invade the extracellular matrix, and myofibroblasts differentiate to contract the wound area.

3.2.1.3 Maturation phase (day 6 to 14)

Matrix metalloproteinases trigger collagenolysis and synthesis in order to reorganize the extracellular matrix and granulation tissue. The fibroblastic phase is determined by the formation of type III and I collagen and improves the tensile strength and elasticity of the new tissue. Integrins in the cell membranes consolidate the provisional matrix through α- and β-heterodimer proteins and enable reepithelialization. Integrin α5β1 not only stimulates adhesion and migration in this process, but also has a decisive effect on cell growth through signaling.[12,86,109]

3.2.2 The reactions of tissue to sutures

Suture materials are a foreign body and inevitably lead to mild inflammatory reactions in tissue, which may locally reduce resistance to infections. Specifically, needle and thread penetration sites represent biologic niches where bacterial invasions are possible.[6]

Wound healing in the oral cavity involves a higher risk of bacterial contamination, the so-called 'wick effect.' Biofilm formation therefore needs to be reduced as much as possible by using monofilament threads. Suture materials must possess high tensile strength and tear resistance, good knotting characteristics, and high knot strength.[174] In this context, it was shown that atraumatic microsurgical application significantly supports flap and wound healing.[25] The use of atraumatic monofilament suture threads with a maximum thickness of 0.01 mm (i.e. ≤ 6-0) is therefore indicated due to lower levels of bacterial colonization,[114] smaller histologic inflammatory infiltrate, and the reduced formation of scar tissue. At the time of the removal of the sutures after 14 days, the epithelium is already keratinized,[159] and the thread is slightly colonized by rod- and spindle-shaped bacteria. Due to the complex, multilevel suturing techniques used to achieve esthetic and functional results, it is recommended to use resorbable suture threads. Nevertheless, as the metabolic degradation process takes approximately 60 days, these should be removed if accessible after 14 days. This results in greater patient comfort and is obligatory in the particular case of two-layer wound closure. The surgical needle should have a curve length of 11 to 13 mm, and a triangular profile sharpened and polished toward the tip. The needle should be made of stainless steel to achieve the best possible stability while causing the least possible trauma to the tissue (Fig 3-2a to d).

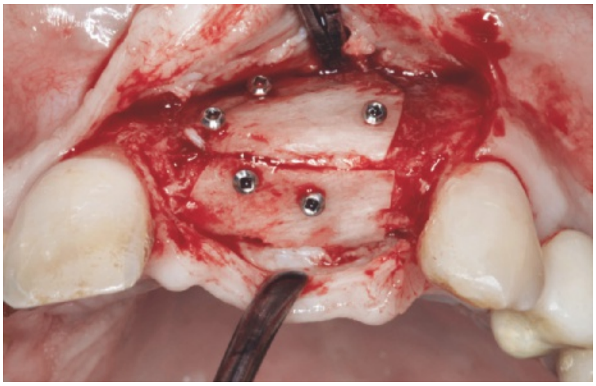

Fig 3-2a Exposure of a 3D-form grafted bone in the anterior maxilla 3 months postoperatively using the same incision line that was made during the grafting procedure, including the releasing incision in the mesial third of the canine.

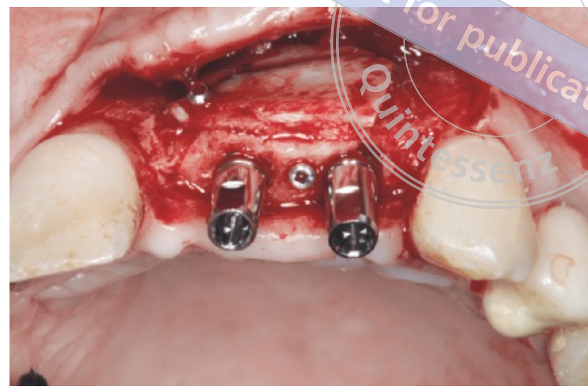

Fig 3-2b Insertion of two implants in the vertically grafted bone.

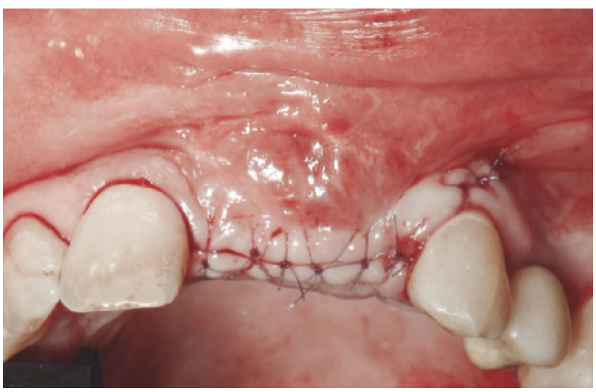

Fig 3-2c Wound closure with 6-0 monofilament resorbable sutures.

Fig 3-2d Clinical situation 4 weeks postoperatively.

3.3 Instruments

Microsurgical concepts have become established in soft tissue management.[46,189] Microsurgery is understood to mean surgical procedures that require optical magnification aids, miniaturized instruments, and suturing materials that have been adapted accordingly. The atraumatic management of tissue and the optimal closure of wounds by way of microsurgical techniques have produced significantly improved results. The improved and predictable wound healing process was described by Burkhardt and Lang,[25] who compared macrosurgical and microsurgical procedures.

The shape of the instruments' grip should be round and well-balanced and have a length of at least 16 cm. In particular, in the case of lengthier procedures, such ergonomic work in the posterior sections of the jaw may have advantages. Grips with a round profile make possible the significantly more precise manipulation of instruments in the pencil-grip position.

On the one hand, an incision without any tissue loss is possible with a single-edged No. 15c blade with a pointed tip and adequate width in the case of two-layer dissections; on the other hand, one could use a double-edged SM69 micro scalpel. In the selection of raspatories (e.g. Partsch Raspatories), a slender de-

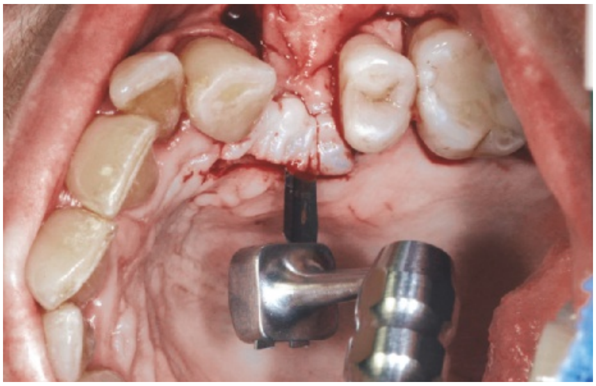

Fig 3-3a Angulated scalpel for better access from the palatal side.

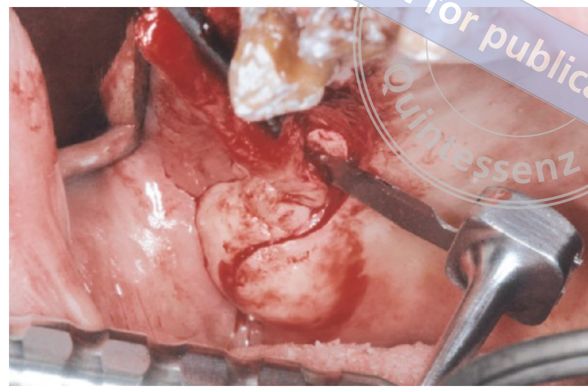

Fig 3-3b A supraperiosteal flap preparation in the posterior maxilla is made easier using an angulated scalpel.

sign is best. Larger raspatories can only be used for the atraumatic lifting of flaps. There should be at least one anatomical and one surgical forceps, the latter specifically designed for microsurgery. Without lip and muscle retraction, a delicate flap, or a free or pedicle connective tissue graft, can be optimally held using a surgical Cooley forceps without much pressure. If too much pressure is applied in the case of anatomical forceps, the delicate flap can be significantly traumatized or bruised. In the case of very thin flaps or free mucosal grafts, an anatomical forceps is the best choice for atraumatic handling without the risk of perforation. For knotting suture threads, either an anatomical or a surgical forceps with plateau is suitable to avoid any damage to the suture materials when grabbing them. As regards the choice of needle holder, in addition to the needle size to be used, the level of experience and the preference of the surgeon play a decisive role. Various sizes of the required shape as well as a slender design are needed to ensure appropriate access to the interdental areas. Microsurgical needle holders are usually not equipped with a lock, although it is of great help in oral and periodontal surgery for controlled rotating movements. The needle holder by Castroviejo is, for example, equipped with a gentle locking mechanism. In the case of micro scissors, curved shapes with pointed blades have proven to be practical.

Some special instruments, e.g. the multi-positioned angulated scalpel, can be very useful to gain access to different intraoral areas for specific surgeries (Fig 3-3a and b).

3.4 Soft tissue management before augmentation

Inflammatory processes and tooth extractions sometimes lead to pronounced damage to both hard and soft tissue. In particular, the quantity and quality of soft tissue, including its regenerative characteristics, are severely compromised in cases involving infected biomaterials or failed implantation attempts with multiple previous surgeries. It can be an advantage in all these situations to improve the quality of soft tissue in this region before actual augmentative measures. This allows for an easier and safer closure, primarily in relation to vertical bone augmentations. Soft tissue improvement is most frequently indicated in patients with a thin gingival biotype, as the improved soft tissue has a protective effect on the hard tissue graft and ensures a better long-term esthetic result.

Fig 3-4a Poor esthetic situation after looseness of an implant at the position of the first left central incisor, and bone and soft tissue loss on the implant at the position of the lateral incisor.

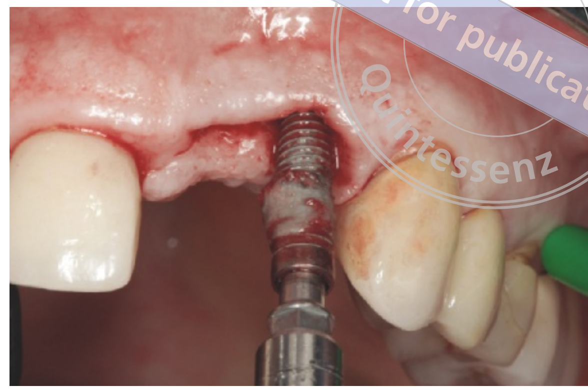

Fig 3-4b After removal of the crown, explantation of the implant using the BTI explantation system (BTI, Vitoria-Gasteiz, Spain).

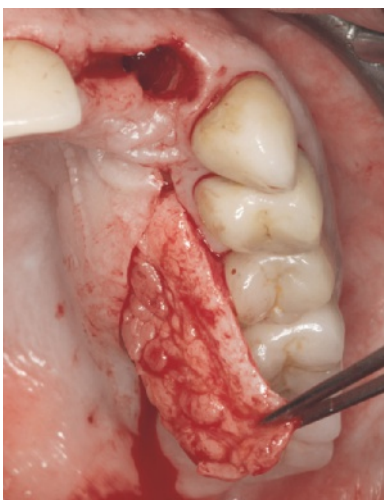

Fig 3-4c Preparation of a pedicle connective tissue flap in the left palate.

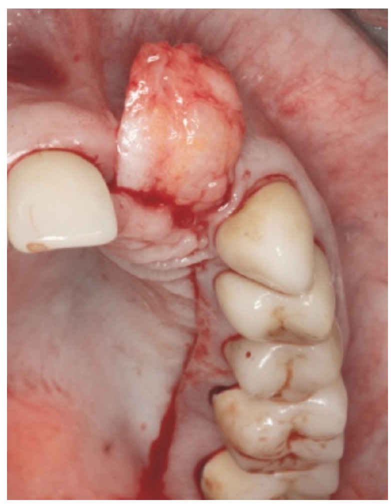

Fig 3-4d The pedicle connective tissue flap is tunneled under a soft tissue bridge to cover the defect and improve the quality of the soft tissue.

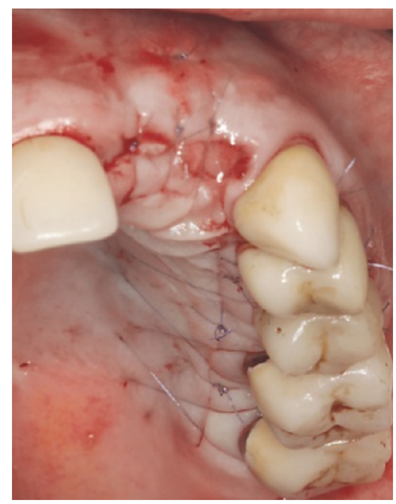

Fig 3-4e Wound closure with 6-0 sutures without any releasing incision.

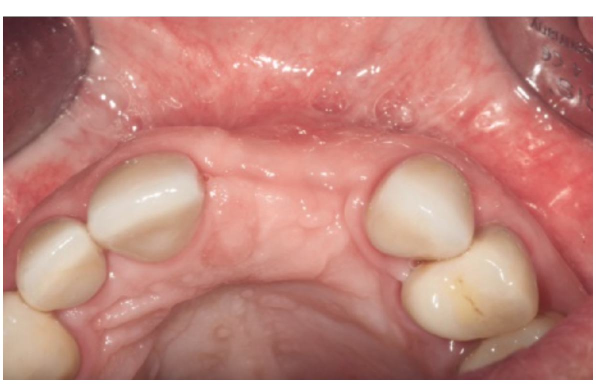

Fig 3-4f Clinical situation 2 months postoperatively.

A thin biotype is easily diagnosed by probing, as the periodontal probe is visible through the tissue, and it is a predisposing factor for the formation of recessions. It may therefore be reasonable to change biotypes from thin to thick, with consideration of esthetics. This can be achieved by both free gingival and connective tissue grafts and palatal pedicle connective tissue flaps (Fig 3-4a to l). Rotation flaps can be created, epithelialized or deepithelialized from buccal mucosa or the palate. The volume and quality of the soft tissue can also be improved

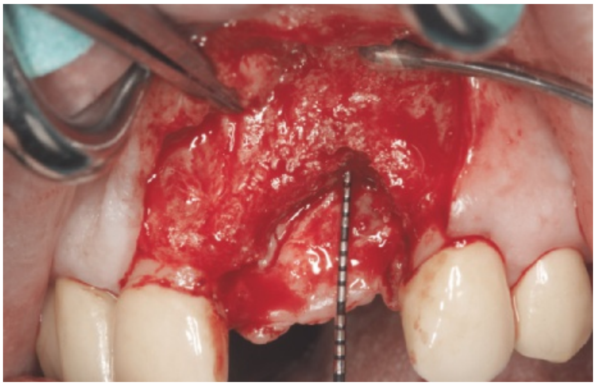

Fig 3-4g Exposure of the bony defect.

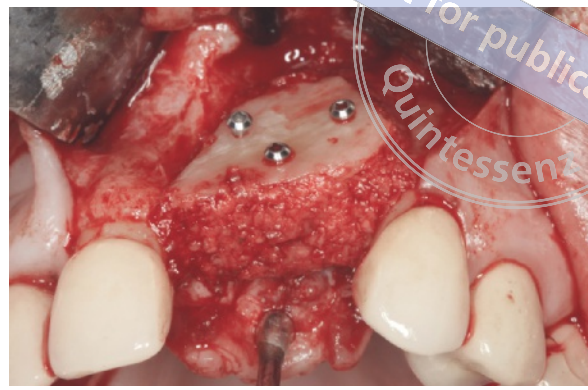

Fig 3-4h Vertical bone augmentation with bone grafts from the left mandibular retromolar area following the protocol of the SBB technique.

Fig 3-4i Closure of the wound with 6-0 monofilament sutures (only one releasing incision was necessary for the wound closure).

Fig 3-4j Clinical appearance 3 months postoperatively.

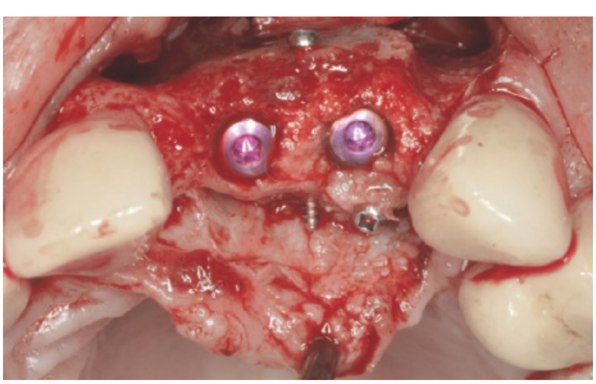

Fig 3-4k Bone exposure using the same incision line made during the grafting procedure: insertion of two implants in the grafted area.

Fig 3-4l Clinical situation after the definitive restoration.

Fig 3-5a Soft tissue recession on the two mandibular central incisors and agenesia of the two lateral incisors.

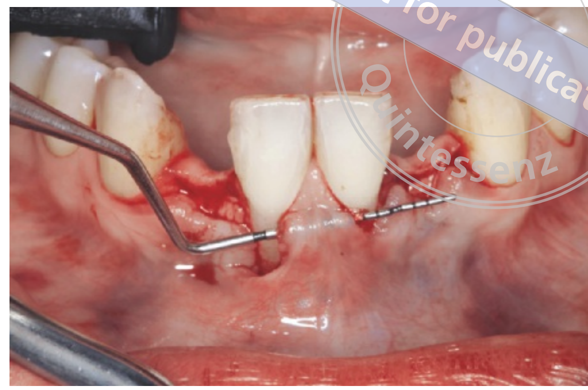

Fig 3-5b Preparation of a partial thickness flap on the area of the lateral incisors, and tunneling the buccal mucosa of the central incisors.

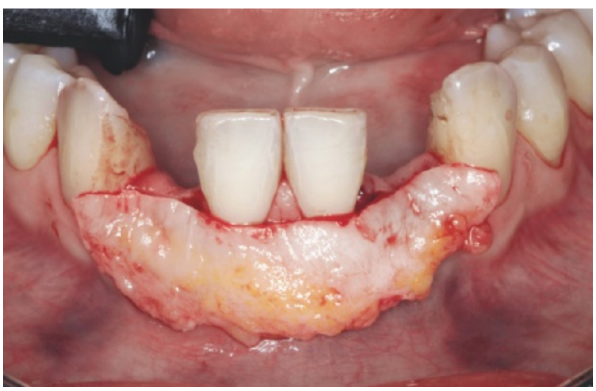

Fig 3-5c Connective tissue graft harvested from the palate for the soft tissue augmentation.

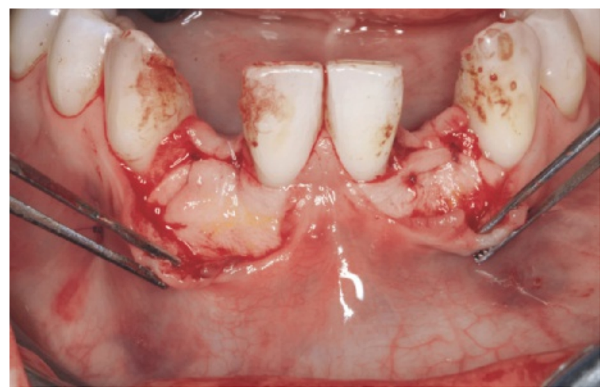

Fig 3-5d The connective tissue graft is placed under the tunneled mucosa and stabilized with 6-0 sutures at the area of the lateral incisors.

through free gingival and/or connective tissue grafts, which can at the same time counteract shifts in the mucogingival junction.

3.4.1 Incisions before augmentation

From the very beginning, the adequacy of the cuts has great significance for the later esthetic success. If the existing tissue is thin, it is recommended to place the incision strictly vertically in order to achieve two equally thick flap margins and thereby optimize suture closure, healing, and the final results. Independent of the phase of soft tissue management, the incision should ensure the necessary accessibility of the operation site and offer the required mobilization opportunities. In the case of sulcular incisions, the blade cuts papillae directly under the tooth contact point, parallel to the tooth axis, and the whole gingiva is incorporated into the flap. Releasing incisions in the gingival margin should be altogether avoided before augmentation; the only exception is in the case of auxiliary access incisions in the mucosa for the placement of grafts. In the pre-augmentative phase, only mucosal flaps – also called split-thickness flaps – should be used (Fig 3-5a to o). If a thin layer of connective tissue and periosteum are left on the bone, grafts heal better due to the vascular supply from all sides.[134] In addition, the resulting bone resorption can be minimized in the case of a split-thickness flap

Fig 3-5e Wound closure.

Fig 3-5f Occlusal view of the grafted area.

Fig 3-5g Clinical appearance 6 weeks postoperatively. The temporary restoration is performed as a Maryland bridge.

Fig 3-5h Occlusal view with the etched restoration.

Fig 3-5i Exposure of the atrophied crestal bone.

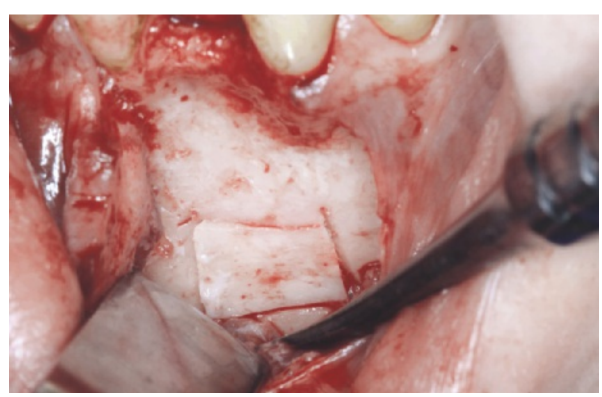

Fig 3-5j Bone block harvesting from the apical area.

dissection, as compared with mucoperiosteal flaps with denudation of bone.[60,135,166,187] Exceptions to this concept are situations where the soft tissue augmentation has to be combined with the removal of foreign materials (e.g. biomaterials after infection). In such cases, the flap preparation must include bone exposure to remove the foreign materials.

Fig 3-5k Bone grafting with simultaneous implant insertion on the left side.

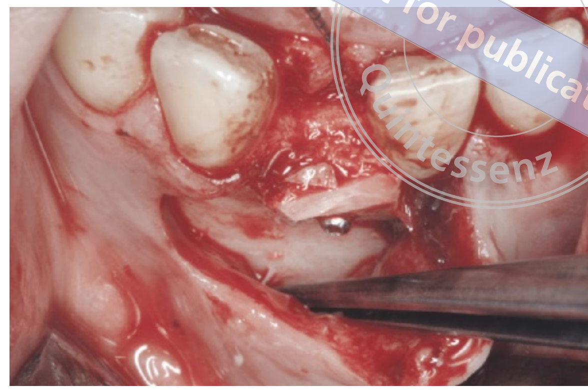

Fig 3-5l Bone block grafting on the right side. Simultaneous implant placement was not possible here.

Fig 3-5m Wound closure.

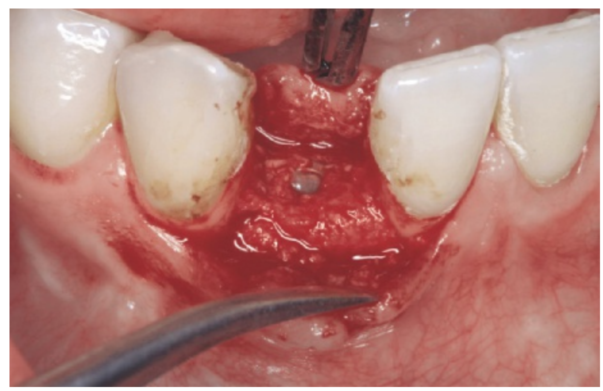

Fig 3-5n After 3 months, implant insertion in the grafted bone on the right side.

Fig 3-5o Definitive restoration performed by the referring dentist.

3.4.2 The split-thickness tunnel technique

Soft tissue thickening is mostly achieved with connective tissue grafts. The split-thickness tunnel technique involves the use of free grafts that restore volume, in particular on the vestibular aspect of the defect, and therefore completely exclude the risk of exposure during later augmentation measures. After the free connective tissue graft is harvested from the palate, the graft bed is opened – beginning with a vertical mucosal incision – and a Partsch Raspatory or Kornman scissors are used to bluntly dissect a tunnel toward the target site. The tunnel is created to be 1.5 times the size of the excised graft, preserving the anatomical structures as much as possible (Fig 3-6a to e). The tunnel is centered on soft tissue deficits and reaches the keratinized areas of the gingiva, if necessary. If the keratinized gingiva is very thin, a transition into a mucoperiosteal flap at the mucogingival

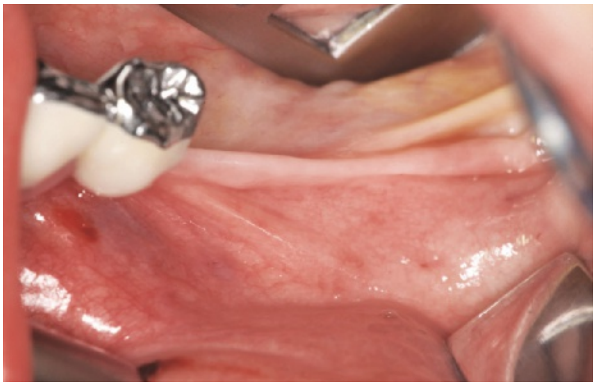

Fig 3-6a High bone atrophy in the posterior mandible with an extremely thin gingival biotype.

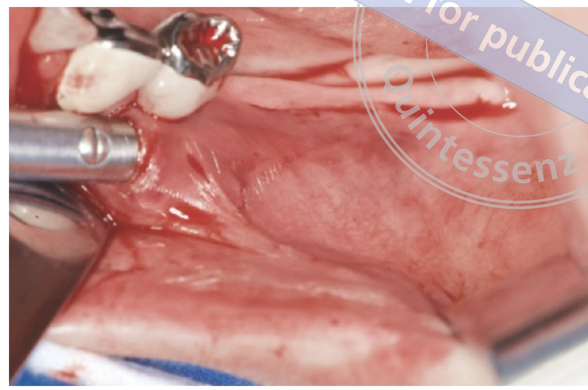

Fig 3-6b Tunnel preparation for soft tissue grafting.

Fig 3-6c Connective tissue graft harvested from the palate is prepared to be placed through the tunnel.

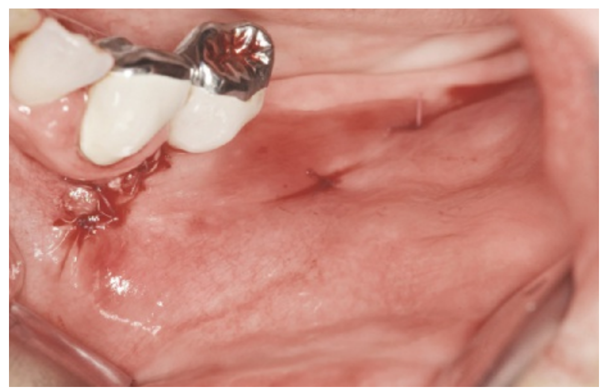

Fig 3-6d Clinical situation at the end of the surgery.

junction may be necessary to avoid perforations. The graft is pulled in using a sling suture at the distal end of the tunnel, which can then be knotted in the same step to a mattress suture. The graft should be fixed in the correct position by at least two mattress sutures, with the use of a few simple interrupted sutures to prevent rotation before the vertical access incision can be closed (Fig 3-7a to l).

3.4.3 Free connective tissue grafts before augmentation

Connective tissue grafts are primarily harvested from the lateral palate, independently of the phase of soft tissue management. Further donor sites include the *tuber maxillae* and the mandibular retromolar region. Free tissue grafts can

Fig 3-6e Clinical situation 2 months postoperatively presenting an improved soft tissue appearance prior to the bone grafting.

be categorized into connective tissue grafts, gingival grafts, and grafts, the last being a combination of the first two. The ‘lateral palate’ donor site should, however, be further specified,

Fig 3-7a Thin soft tissue biotype in the atrophied right mandible.

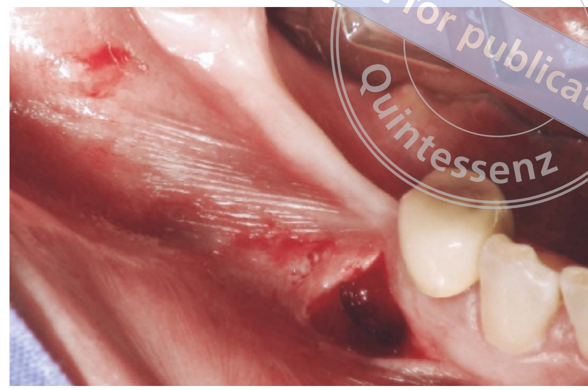

Fig 3-7b Tunnel preparation on the vestibular side.

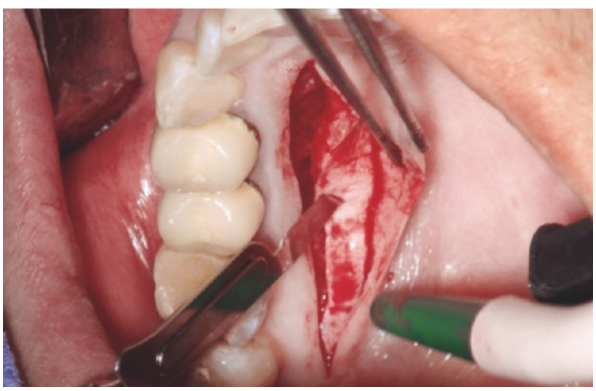

Fig 3-7c Connective tissue graft harvested from the right palate.

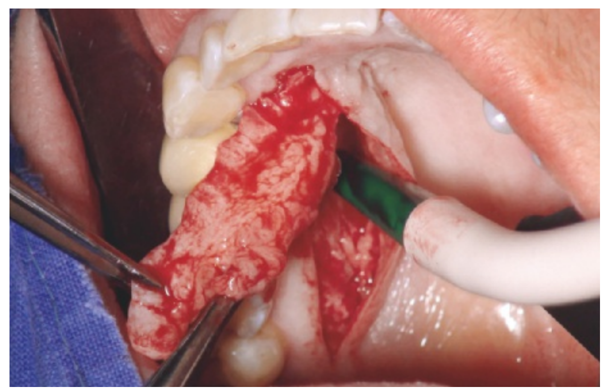

Fig 3-7d Harvesting of a connective tissue graft from the right palate.

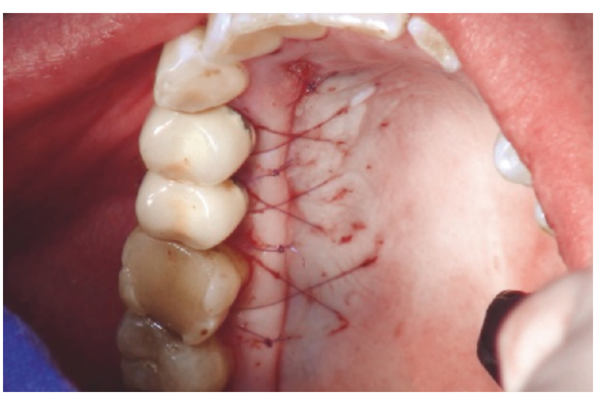

Fig 3-7e Wound closure in the right palate.

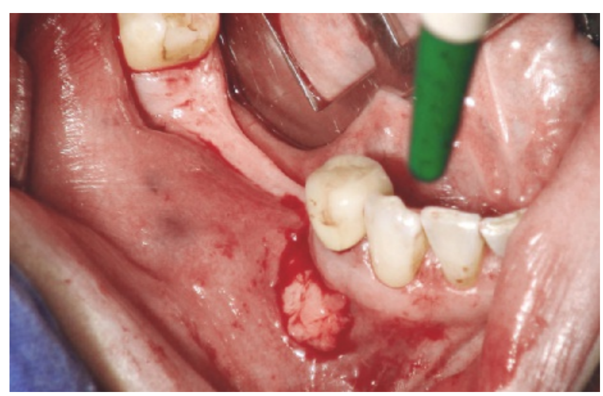

Fig 3-7f The connective tissue graft is placed inside the prepared tunnel.

as the tissue is thickest in the premolar region of the palate. Depending on the patient, subepithelial tissue grafts also include fatty and glandular tissue, in addition to collagenous areas (Figs 3-5c and 3-7d). The palatine artery is to be preserved; it emerges from the *foramen palatinus major* at the approximal space of the second and third molars,[101] and continues anteriorly at an average distance of 12 to 14 mm from the gingival margin,[123] depending on the height of the palatal vault.[142] The so-called 'single-incision technique' has been preferred in

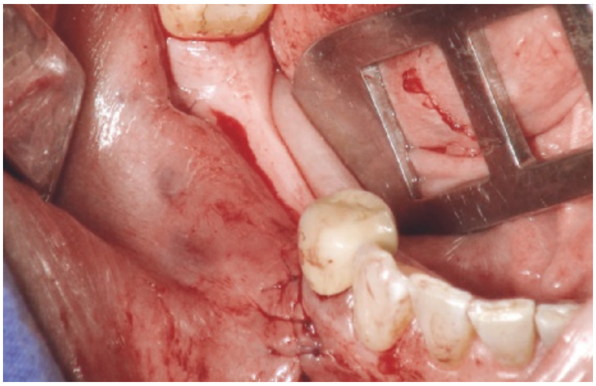

Fig 3-7g Wound closure.

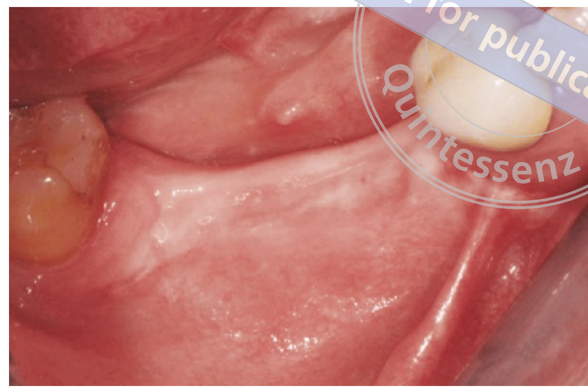

Fig 3-7h Clinical situation 2 months postoperatively.

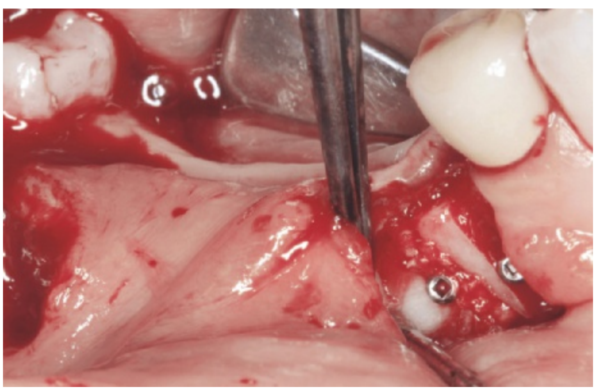

Fig 3-7i Bone block grafting through the tunnel approach.

Fig 3-7j Postoperative radiograph.

Fig 3-7k Clinical situation 6 years postoperatively.

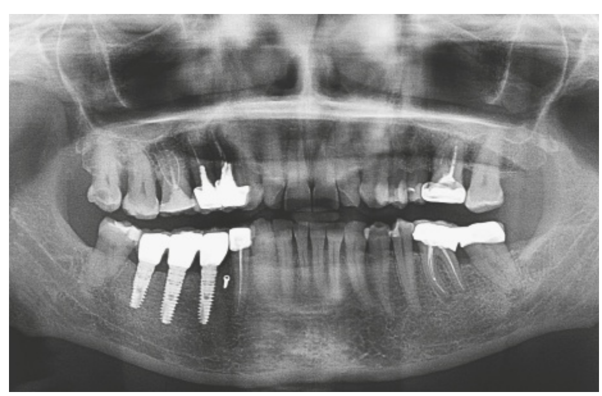

Fig 3-7l Radiographic control 6 years postoperatively.

many described harvesting techniques used to dissect subepithelial grafts,[83,107] as it has been found to improve postoperative healing and patient morbidity. The technique involves a horizontal incision on the palatal side, followed by a sharp undermining dissection. The wound margins can be optimally stabilized during later suturing if the harvesting incision is 1 to 1.5 mm from the first incision. Depending on the patient, a decision needs to be made as to whether the graft should be elevated from the bone bluntly or by using a further split-flap dissection.

Fig 3-8a Clinical situation before extraction of the left central incisor due to a length fracture.

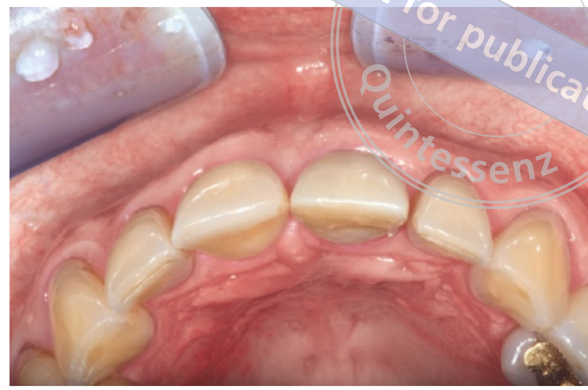

Fig 3-8b Occlusal appearance.

Fig 3-8c Clinical situation after atraumatic extraction of the central incisor.

In addition to own tissue-specific proteins, autologous connective tissue grafts also contain a significant number of fibroblasts, the majority of which are accessible for initial plasmatic circulation and the revascularization that follows, for which reason they have a more favorable prognosis.

The blunt approach enables the excision of a more voluminous and more stable graft, incorporating the periosteum but at the price of slightly greater patient morbidity. For suture care, a combination of continuous sling sutures, simple interrupted sutures, and a palate plate is recommended (Fig 3-7e).

If connective tissue with a higher ratio of collagen and less fatty and glandular tissue is required, a deepithelialized gingival/connective tissue graft is recommended. Alternatively, the tuberosity region is recommended as a secondary donor site. Grafts gained using a distal wedge excision will shrink less due to their structure, and have a special form, which makes revascularization difficult. For this reason, the tuberosity region remains the secondary donor site.

3.4.4 Punch technique

If there are no acute inflammatory symptoms, the so-called 'punch technique'[90] – involving a combined graft consisting of connective tissue and epithelial parts – can also be used for the closure of extraction or explantation alveoli. This technique results in an optimal stability of the coagulum in the alveolus, and it compensates for the volume and keratinization of the soft tissue. The graft can be harvested from the tubera behind the last molar in cases where there is a wide keratinized gingiva in this area (Fig 3-8a to j) or from the palate in the premolar area. In the case of the palate, a rotated punch bur can be used to facilitate the harvesting procedure (Fig 3-9a to l). In the case of the graft being harvested from the tubera, an incision is made in the middle of the connective tissue area that will create two strips of connective tissue by keeping a central epithelial area, with a diameter corresponding to that of the extraction socket. Split-thickness flaps are dissected without