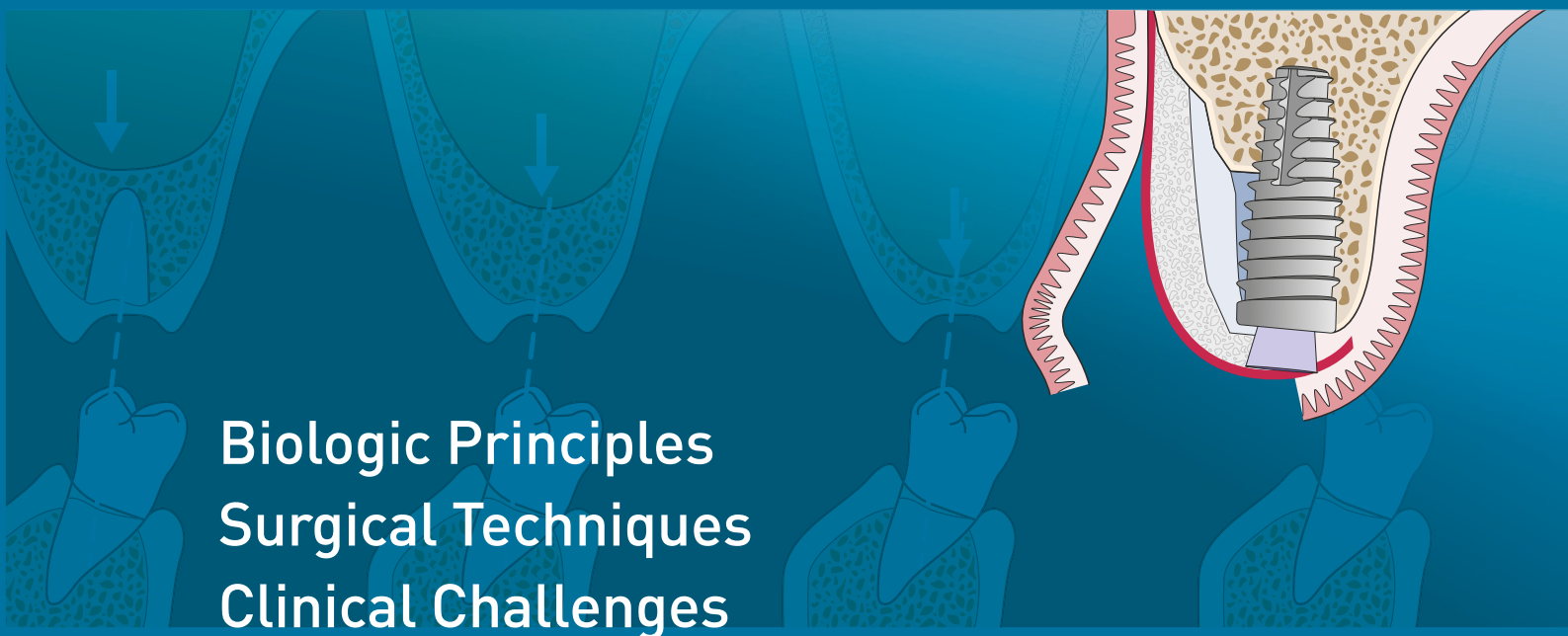
Hendrik Terheyden

AUGMENTATION SURGERY



Biologic Principles
Surgical Techniques
Clinical Challenges

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Preface

Bone augmentation of the alveolar process is something special for medicine. In addition to the dental prosthetic options, there is the possibility here of true biologic regeneration of the alveolar bone, a *restitutio ad integrum*. The new bone can be functionally preserved over the long term thanks to dental implants. Bone augmentation is therefore in principle a functionally based medical rehabilitation, the esthetic aspects of which must not be disregarded. As my teacher Prof Dr Dr Franz Härle used to say, "If you get the function right, the esthetics will fall into your lap."

This book is aimed at dental colleagues as an introduction to the topic of augmentation and is intended to provide experienced colleagues as well as oral and maxillofacial surgeons with many practical tips. There is a relatively wide range of information and training available in the new media; it is even possible to receive surgical training on video portals. In knowledge management, the task is to separate the wheat from the chaff and to distill the relevant information from the mass of it. It takes a lot of judgment to be able to better assess from the abundance of innovations what will prove itself in the future and what is therefore already worth an investment in clinical practice today. Therefore, even in the modern world of technology, there is still a place for a classic scientific textbook. This book aims to contribute to knowledge management and judgment within the practical background of clinical care and practice.

The book includes the topics of *basic biology*, surgical techniques, and clinical challenges and decision making. The biologic principles are addressed to the extent that they have clinical consequences. Fundamentally, classical dentistry has long been based relatively heavily on material science, and consequently so has academic training. This was consistent because classical conservative and prosthetic dentistry took place outside the ectodermal barrier, essentially outside the body. Today, dental implants mean that dentists are increasingly working invasively inside the body, so that the classical training content needs to be supplemented. Today, among other things, the biology of wound healing, the body's reaction to antigens and foreign materials, and antibiotics and resistance are coming more to the fore, alongside the medical management of an invasively treated patient and the reaction to complications.

The *operational techniques* require surgery, unless one specializes in the prosthetic restoration of dental implants. But even then, knowledge of the surgical options is helpful in advising the patient. Even if one does little augmentation oneself at first, one should know the augmentation possibilities, along with their limitations in at-risk patients, in order to be able to properly refer them to a specialist. In general, a certain restraint is advised when teaching surgical techniques via drawings and animations because paper is known to be uncomplaining, which is why this book relies more on clarification through real clinical cases.

Experience and knowledge of the biologic background are essential for overcoming *clinical challenges and making decisions*, because dentistry is a science-based discipline. Differential indication means the risk-benefit assessment of which procedure offers the highest safety and the best effect for which situation and patient. This book attempts to facilitate this step in the form of a treatment-planning concept based on indications. It is therefore about decision making, preferably in consensus with the patient as shared decision making.

I would like to thank Quintessenz Verlag, especially senior director Dr h.c. Horst-Wolfgang Haase for the invitation and managing director

Christian Haase for the publishing realization despite coincidence with the coronavirus crisis. I have been in close contact with Dr rer. biol. hum. Alexander Ammann for years, among other things through his work in the film and book series *Visual Biology*, and I am also indebted to him for this book for numerous intellectual suggestions. I would like to thank Bryn Grisham and her team, Anita Hattenbach and Viola Lewandowski for editing the book, as well as my son, Immo Terheyden, DDS. The patience and skill in translating my wishes into perfect drawings are worthy of special thanks to Mrs. Christine Rose. For the production I could rely on Mrs. Ina Steinbrück. Last but not least I would like to thank the numerous colleagues in the scientific exchange internationally and nationally. In particular, the participants in my courses and continuing education courses have always stimulated me to further thinking and practice in bone augmentation by asking questions and reporting on the challenges of their practice activities. In particular, I would like to mention the Implantology Curriculum of the German Society for Implantology and the Academy for Practice and Science of the German Society for Dental, Oral and Maxillofacial Medicine, as well as the Master of Science course. Not the least thanks are due to my wife, Dr med Eva Ulrike Terheyden Niemann for her professional suggestions and corrections and support during the time-consuming and not very family-friendly business of book writing. I would like to address the last sentence to you, dear readers, with the request to enter into an exchange with me and to discuss the contents—this is the only way to move our field forward. Thank you very much for your time.

Prof Dr med Dr med dent Hendrik Terheyden, FEBOMFS

Author

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Hendrik Terheyden studied dentistry from 1983 to 1989 at the University of Kiel. In 1989, he was a staff physician for the Navy in Flensburg. From 1989-1992 he studied human medicine at the University of Kiel. In 1993 he became a specialist in oral surgery and in 1997 a specialist in oral and maxillofacial surgery with the additional title of plastic surgery (1999). In 1999 he completed his PhD (Habilitation) at the University of Kiel. He received the Wassmund Prize of the German Society for Oral and Maxillofacial Surgery (DGMKG). In 2004, he became an adjunct professor at Kiel University. From 2009 to 2012, he was president of the German Society for Implantology, and from 2017 to 2019, he was Chairman of the Oral and Maxillofacial Surgery Working Group of the German Society for Oral and Maxillofacial Surgery (DGZMK). Since 2006, Prof Terheyden has been section editor of the *International Journal of Oral & Maxillofacial Surgery,* and since 2012 he has been editor in chief of the *International Journal of Implant Dentistry*. Since 2021, he has served on the board of the Working Group of Senior Hospitalists of the German Society for Oral and Maxillofacial Surgery

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A

BIOLOGIC BASICS

1 General Principles of Augmentation Surgery

Information has never been as widely available as it is today. This is especially true for dental implantology, which is still very much in flux many decades after its establishment. In the dynamic interplay between product developers and clinicians, new biomaterials and augmentation procedures enter the practice almost daily. There are countless publications and tempting continuing education courses on everything. The art of the (dental) practitioner is to correctly classify the amount of innovations and information for the benefit of the patient. What is good and what is bad for my patient? What is risky and what is predictable? What is effective and what is unnecessary? What pays off and what only costs? What is fashionable and what is enduring? The basis of judgment is experience and profound knowledge.

Dentistry has traditionally been strongly influenced by material sciences, because until a few years ago it took place predominantly outside the better ectodermal envelope of the body. Through implantology, among other things, the spectrum of dental treatment has expanded into the interior of our patients' bodies. This requires better: a broadened theoretical basis for dentistry, which is derived from biology and medicine. The performance of the surgeon in augmentations depends not only of the correct technical execution, but above all the correct therapeutic recommendations under consideration of numerous influencing factors. This book is intended to help the practitioner build self-confidence and critical judgment in making good decisions and to provide some joy when the biology behind one's clinical observations becomes apparent and sustained success is achieved.

1.1 Bone as a Success Factor in Implantology

The opportunity for functional and biological tissue regeneration is a privilege of dentistry compared to most other branches of medicine. Today, bone regeneration techniques allow dentists to accept almost no deviation in the shape of the jaw bone as a given, whether acquired by accident, tumor, or atrophy of the alveolar ridge after tooth loss or as the result of congenital lack of dentition.

This also applies to corrections of the occlusal relation and vertical dimension of the jaws. The foundations for surgical correction of the bone and

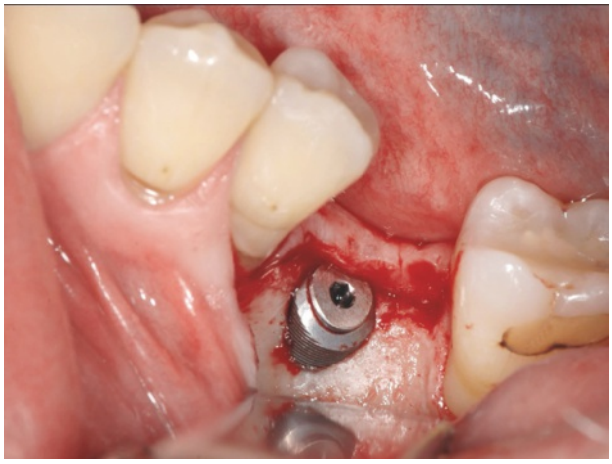

Fig 1-1 The fate of the implant is decided by the first millimeter. Roughened implant parts must not come into contact with the bacteria of the sulcus. Augmentation is required here.

Fig 1-2 Photo superimposition. Replacement of the maxillary lateral incisors with titanium implants. A gray discoloration by titanium should be prevented by sufficiently thick bone and soft tissue.

the overlying soft tissues in preparation for tooth replacement treatment were largely laid by specialists in preprosthetic surgery in the 1970s and 1980s.[1] Bone augmentation is a safe procedure in the long term. Data from prospective 10-year studies exist today for major techniques.

The fate of the implant is decided on the first millimeter[2] (Fig 1-1). A circumferential ring of bone covering all roughened portions of the implant on all sides can prevent downgrowth of the junctional epithelium and thus pocket formation[3] and supports a good long-term prognosis for lasting implant health.[4] Circumferential bone of at least 1-mm but preferably 2-mm thickness supports a good long-term prognosis and the basis for a soft tissue sealing apparatus. Sufficiently thick bone creates a natural gingival color by preventing a discoloration by the dark titanium of the dental implants (Fig 1-2). Bone is generally the basis of esthetics as it defines the height of the gingiva (Fig 1-3) and anchors the facial soft tissues. The alveolar process must be sufficiently wide to accommodate a stable implant with sufficient material thickness that will not deform or even fracture under mastication. In addition, the bone height should be sufficient to avoid long dental crowns and interdental plaque retention. Bone should be present within the prosthetic and functional loading axis of the restoration. This allows the prosthesis to be more delicate and esthetic (Figs 1-4 to 1-6).

1.2 Aims of Bone Augmentation: Function – Esthetics – Prognosis

The aforementioned guidelines result in the following goals of bone augmentation:

- Function
- Esthetics
- Prognosis

Implantology has masticatory rehabilitation as its primary medical goal. With good function, good esthetics often results automatically. In addition, esthetics is becoming more important as a therapeutic goal. The position of the bone shoulder determines the position of the overlying soft tissue and thus the gingival (pink) esthetics. These relationships are summarized in the English rhyme:

The tissue is the issue,
but the bone sets the tone,
and the clue is the screw. (D. Garber, Atlanta)

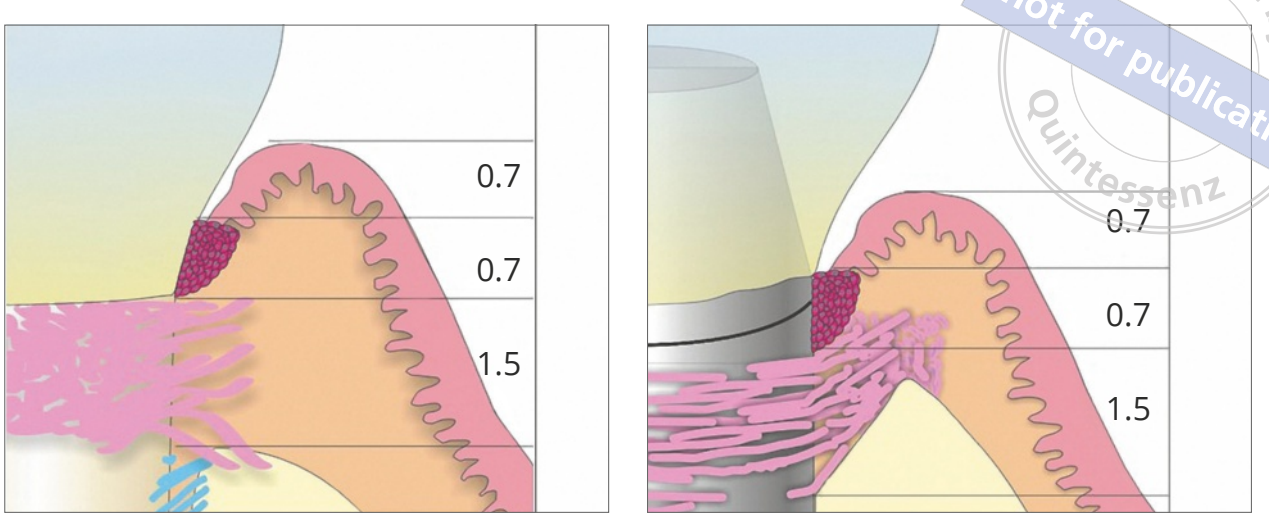

Fig 1-3 The soft tissue height (biologic width) is composed of the following elements: connective tissue attachment, junctional epithelium, and sulcus depth or free gingiva. It is the same for teeth and implants, averaging about 3 mm. Because the soft tissue height is a constant, it can be planned in advance by augmenting the bone height.

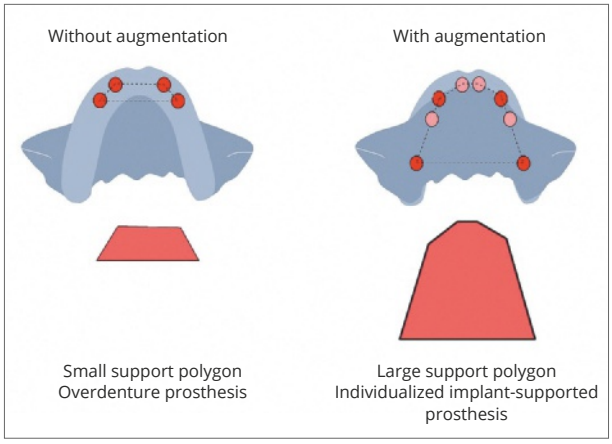

Fig 1-4 In implant-retained prosthetic restoration of the maxilla, the implants can be placed intersinusoidally in the anterior region, avoiding sinus floor augmentation. In this case, however, the prosthesis must be an overdenture or otherwise made very solidly to avoid fracture. With augmentation, the support polygon is large, allowing the placement of 6 to 8 implants and the use of a removable prosthesis that can be designed much more delicately because the risk of breakage is low.

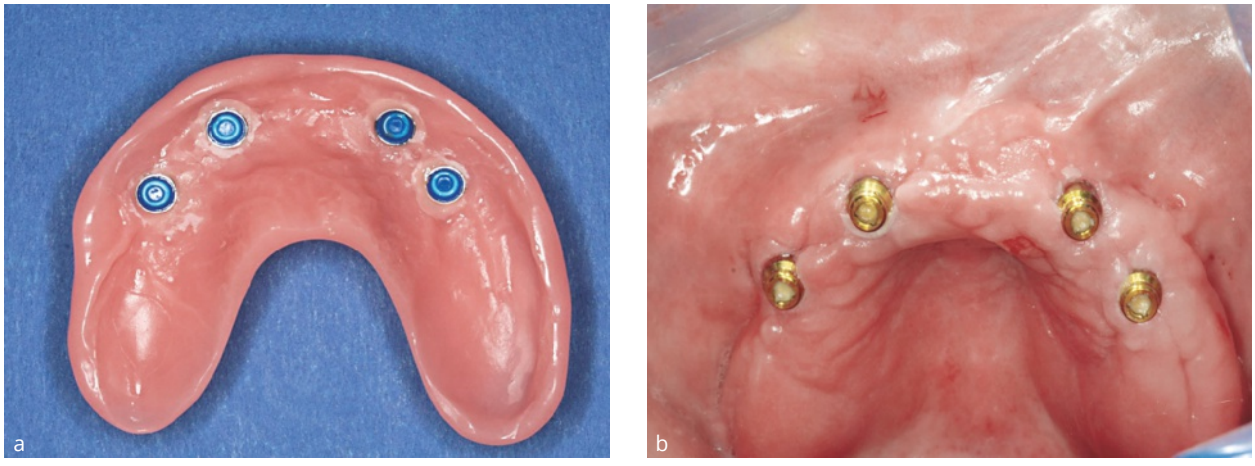

Fig 1-5 Maxillary restoration without augmentation. **a.** Overdenture for the maxilla with intersinusoidally placed implants, avoiding augmentation. **b.** Lack of salivary irrigation underneath the overdenture leads to reddening of the palate (ie, denture stomatitis, candidiasis) and gingival hyperplasia at the implants with pseudo-pocket formation. The masticatory load-bearing capacity is relatively low due to the lack of abutment spread.

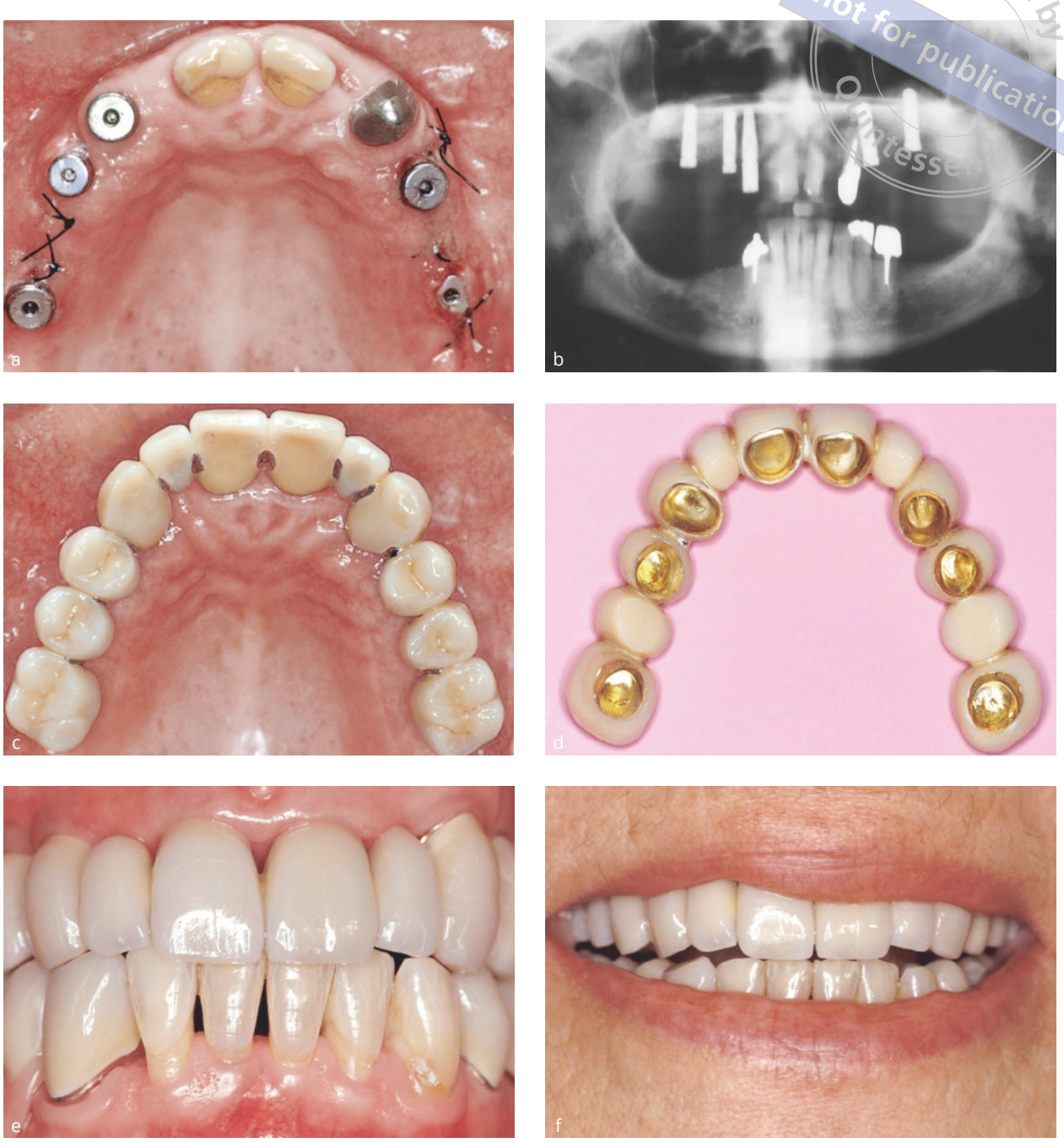

Fig 1-6 Maxillary restoration with augmentation. a. Sinus floor augmentation allowed the placement of more implants, providing a greater number of abutments. **b.** Panoramic image after sinus floor augmentation on both sides. **c.** Prosthetic restoration with a delicately crafted removable and prosthesis that allows for irrigation and interdental cleaning (Prof. Dr. M. Kern, Kiel). **d.** Galvano-telescopic copings. **e.** Intraoral frontal view of prosthesis. **f.** Extraoral appearance of the lips with natural esthetics.

1.3 Atrophy of the Alveolar Process

In contrast to the jaw base, the alveolar process in the maxilla and mandible is not embryologically endochondrally preformed. The alveolar process bone is formed via intramembranous ossification alongside the eruption of teeth to the occlusal plane. Accordingly, this bone also disappears after the teeth are lost. Alveolar ridge atrophy therefore is physiologic and not a disease; however, the consequences, ie, loss of masticatory function and the inability to wear dentures, can lead to disease, especially since the atrophy progresses very rapidly in some patients. Resorption of alveolar bone begins at the buccal bone lamella and later involves the oral bone lamella. The resorption of the maxillary alveolar process is also explained by the principle of bundle bone (Fig 1-7). This type of bone consists of the calcified insertions of ligaments. In the alveolar process, these are the insertions of Sharpey fibers (after William Sharpey, anatomist in London). After tooth extraction, the periodontal ligament disappears as does, inevitably, the bundle bone, which can make up the entire facial lamella of the dental compartments. Loss of the alveolar process is accelerated by, among other things, marginal periodontitis, traumatic tooth extraction, unstable overdentures, and generalized osteoporosis. Particularly severe atrophy with formation of a flappy ridge and irritation fibromas is seen in combination syndrome (Fig 1-8) in the anterior maxilla when hard mandibular residual dentition or mandibular dental implants occlude against a maxillary full denture supported only by soft tissues. As atrophy occurs, there is also decreased blood flow to the jaws, which can cause a reverse flow in the mental artery. The risk of fracture increases due to the reduction in the cross-section of the mandible.

Since the teeth and the alveolar process in the maxilla are physiologically inclined buccally and there is a narrow apical base, height reduction of the bone results in a shift of the ridge center inward, ie, centripetal atrophy of the maxilla (Fig 1-9). With a wide apical base and inwardly inclined teeth in the mandible, the opposite occurs in the mandible. The ridge center moves outward with the height reduction of the alveolar process, ie, centrifugal atrophy of the mandible. This effect can lead to a change in the jaw relationship, causing pseudoprognathism and crossbites in the posterior region. The pseudoprognathism is exacerbated because the vertical occlusal dimension usually decreases over the course of life due to tooth attrition, abrasion, tooth extractions, and periodontal tooth migration, among other factors. This causes the mandible to rotate forward in the temporomandibular joint.

Due to the shrinkage of their attachment sites on the tooth-bearing alveolar process, the perioral mimic muscles lose their tension. The lips curl in and narrow. Because of the loss of support of the teeth and alveolar processes, the cheeks and lips collapse. As a result of the loss of vertical occlusal dimension, the corners of the mouths tend to turn downward, and lip incontinence may occur, causing drooling and Candida infestation. The mentalis muscle increasingly loses its attachment to the anterior alveolar process, and the chin may droop. All in all, the stigma-

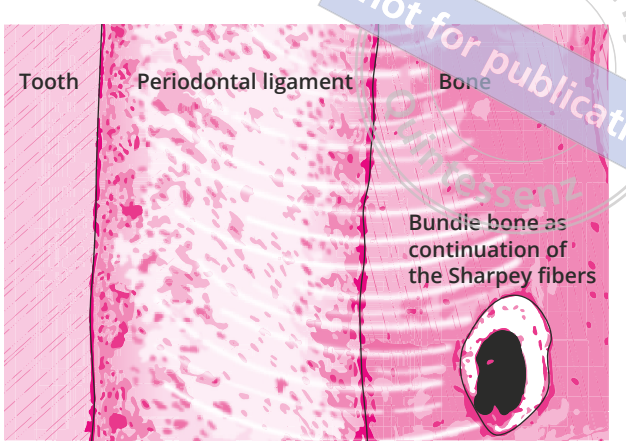

Fig 1-7 Bundle bone is the anchorage of tendons and ligaments in the skeleton. The alveolar process consists almost entirely of bundle bone, especially in the maxilla. Alveolar bone is carried alongside the teeth as they erupt to the occlusal plane. When the teeth are lost, the bundle bone also disappears, initially buccally and later lingually and palatally. This effect explains the rapid volume loss of extraction sockets and alveolar ridge atrophy as a physiologic and unavoidable phenomenon unless the bone is physiologically loaded again by dental implants (ie, the bone-protective effect of dental implants).

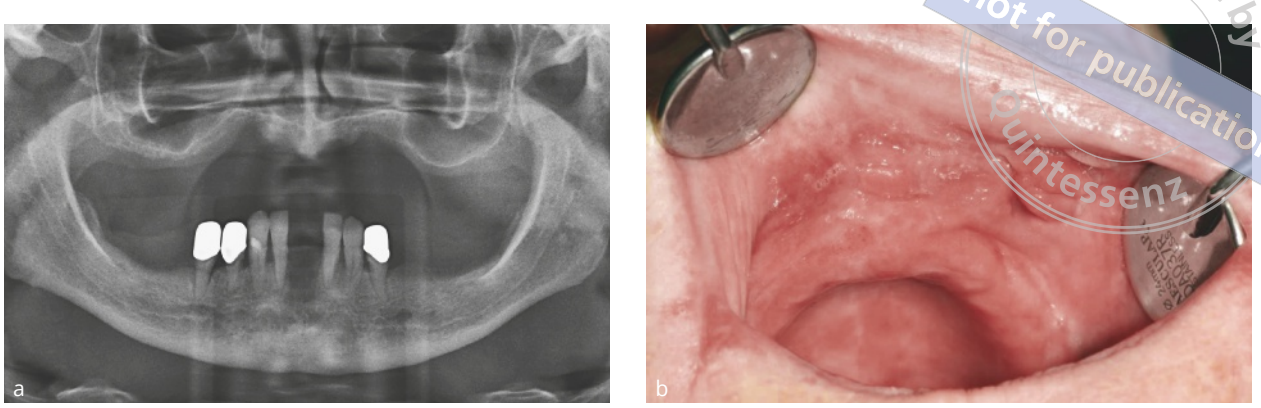

Fig 1-8 Patient with combination syndrome. a. The panoramic view shows the isolated alveolar ridge atrophy in the anterior maxilla. The hard occlusal force of the mandibular residual dentition meets the soft tissue–supported maxillary full denture, which repeatedly tilts forward, especially under protrusive contacts, thus accelerating the physiologic alveolar ridge atrophy in a localized manner. **b.** Irritational fibromas in the anterior maxilla caused by ill-fitting full dentures. These pathologies of the vestibular mucosa result particularly when full dentures are advanced anteriorly well beyond the ridge. If they are overloaded anteriorly due to a combination syndrome and the occlusion is not balanced, the prostheses can increasingly tip forward during advancement. In parallel, the corner of the mouth shows candidiasis.

tizing typical lower face of a toothless old person develops. The decreasing chewing ability often causes a change of diet to diabetogenic food and is statistically correlated with premature onset of dementia,[6] without a causal relationship being proven. Thus, severe alveolar ridge atrophy is not a simple sign of aging but a pathological condition with consequences for the whole organism. Masticatory rehabilitation with dental implants becomes a general medical goal.

1.4 Classifications of Alveolar Ridge Atrophy

The atrophy of edentulous jaws as a whole is best described by the international classification according to Cawood and Howell (1991)[7] (Fig 1-10).

The resorption stage of the individual implant site can be classified by the quarter rule according to Terheyden (2010)[8,9] (Fig 1-11). This classification is based on the typical pattern of resorption of the alveolar process after tooth extraction and has the advantage that suitable treatment methods can be assigned to the respective stages (see chapter 12).

Initially, the facial alveolar wall usually resorbs first. If its coronal portion is atrophied, an implant can still be placed with primary stability, but a vestibular dehiscence defect is present (first quarter). With further atrophy, the entire facial wall is resorbed, resulting in a knife egde ridge (second quarter), with the oral wall still standing (corresponding to Cawood class IV). At this stage, there is usually insufficient bone to stabilize an implant, so a staged bone augmentation is necessary. The next stage is a reduction in the height of the ridge as a whole, with the oral wall still partially intact (third quarter), until finally the alveolar process is completely resorbed (fourth quarter; (corresponding to Cawood class V).

This consideration of the cross-section of the individual implant site should be supplemented by an occlusal view of the *alveolar bone envelope* (Fig 1-12). The term alveolar bone envelope was originally established in the orthodontic and peri-

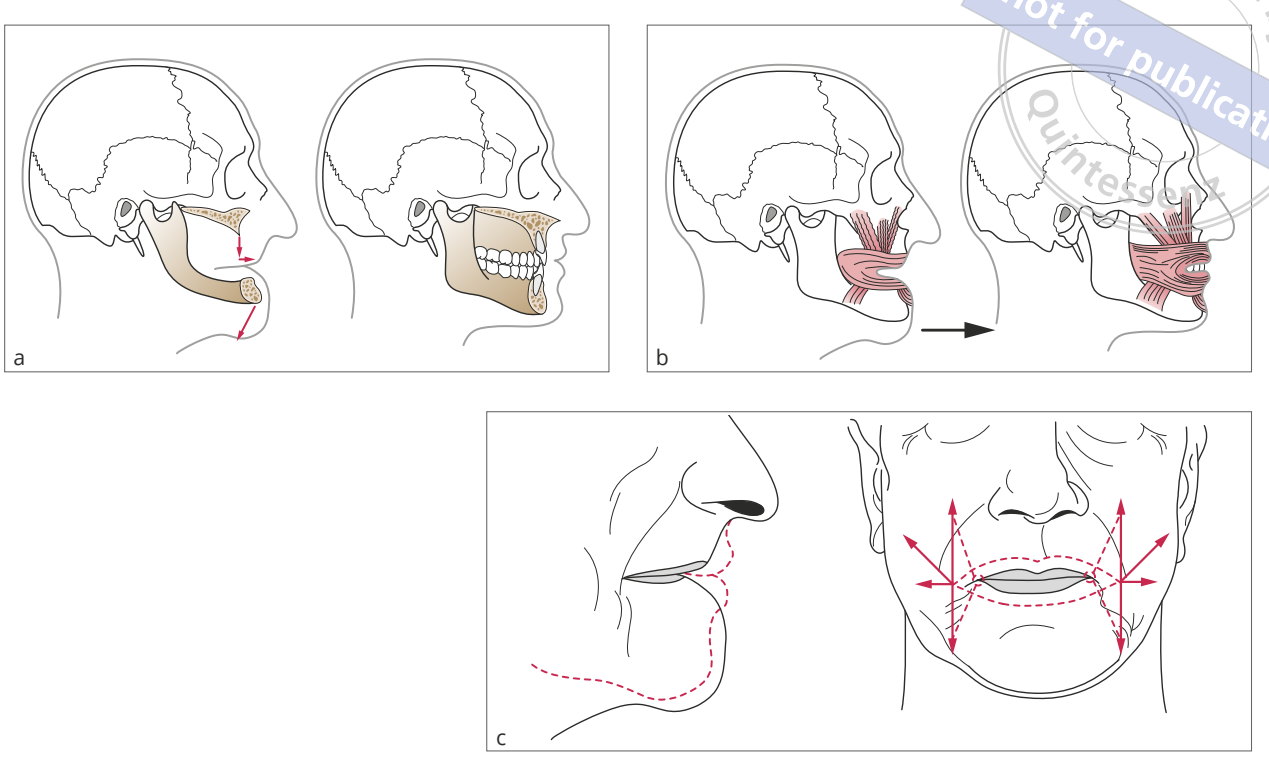

Fig 1-9 Effects on alveolar bone atrophy. a. Alveolar ridge atrophy has resulted in maxillary retroposition due to the oblique position of the superior alveolar process and the narrow apical base of the maxilla (left image). The reduced vertical occlusal dimension due to alveolar ridge atrophy has resulted in counterclockwise rotation of the mandible at the pivot point of the temporomandibular joint. This has caused pseudoprognathism. Alveolar bone augmentation (eg, by LeFort I interposition in the maxilla and sandwich interposition in the mandible) leads to forward and downward movement of the upper alveolar process in the direction of the red arrows. The goal is to create the conditions present with a full dentition (right image) through dental implants. **b.** Due to alveolar ridge atrophy, the perioral mimic muscles have lost their bony attachment point. The lips become narrower and inverted, and especially the mentalis muscle loses its upper attachment point at the level of the roots of the mandibular incisors. As a result, the chin sags. Passive relining of the lips by a dental prosthesis does not improve the muscle attachments or traction. Bony regeneration of the alveolar processes can restore a condition similar to that before tooth loss. **c.** In contrast to conventional complete dentures, implant-supported dentures can achieve better pretension of the facial muscles because they do not dislocate as easily as conventional complete dentures when the lips are pulling back. If the alveolar processes are also reconstructed by bone augmentation, the mimic muscles regain their correct attachment points. In addition, stretching of the lower face and retraction of the chin can be achieved by increasing the vertical occlusal dimension, so that the nasolabial and supramental folds are smoothed. The goal is a relaxed and younger facial expression as a side effect of masticatory rehabilitation. (Adapted from Cawood.[5])

odontal literature[10] and describes the buccal contour line of the alveolar bone in the dental arch. If intact neighboring periodontium is present in a single-tooth gap, this is referred to as a contained defect within the envelope (single- or double-tooth gap with intact neighboring periodontium). The situation becomes more difficult with larger gaps or gaps without neighboring periodontium with a poorly defined envelope or in the edentulous jaw with an undefined envelope.

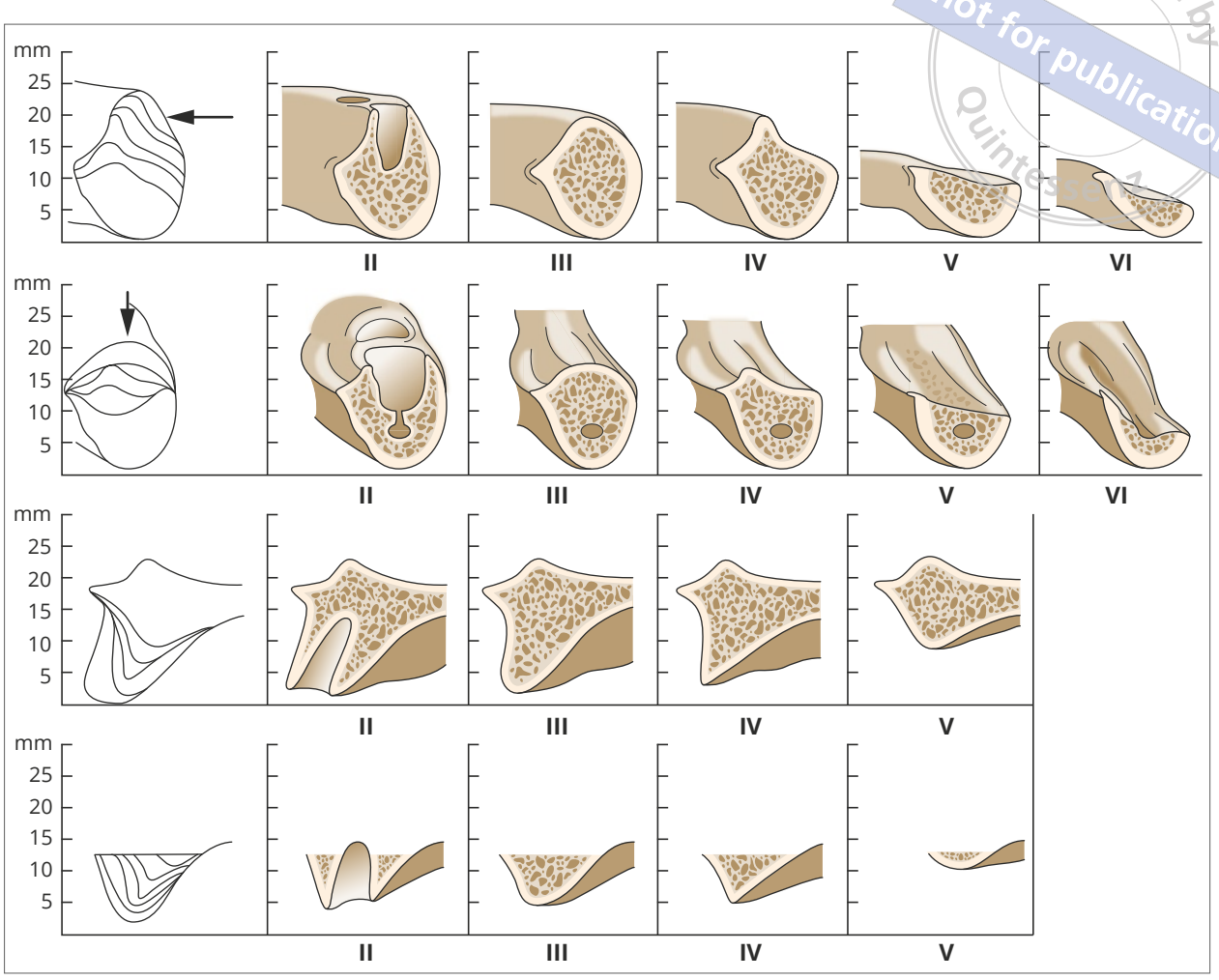

Fig 1-10 The classification of alveolar process atrophy of the edentulous maxilla according to Cawood and Howell.[7] (Adapted from Cawood.[5])

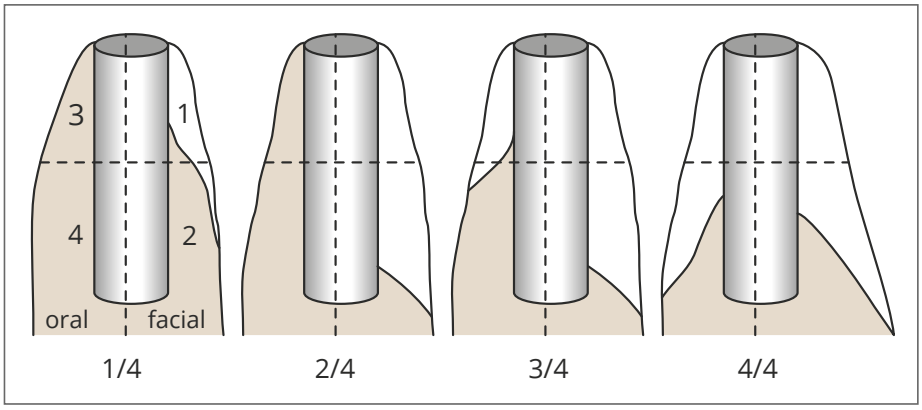

Fig 1-11 Classification of the implant site following the natural resorption stages in quarters, according to Terheyden.[8]

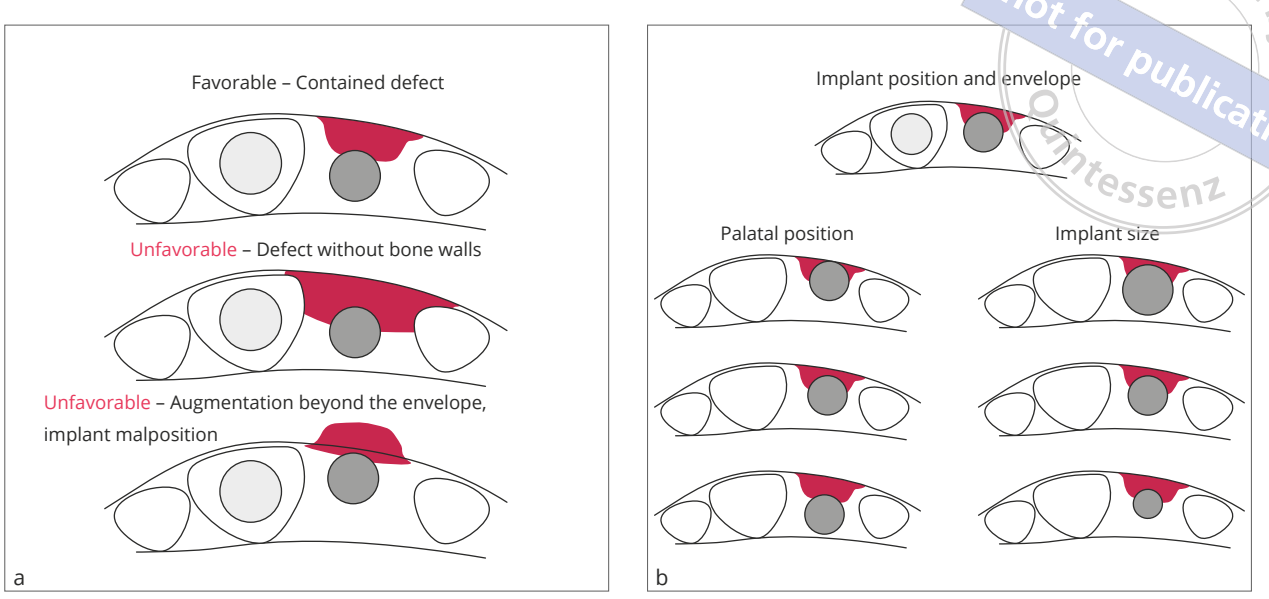

Fig 1-12 **a.** The position within the envelope (contour line of the dental arch) is important for the prospective success of a localized augmentation. Also, it is favorable for success if a defect is enclosed by bony walls (ie, a contained defect). **b.** The chances of success of a localized augmentation increase if the augmentation volume is within the envelope. Therefore, the implant should usually be placed against the palatal/ lingual wall and should not be too large in diameter.

1.5 Alternatives to Alveolar Ridge Augmentation

Augmentation surgery always comes at a price, in terms of surgical burden, discomfort, and cost for the patient; surgical complexity for dentists and their teams; and increased possibility of complications. The risks and benefits of augmentation surgery should always be well communicated and weighed. Many efforts are underway to reduce the surgical burden of bone augmentation through alternatives and minimally invasive techniques.

Overall, the development of implantology, supported by new materials, is showing that good masticatory function can be achieved even without augmentation measures. This is particularly relevant for patients undergoing antiresorptive therapies, which do not allow bone augmentation surgery at all. Furthermore, the success of therapy is made less dependent on the individual skill of a clinician, which is a general trend in medicine. Examples of augmentation-free implant surgery are zygoma implants or the renaissance of the subperiosteal-implants in severe alveolar ridge atrophy (see chapter 14).

1.6 Prosthetic Versus Regenerative Approaches to Defects

According to Newton, every movement produces a countermovement (Actio = Reactio). Many patients and dentists today are no longer satisfied with the osseointegration of an implant at any position for the mere fixation of an overdenture; the implant is expected to be placed in the ideal functional and esthetic position. In implant dentistry, a prosthetic approach to treating defects can be differentiated from a regenerative therapeutic approach, describing two polarizations of a continuum of options (Fig 1-13).

In the defect prosthetic approach, missing tissue and function is replaced by foreign material, ie, a prosthesis made of plastic, ceramic, and metal, similar to a prosthesis for missing limbs. In this therapeutic approach, the dental implant is a retaining anchor for the prosthesis. Because the implant is also a risk factor due to the risk of biologic complications, as few implants as possible are planned, sometimes as few as only one. The rationale is that

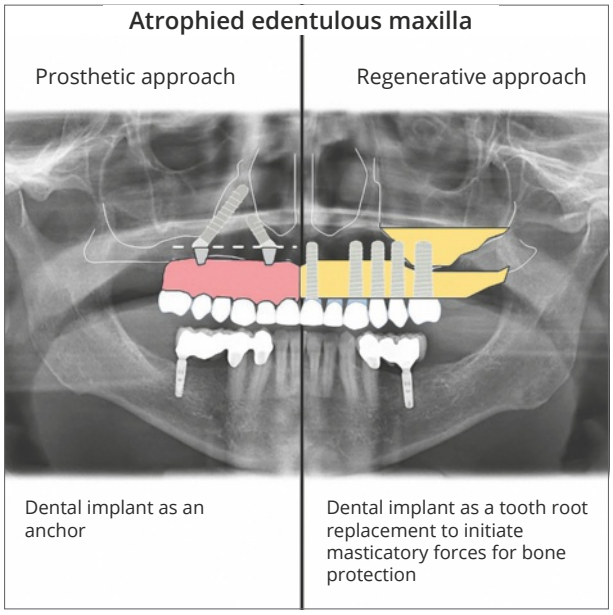

Fig 1-13 Prosthetic versus regenerative approaches to defect treatment.

the patient can concentrate their hygiene efforts on a few posts, and that fewer implants equate to lower costs.

The replacement of missing body parts with a prosthesis is the conventional procedure in many medical fields; the regenerative approach of augmentation is seen as the future.[11] This approach has broader goals than mere prosthesis retention, including a functionally and biologically complete regeneration of the missing tissue by the body's own material and a long-term, if not lifelong, prognosis of implants. In regenerative replacement, the primary function of the implant is as a tooth root for the introduction of masticatory forces into the jaw. Only the introduced masticatory forces initiate the functional remodeling of the tissues, which ensures their lifelong preservation. In the body, only what is functionally defined is preserved. Therefore, with this approach, there is also more of a tendency for a higher number of dental implants. This concept incorporates delicate dentures reduced to single crowns with little metal or other foreign materials, almost a conservative dentistry approach.

In practice, the decision between the two therapeutic approaches is usually relativized by the age of the patients, in that younger and healthy patients tend to be good candidates the regenerative approach, and older and sick patients are better served by the defect prosthetic approach. This is related to the physical resilience, the service life, the baseline situation of the defects, the patient's hygienic ability, and the desired masticatory function.

1.7 Soft Tissue Augmentation and Management

For didactic reasons, bone augmentation and soft tissue augmentation are often treated in separate lectures and textbooks. In clinical practice, this separation is difficult. This book instead follows a common path for both, because a good implant prognosis requires a mucosal thickness of 3 mm[12] and keratinized tissue width of 2 mm,[13] which corresponds to the dimensions of the biologic width. Also, bone grafts heal better and undergo less resorption under thick soft tissues than under thin ones. Some of the goals of bone augmentation, such as preventing gray show-through of titanium (Fig 1-14), can also be achieved with soft tissue grafts, but their long-term stability is not as well documented scientifically, with 1- to 3-year data available,[14] while 10-year data are available for the same indication in bone.[15] However, the soft tissues

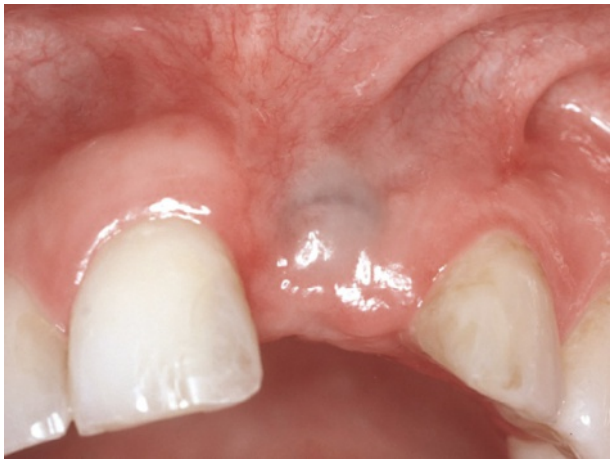

Fig 1-14 Titanium shows through thin soft tissues.

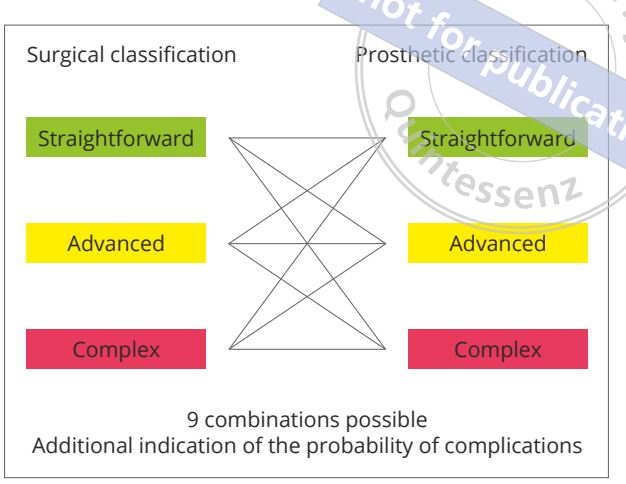

Fig 1-15 The SAC classification of the International Team for Implantology (ITI)[16] for the surgical and prosthetic aspects of implant treatment.

must also not be too high or overaugmented to avoid the formation of pseudopockets as a space for pathogenic flora. Finally, bone augmentation will only heal without loss if the soft tissue wound above it heals reliably. Good soft tissue management is therefore an inseparable part and a basic requirement of augmentation surgery (see chapter 7).

1.8 Risk Management: SAC Classification

Augmentation surgeries usually have an increased degree of difficulty compared to simple implant placement and belong to groups A and C of the SAC classification[16] (Fig 1-15). Augmentation operations place higher demands on the surgeon's training and equipment than S-level implant procedures:

- **S**traightforward: No augmentation. This corresponds to a standard treatment without increased surgical anatomical risks and/or prosthetic problems.
- **A**dvanced: One-stage augmentation. In this situation, there is still enough residual bone for simultaneous implant placement. This refers to a demanding treatment with increased surgical and/or prosthetic risk potential and corresponding equipment and training requirements for the team.
- **C**omplex: Two-stage augmentation. In this situation, there is not enough bone for simultaneous implant placement. Complex implant treatment at the specialist level with associated risks is required.

1.9 Teamwork

Due to the stress and risks of surgical intervention, many patients and dental practitioners decide against implant treatment in cases of bone deficiency, although perhaps both sides would benefit from an osseointegrated prosthesis. By collaborating with surgically specialized colleagues with appropriate expertise, this threshold can be lowered. The discomfort associated with wound healing can be temporarily outsourced to the surgeon by a referring dentist. Subsequent prosthetic treatment is performed back in the home practice. In such a team, the family dentist functions as the architect of the overall treatment, coordinating the individual steps and continuing the patient's care thereafter.

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B

OPERATING TECHNIQUES

6 Bone Grafting: Standards and Surgical Technique

Unlike most other tissues, bone can be freely avascularly grafted even in larger volumes and layer thicknesses. In the case of bone, unlike many soft tissues, survival of all cells of the graft is not necessarily required, because bone morphogenetic protein (BMP)-driven remodeling can also restore avascular grafts to vital functional bone. The natural regenerative potency of autogenous bone can be therapeutically stimulated and controlled in terms of form and speed by augmentation materials.

6.1 Conditions for Bone Grafting

Nonsterile environment and defensins

Although the oral cavity is not a sterile surgical field, bone wounds in the mouth heal with astonishing speed compared to other body regions, and bone can even be freely grafted via intraoral approaches. This is due in part to β-defensins.[1] Defensins are a group of small proteins with a high proportion of cationic and hydrophobic amino acids that have a high affinity for cell membranes not containing cholesterol, as found only in bacteria. There they form membrane pores that lead to the death of the microorganism. Defensins are part of the genetically ancient innate nonadaptive immune system and make up much of the content of the granules of neutrophil granulocytes, in which they serve to kill bacteria. They are also expressed in high concentrations by cells of the oral mucosa and jawbone.[2,3] Despite this special defense situation in the oral cavity, careful preoperative bacterial count reduction and sterile instrumentation are prerequisites for the clinical success of an augmentation.

In the case of bone grafts, care must be taken to ensure complete fill of the defects with coagulum of the defects, which can be supplemented by admixing venous blood to the bone grafts in case of doubt. The cells of the medullary cavity may need to be allowed to connect to the defect by perforating the cortical bone of the recipient bed. In a small human study, perforation of the recipient bone during augmentations resulted in greater and faster graft vascularization and better bone formation.[4]

Storage of bone grafts

Bone proteins are stable up to about 60°C, above which they denature, especially the BMPs. This, in

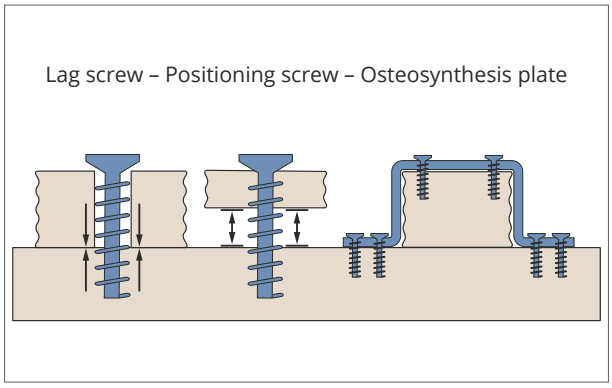


Fig 6-1 Three types of osteosynthesis for intraoral bone grafts: Lag screw, positioning screw, and plate fixation.

Fig 6-2 Commercially available microscrew osteosynthesis set in a sterilizable container (1.5 mm Centre Drive System, KLS Martin).

addition to cell vitality, is the reason why drilling on bone should only be done under abundant water cooling. Normal sterile physiologic saline solution is sufficient for cooling.

Experimental data are available on the proper storage conditions for autogenous bone grafts after harvesting. The vitality of bone cells of bone grafts decreases significantly by dry storage compared to storage in physiologic saline or covering with compresses moistened in physiologic saline. In contrast, storage in more elaborate media such as cell culture medium did not provide a significant advantage.[5] Platelet-poor plasma also did not provide an advantage over saline.[6] Since cell viability decreased significantly as early as 2 hours after harvesting, bone grafts should be harvested immediately prior to placement if possible.[7] Ice cooling (without freezing) increased cell viability compared to room temperature storage.[8] In an experimental study, bone grafts with vital cells resulted in 30% more bone growth than grafts without vital cells.[9]

Mechanical rest

Mechanical stability during the healing phase should be ensured by good fixation of the bone grafts with screws and by avoiding soft tissue pressure.

Internal resorption of the bone graft is desired and necessary in the sense of "creeping substitution" (see chapter 2). Beyond the healing phase, desired internal resorption occurs as part of the functional remodeling of the bone, starting from the recipient side of the bone graft. After about 3 to 4 years, free bone grafts will be almost completely internally resorbed and replaced by regrown new autologous bone. The bone cutting cones are responsible for the remodeling process. To ensure that the bone cutting cones can advance from the recipient bone into the graft without interference, a form-fitting adaptation of a bone block to the recipient bone or at least relining with autogenous chips is helpful. An intermediate layer of bone graft substitute should therefore be avoided under bone blocks, and when using the shell technique with autogenous compact blocks, autogenous chips should be used to backfill the shell.

Fixation of bone block grafts

Mechanical stability is essential for bone healing. There is almost constant unrest in the oral cavity due to chewing, tongue movements, and swallowing. Therefore, it is important to reliably secure bone grafts against movement during augmentations. This is done by means of lag screws, set screws, or plate fixation (Fig 6-1). Suitable screw sizes (eg, 1.5 mm Micro System, KLS Martin) are available from osteosynthesis material manufacturers (Fig 6-2).

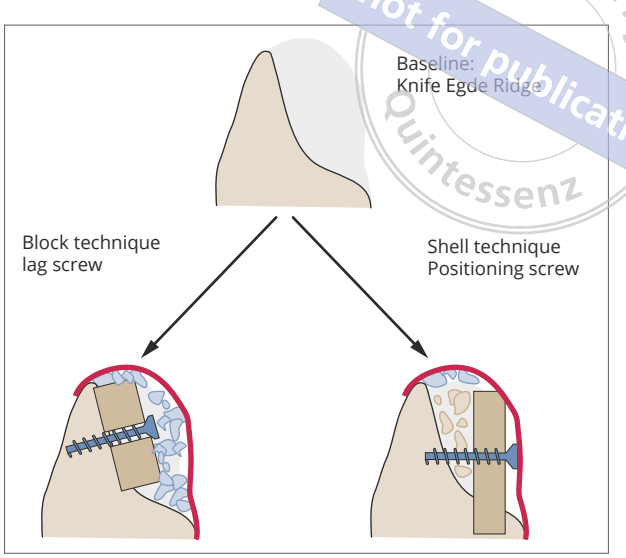


Fig 6-3 Two types of fixation of an intraoral bone block graft. Bone shells should not be backfilled with bone substitute material, only with autogenous bone chips to allow rapid remodeling by bone cutting cones.

The screw is applied as a lag screw, by drilling the screw access channel in the graft larger than the largest screw diameter. Then the screw head pulls the graft against the bone base when it is screwed in, wedging it. If tightening is not desired, a positioning screw is indicated. These are needed for shell techniques, for example (Fig 6-3). For this purpose, the screw channel is not overdrilled in the graft. When the positioning screw is screwed in, the distance between the graft and the base is adjusted first. The distance does not change even with the strongest tightening of the screw. If there is no space to fix a lag screw, eg, due to existing implants or tooth roots, the graft can also be fixed with osteosynthesis plates with slightly increased materials use and cost (Fig 6-4).

As a rule, at least two screws are placed per block to secure it against rotational loading. Smaller grafts and bone substitute material should be placed around the block as fillers. Small grafts that cannot support screws are somewhat stabilized by the blood coagulum and the tension of the uninjured periosteum (Fig 6-5).

A barrier membrane performs well for positional fixation of smaller grafts. However, the block graft provides much more stability after osteosynthesis than all membrane techniques. When handled correctly, it is stable as a rock in the surf. This allows more frequent single-stage implant placement, even if there is insufficient support in the local bone volume for the implants. In addition, the regeneration potential and resorption stability of the block graft are higher than those of particulate materials in guided bone regeneration (GBR), even in critical cases. Osteosynthesis material removal after 4 months should be performed minimally invasively via stab incisions, if possible, because deperiostation of the block can jeopardize it and triggers unnecessary surface resorption (Fig 6-6).

Bone graft healing time

For the practice workflow, it makes sense to set the healing times of the two-stage bone grafts uniformly to about 4 months prior to implant placement. This period is based on the healing time required for ridge augmentation with an autogenous block graft from the external oblique ridge. If less than 4 months is allowed for autogenous block grafts to heal, the block may detach from the recipient bone during implant drilling due to lack of a strong connection. However, with longer healing periods, the surface absorption progresses too much.

The sinus elevation healing period can also be established as 4 months, as it frequently has to be performed together with block grafts in the edentulous maxilla. With autogenous iliac cancellous bone, a sinus elevation heals in as little as 4 weeks; only bone substitute requires 8 months. The mean value of 4 months is achieved with a mixed bone graft (25%/75%).

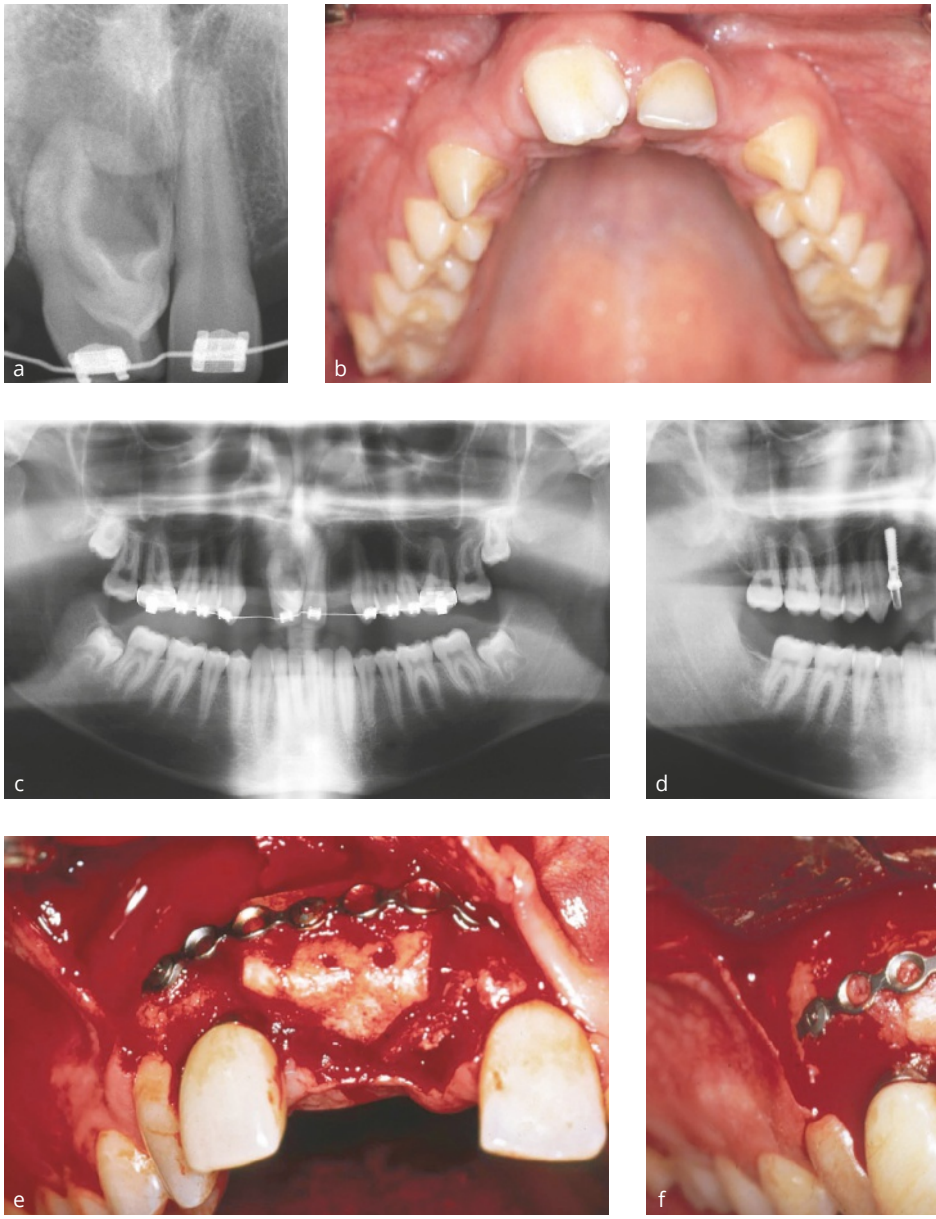
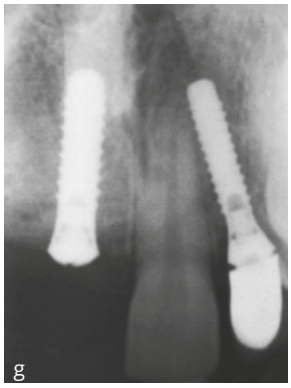
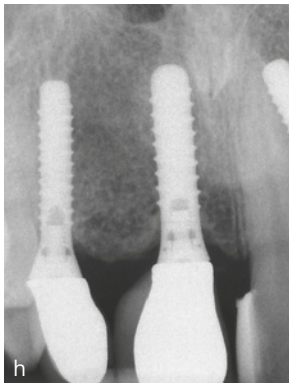
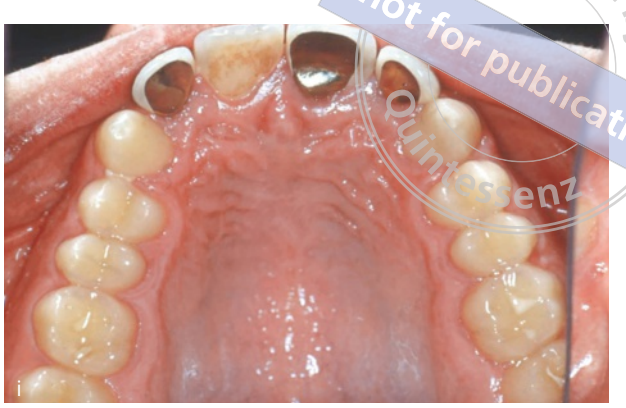
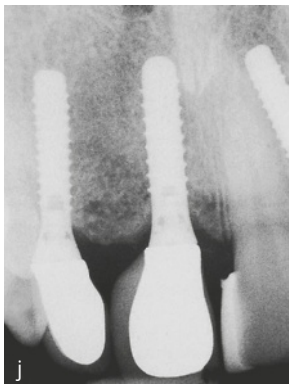


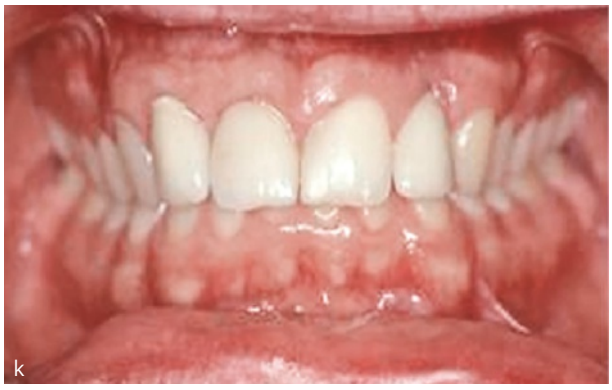
Fig 6-4 Long-term follow-up of a bone block graft. a. Tooth malformation in the maxillary right central incisor area with apical radiolucency in a 17-year-old patient. **b.** Clinical image of the right central incisor malformation combined with agenesis of both lateral incisors. **c.** Panoramic radiograph after gap opening. **d.** Panoramic radiograph after placement of dental implants in the maxillary lateral incisor sites immediately after gap opening. **e.** Defect after removal of the right central incisor filled by a contoured autogenous bone block graft from the external oblique ridge using an osteosynthesis plate. The block was multiply perforated to accelerate healing. **f.** Four months after grafting, removal of the osteosynthesis material and placement of the dental implant. Bleeding from the perforation holes is a sign of the beginning of vital healing of the block.











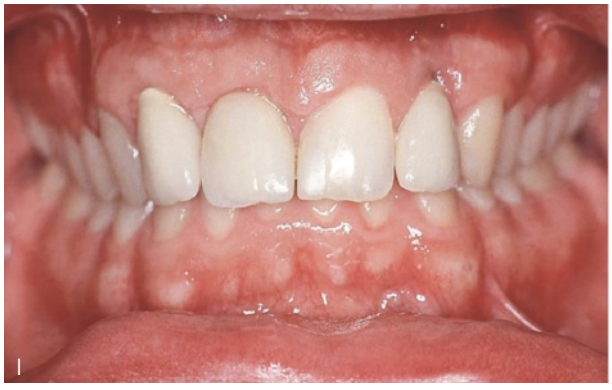


Fig 6-4 Long-term follow-up of a bone block graft. g. Radiograph after implant placement in the block graft. **h** Peri-implant bone resorption as a sign of remodeling with formation of a peri-implant soft tissue cuff (biologic width). **i.** Mirror image of the maxilla after prosthetic restoration. **j.** Radiograph 7 years later, nearly identical to that in *h*, with no further marginal bone resorption. Remodeling is complete, and the bone is now functionally defined. **k.** Intraoral situation at 24 years of age. Slight recession is evident at the implants in the agenesis sites. Stable tissue conditions at the site of bone transplantation. **l.** Intraoral situation at age 33. Stable tissue conditions at the site of bone block grafting.

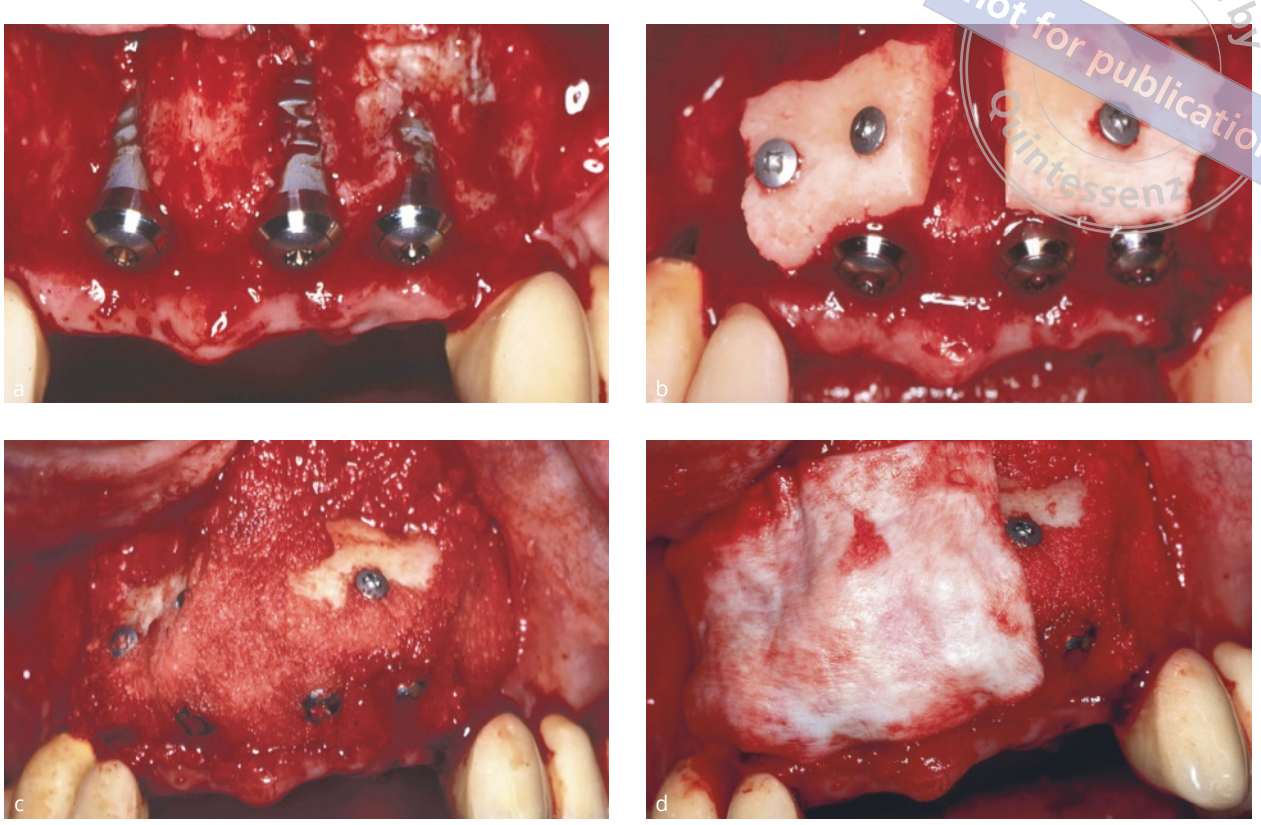


Fig 6-5 Bone block grafting for a large maxillary defect. a. Dehiscence defect (1/4 according to the quarter rule; see Fig 1-11) at both central incisor the left lateral incisor implants with single-stage implant placement. **b.** Two autogenous bone blocks from the external oblique ridge. The block in the right central incisor region was regularly fixed with two screws to secure it against rotational movement. The block in in the left central incisor site fit tightly to the bone surface so that one screw was sufficient. **c.** Autogenous bone chips from the bone filter were used for contour filling. **d.** Covering with a collagen membrane to stabilize the position of the bone trap and to protect the block grafts against resorption.

Sandwich interposition in edentulous segments and jaws also requires 4 months, as does GBR with a mixed graft and ridge splitting.

6.2 Mixed Bone Grafts

Autogenous cancellous bone is rich in cells and BMPs and is osteoinductive. The material heals quickly, within about 4 weeks, but also tends to resorb rapidly. Mineral bone substitute material is devoid of cells and BMPs and therefore takes many months to heal from the defect walls by osteoconduction, if it ossifies fully at all. On the other hand, xenogeneic bone mineral, for example, is very stable to resorption resistant, so that a selected augmentation level is maintained until the implants are osseointegrated and from then on can contribute to the maintenance of the augmentation by functional loading. The best strategy is therefore to use autogenous chips with the resorption-stable bone substitute material. The mixing ratio is a compromise between good healing and good resorption stability. According to animal data on sinus elevation, this compromise is best achieved with a ratio of 25% autogenous chips to 75% bone substitute.[10] Ridge augmentations are more challenging as a defect type than sinus elevations; here, osteoinduction is even more important. In a

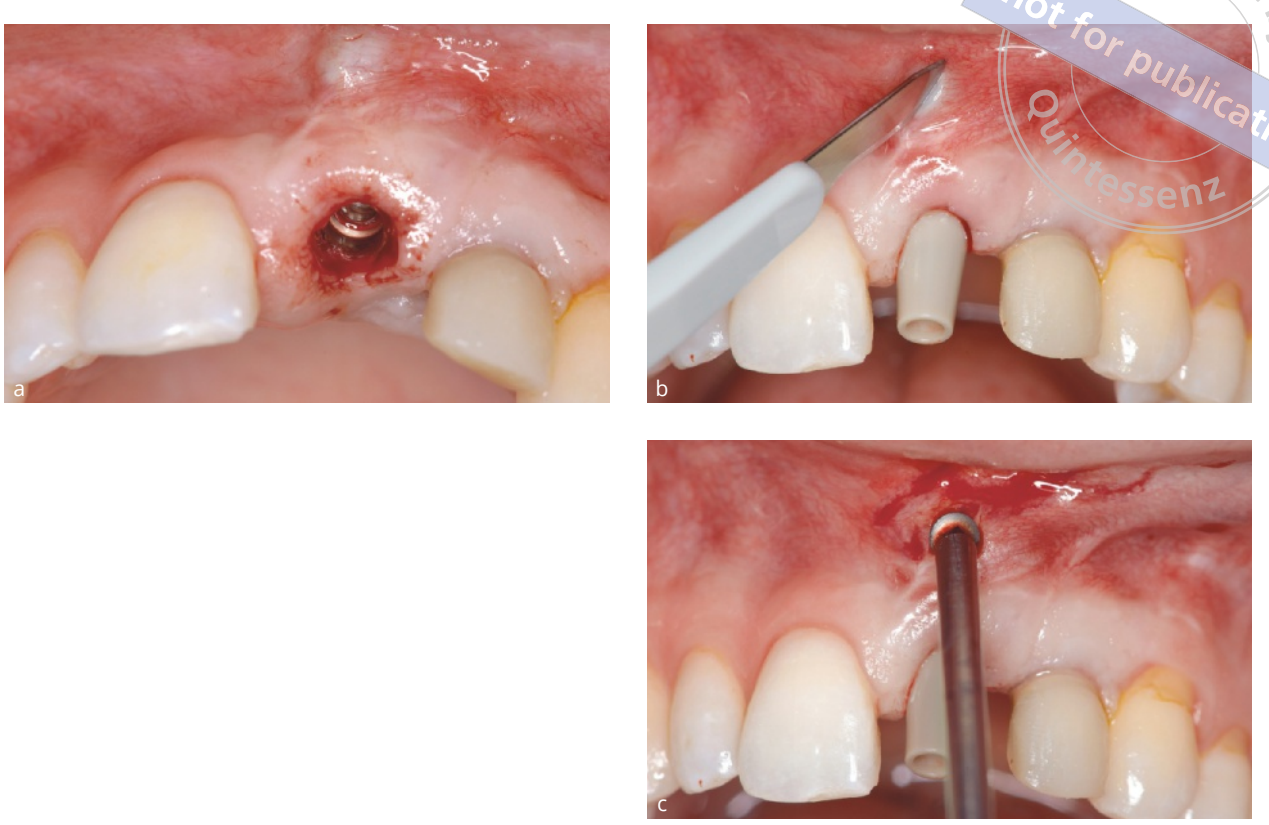


Fig 6-6 Minimally invasive osteosynthesis material removal. a. Implant exposure after single-stage bone block grafting. The position of the osteosynthesis screw can be identified by the protrusion and anemia in the vestibule after palpation. **b.** To avoid compromising the block by re-entry and deperiostation, the screw is minimally invasively located by stab incision. **c.** The square head of the Centre Drive System attachment automatically engages in the screw head at depth, even without direct vision. This allows the screw to be removed without raising a flap.

clinical study on ridge augmentation, the autogenous bone in a 90:10 mixture was too low in dose; a 60:40 mixture performed better.[11]

Autogenous chips have the disadvantage that they were usually obtained in the contaminated oral cavity and are therefore themselves bacterially contaminated. If porous bone substitute material is inoculated with bacteria, there is a risk of biofilm formation and thus infection of the augmentation. This can be minimized by first mixing the porous bone graft material with sterile venous blood in a sterile dish. In this way, all cavities of the bone graft substitute are sealed with sterile liquid and all surfaces with sterile blood protein, so that bacteria do not find an interface on which to settle. However, the blood does not yet coagulate after this mixing, so that the particles of the bone substitute material do not hold together and are difficult to apply.

Tissue thrombokinase (tissue factor) is required for coagulation to activate the extrinsic pathway. It makes sense in nature that in an extraction wound the bleeding stops at the level of the alveolar opening. This is ensured by saliva, which is a rich source of tissue thrombokinase.[12] If some filter bone is added to the blood/bone substitute mixture, the blood will clot unless the patient is taking anticoagulants. Filter bone, when harvested intraorally, always contains some saliva and therefore tissue thrombokinase. After a few minutes, a firm sheet of bonded bone and bone

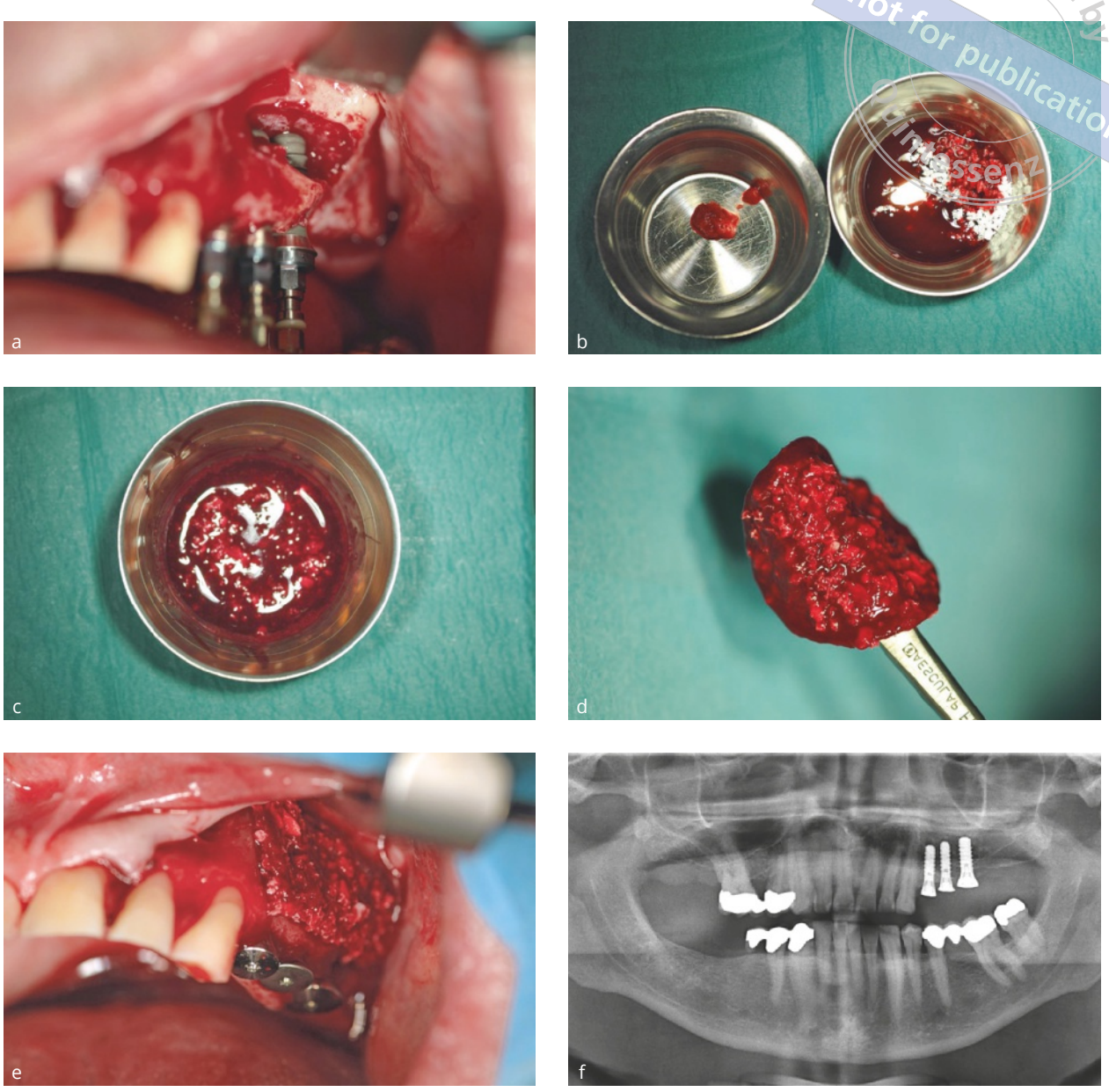


Fig 6-7 Mixed bone graft. a. Sinus elevation case with single-stage implant placement. **b.** Bone graft material is mixed with sterile venous blood. However, this does not clot. Bone chips from the bone filter (left) can trigger clotting. **c.** Clotting takes a few minutes. In this case, the volume fraction of the autologous chips is well below 10% because little chip material could be collected on the facial wall of the maxillary sinus and during implant drilling. **d.** Coagulation produces easily manageable pieces of bone substitute material that can be grasped with forceps and have intrinsic stability in the wound. **e.** The clot is placed in the sinus floor, and the pieces are sculpted onto the exposed implants. **f.** Postoperative panoramic image.

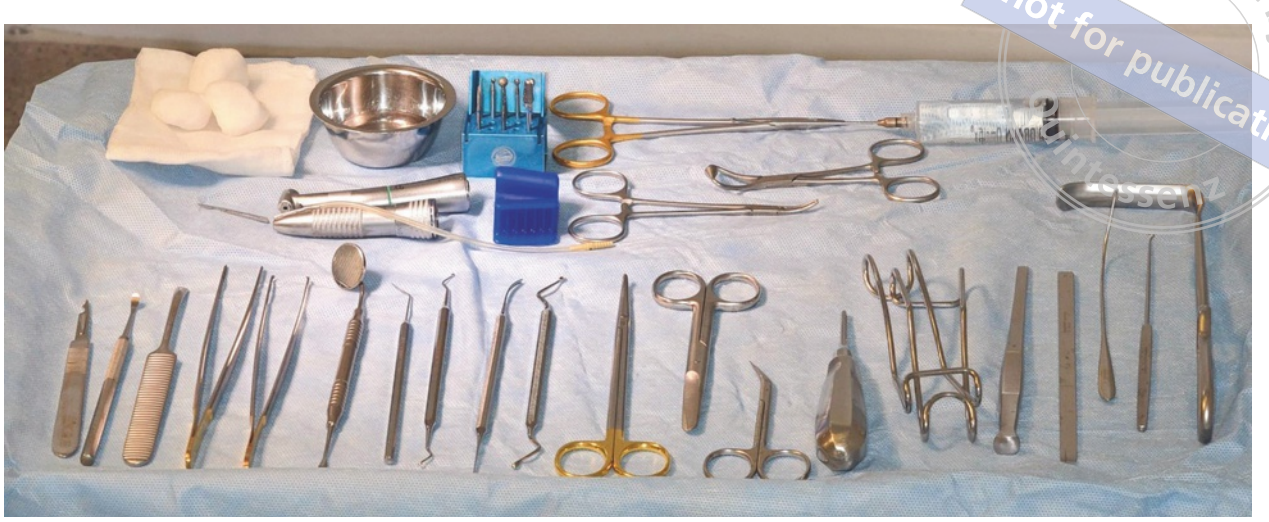


Fig 6-8 Standard instrument table for intraoral bone grafting.

substitute particles is formed, which can be grasped with forceps and applied in the wound without additional stabilization (Fig 6-7).

6.3 Resorption Protection of Bone Block Grafts

A sometimes disturbing disadvantage of avascular bone block grafts is their difficult-to-predict initial surface resorption in the healing phase and later. To compensate for surface resorption, augmentations with bone grafts can be overcontoured by 1 to 2 mm and, to be on the safe side, more autogenous bone than is thought necessary can be harvested. Preventive measures against surface resorption of autogenous block grafts include covering the graft with bone graft substitute[13,14] and alternatively[15] or additionally with membranes.[16] These clinical measures are based on the idea that osteoclasts reach out to the bone surface from blood vessels in the overlying soft tissue, and one blocks this pathway to slow unwanted surface resorption until internal resorption via bone cutting cones has stabilized the block and allowed it to heal. Another way to slow surface resorption is to use very hard, highly mineralized bone types such as block graft from the external oblique ridge. Bone blocks from the cranial vault are even harder and thus more resistant to resorption. Osteoclasts initially degrade bone with acid. This capacity is exhausted when the mineral content of the bone to be resorbed is high. A similar acid-buffering effect on osteoclasts is achieved by overlaying a bone graft with bone substitute material, as mentioned above. Experimentally, the author's group also performed drug inhibition of surface resorption by inhibiting osteoclasts with topically applied bisphosphonates.[17] If a bone graft attached to the alveolar process is not functionally loaded by implants or teeth after the healing phase, complete resorption of the attached bone substance usually occurs within a few years. The placement of the graft within the natural alveolar arch (called the envelope) also plays a role here. Grafts outside these natural boundaries are at greater risk of resorption than those inside the envelope.

6.4 Instruments

Basic tools

The basic instrument set is a small but high-quality standard oral surgery instrument set (Fig 6-8). For grafts in the field of periodontal plastic surgery, a set of micro-instruments is recommended (Fig 6-9).

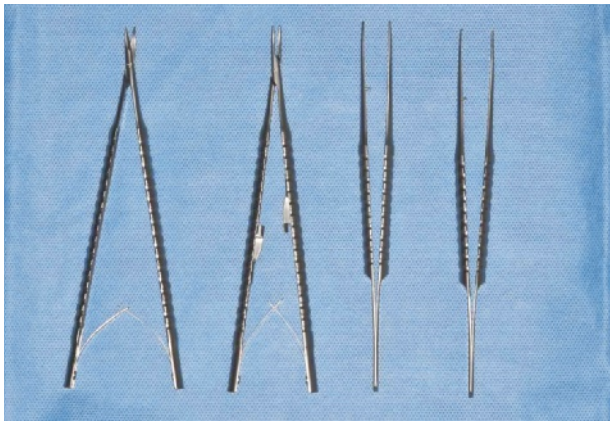


Fig 6-9 Micro-instruments for grafting in periodontal plastic surgery.

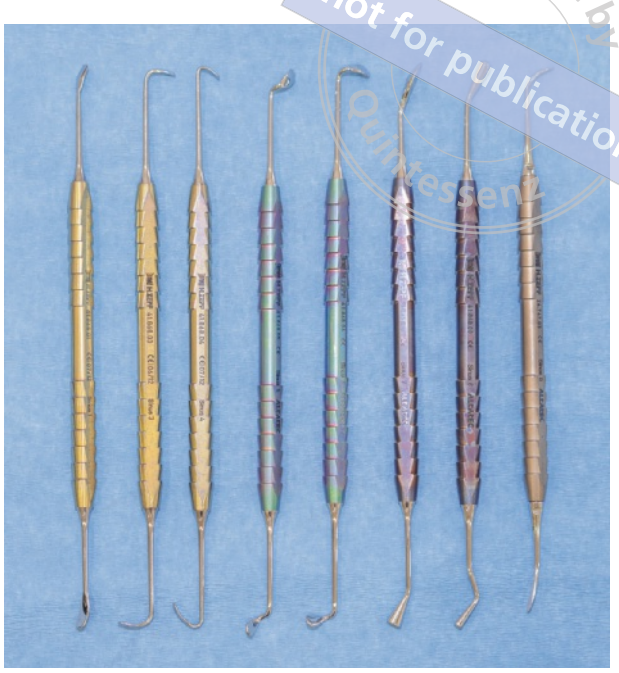


Fig 6-10 Standard set of rounded and angled special curets for external sinus elevation.

For implant procedures, it is important to have a small caliper to measure defect lengths, ridge widths, gap widths, and distances to teeth.

A set of sinus elevation curets is required for maxillary sinus floor interventions, for example, the set according to A. Kirsch (manufactured by Helmut Zepf; Fig 6-10). Gracey curets and other instruments can be added as required.

Optical magnification aids

A microsurgical instrument set is added to the basic set when working under optical magnification. The use of optical magnification aids or a surgical microscope are up to the preference and habits of individual surgeons but is rather uncommon in bone surgery. When using rotary instruments such as the Lindemann bur, it is much more important to have a good view of the surrounding area, for example, to avoid necrosis due to frictional heat at the lip margin (Fig 6-11), which may escape the surgeon's attention under the small field of view of the microscope or magnifying glass. The accuracy of suture closure is most likely to benefit from magnification, and it is recommended for training reasons to suture under the microscope every now and then. With the exception of apicoectomy, for which a better outcome has been demonstrated for the use of magnification aids for the creation and tightness control of the apical seal,[18] there is insufficient evidence in the literature for optical magnification in bone surgery. In periodontal surgery, there is research evidence of benefits for the use of optical magnification aids and for a microsurgical approach.[19]

Osteotomy instruments

The basic equipment includes a green contra-angle handpiece and a blue handpiece. For osteotomies, the basic work is performed with steel ball burs, Lindemann burs, and diamond balls (Fig 6-12).

The use of a piezoelectric device involves an additional expense to the rotating instruments that are on the table anyway because of the implant placement. Certain work, such as the exposure of an inferior alveolar nerve, is more successful with the piezoelectric technique. Its main advantages are selective cutting and the narrow cutting width, which is gen-

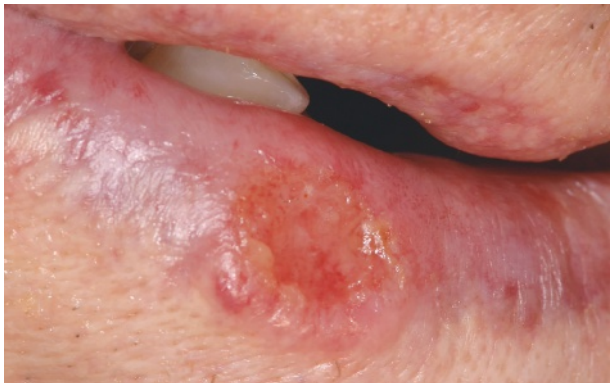


Fig 6-11 Complication: Burn of the lower lip caused by the drill shaft with insufficient field of view due to excessive optical magnification.

Fig 6-12 Sterile milling box with standard bone burs. Back row: ball burs of ascending size; on the far right is a technical bur for processing provisional acrylic restorations. Front row: Lindemann, diamond flame, and diamond ball burs (Komet, Brasseler).

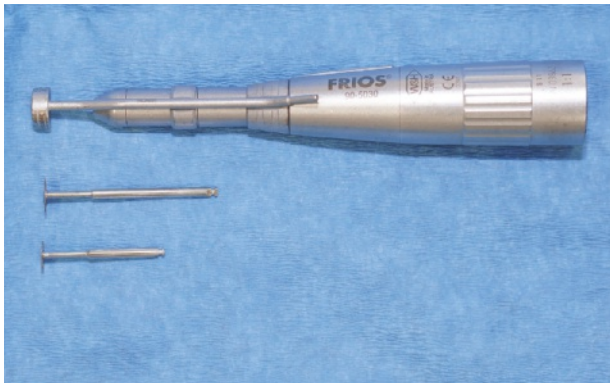


Fig 6-13 Frios MicroSaw according to Khoury.

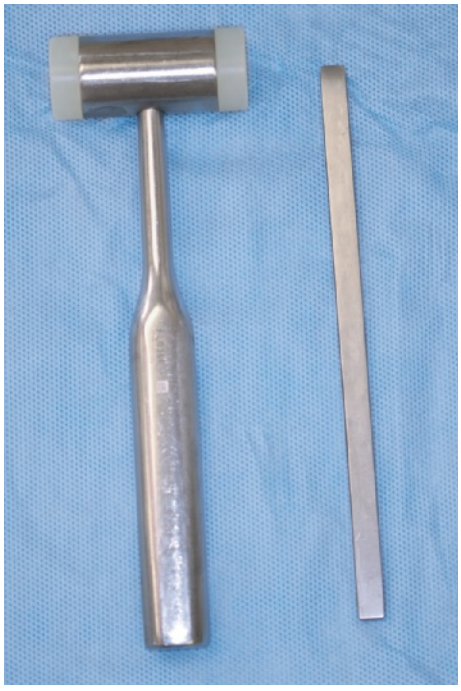


Fig 6-14 Osteotome (chisel) with an 8-mm blade and a surgical mallet.

tle on tissues. However, a systematic review found that when the sinus membrane was exposed, no advantage was shown for the piezoelectric method in terms of perforation rate.[20] The piezoelectric device has the disadvantage of a lower working speed and higher heat generation. Compared to the Lindemann bur, the coolant is less able to reach the depth of osteotomies, for example, when removing blocks, due to the small osteotomy widths. Second, much of the vibration energy is already absorbed at the osteotomy margin, making cuts at depth very cumbersome. There are more frequent indications for using the Frios MicroSaw according to Khoury (Dentsply Sirona), which is also operated with a surgical motor, for ridge splitting, block removal, and access to the maxillary sinus (Fig 6-13).

For ridge splitting, a sharp blade osteotome (blade chisel), 8 mm wide, and a mallet are recommended (Fig 6-14). Smaller ridge splits can also be carried out well with the Bein elevator, which is already included in the standard instrumentation.

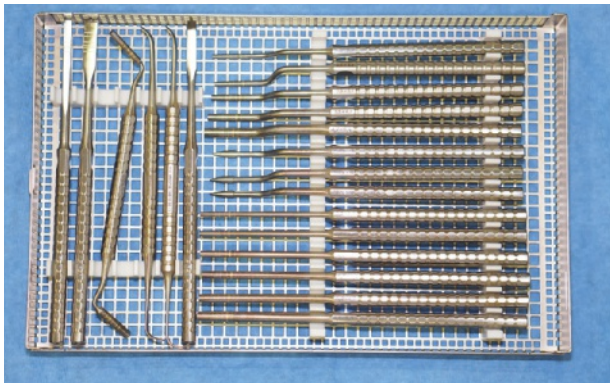


Fig 6-15 Set of osteotomes for internal sinus elevation.

For condensations and internal sinus floor augmentations, a set of standardized osteotomes of assorted sizes should be available, which are also used with a mallet (eg, Stoma Dental; Fig 6-15).

Disposable scrapers (SafeScraperTwist, Geistlich) and a sterilizable bone filter for reuse (Schlumbohm) are suitable for bone harvesting. There are many different bone mills, differing mainly in size. For alveolar ridge atrophy and for thin grinding of block grafts, the medium-sized Mondeal Bone Mill (MBM) is suitable. The bone mill according to R. Quétin (Hess Medizintechnik GmbH, Munich) is somewhat more powerful in design (see chapter 3).

A set of trephine drills of various diameters completes the instrument set.

Special instrument sets, for example from the Bone Management System (Meisinger), can be added for the standard transfer of bone blocks and for mechanical ridge splitting.

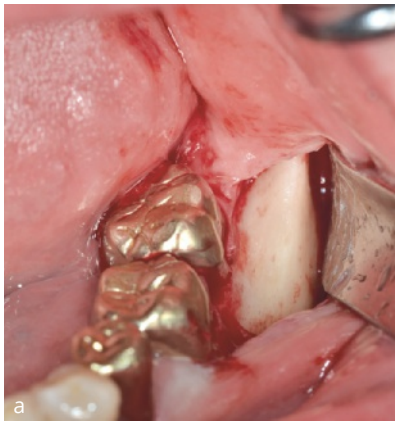
6.5 Surgical Procedure

Harvesting a block graft from the external oblique ridge

A block graft from the external oblique ridge is usually harvested from the mandible via a sulcus incision incision lateral to the three most posterior teeth with the Lindemann bur (Fig 6-16). The distal relief incision is made 45 degrees to the teeth on the ascending mandibular ramus. It should not be longer than 1 cm because otherwise the buccal nerve is endangered. The mobility of the flap is created mostly by the subperiosteal detachment of the flap onto the ascending mandibular ramus. Since the inferior alveolar nerve may be sometimes located directly under the buccal compact bone, a preoperative CBCT is useful but not mandatory.

The bur should always be guided strictly parallel to the outer cortex so as not to injure any internal structures of the mandible. The bur should only be countersunk until the first bleeding as an indication of exclusive corticotomy. The initial enthusiasm for piezoelectric surgery in third molar removal has subsided, and recent studies show no advantage for piezoelectric devices, but the disadvantage of a longer surgical time.[21] Piezoelectric surgery has the disadvantage of sometimes overheating bone grafts, as the thin osteotomy gaps allow little coolant access in contrast to the wide gaps of the conventional bur. However, the wide gaps are not a disadvantage, if you collect the chips in a bone trap anyway. It is therefore advisable to run a bone filter to catch the quite large volume of chips. A prospective compar-

Fig 6-16 Bone block harvesting from the external oblique ridge. a. Visualization via a gingival margin incision and short relief incision at 45 degrees on the ascending jaw branch. **b.** A monocortical relief cut is made in the bone anterior and posterior to the block graft with the Lindemann bur under abundant cooling. The bur is always parallel to the outer wall of the jaw. **c.** The harvesting site is usually lateral to the third molar site. The vertical bone sections extend through the cortical bone, but no further. **d.** The longitudinal cut is marked by a series of dots. **e.** The dots are connected monocortically with the Lindemann reamer. It is not countersunk deeper than the first bleeding point through the cortex. **f.** The apical cut is made through the half-submerged ball bur. **g.** The ball bur creates an apical groove as a predetermined breaking point, and any chips are collected in the bone trap. **h.** A Bein root elevator gently luxates the bone block out. **i.** The block is a pure cortical graft, with little cancellous bone adhering internally. **j.** The block is removed with forceps and stored temporarily in moist conditions. **k.** Further chip material is removed with the ball cutter and collected in the bone trap. This smoothens sharp edges in the donor site defect. **l.** Wound closure by two single knot sutures using Supramid 5-0 (Resorba).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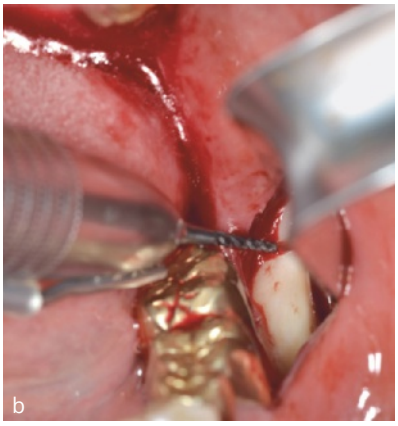
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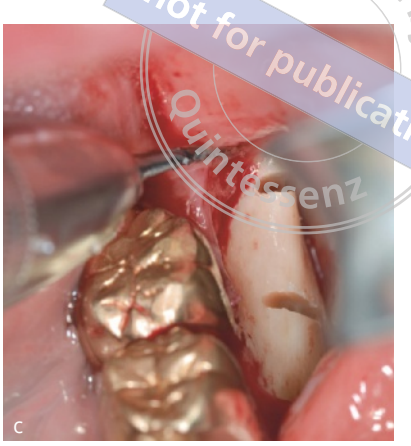
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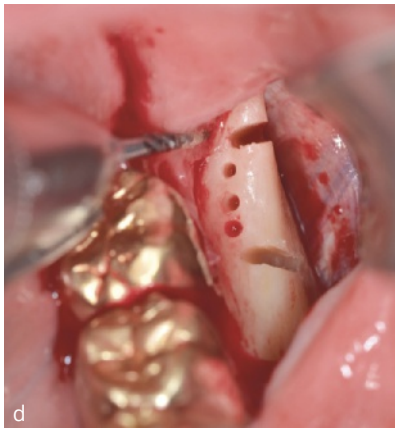
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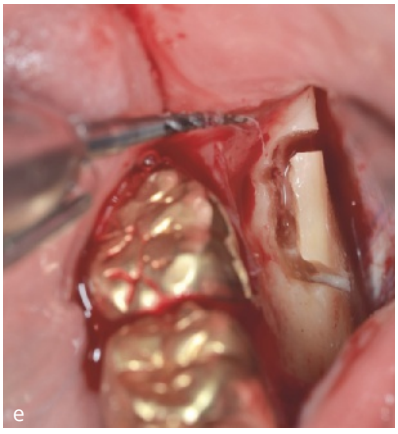
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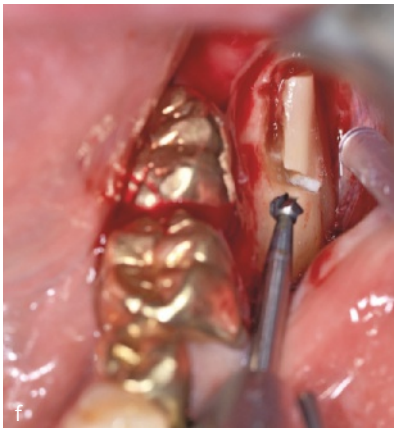
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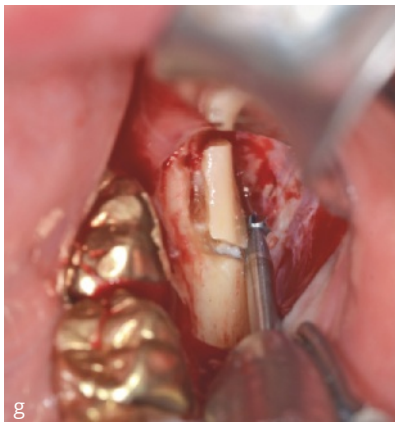
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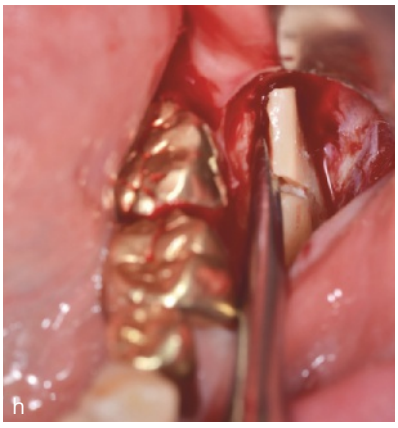
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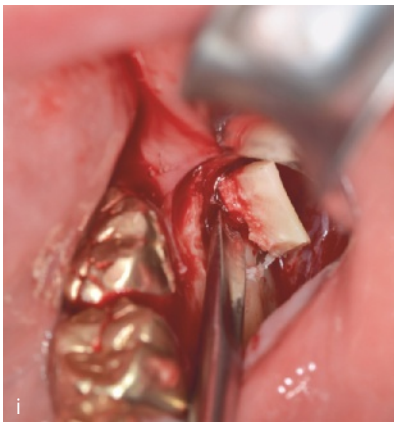
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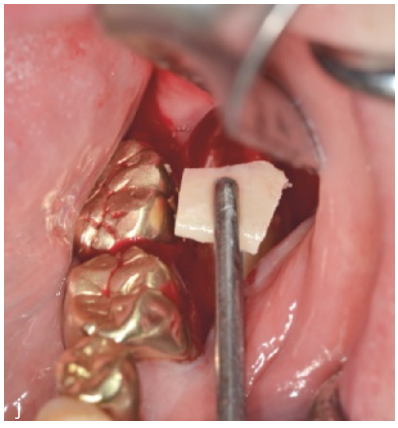
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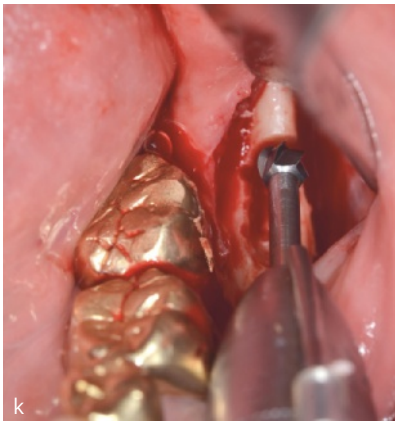
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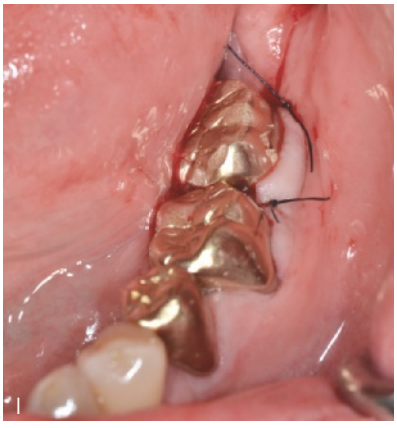
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ative study of piezoelectric surgery to Khoury's diamond cutting disc showed a three times longer surgical time and a lower block volume for piezoelectric surgery with the same patient complaints. In the author's view, there is little reason to set up a second osteotomy system on the operating table for block removal, because the rotating instruments have to be kept on hand anyway for implant placement.

A block graft from the external oblique ridge is generally 2 to 3 mm thick. The apical cut can be made by the Khoury diamond circular saw, but it is easier to half plunge a 4-mm ball mill and create a groove as a predetermined breaking point.

The block can be split into thinner bone shells. Grinding the block into chips is also possible. With most bone mills, the grinding can be done in such a way that chips are produced and a thinner flat block remains, which can then be used, for example, in a shell technique[22] (Fig 6-17).

In cross section, the graft from the external oblique ridge often has the appearance of the letter *J* and is therefore also called a J-graft. The block-shaped compact graft from the external oblique ridge is obtained in the horizontal ramus of the mandible lateral to the second and third molars. Because the external oblique ridge normally transfers most of the masticatory forces to the horizontal ramus of the jaw, block harvesting should not be done too far posteriorly on the ascending ramus but rather lateral to the teeth. For 6 weeks after bone harvesting, the patient should not bite down too hard. Bicortical harvesting in the ascending ramus creates the risk of mandibular angle fractures because the tendon of the strongest masticatory muscle, the temporalis muscle, inserts into this loaded structure.

Complications of block removal from the external oblique ridge include sensory disturbance of the inferior alveolar nerve and dental damage. The author observed a delayed mandibular fracture in an osteoporosis patient who was treated conservatively. If the J-grafts are harvested correctly, sensory disturbances are rare if the depth of cut of the instruments is strictly limited to the compact bone. Second harvesting of bone from the same site has also been reported[23] because the non-atrophying and functionally defined bone of the external oblique ridge grows back in humans. There is no need for defect filling with bone grafts. Sometimes surgical removal of impacted third molars is indicated in implant patients, and thus the surgical approach to the retromolar area.

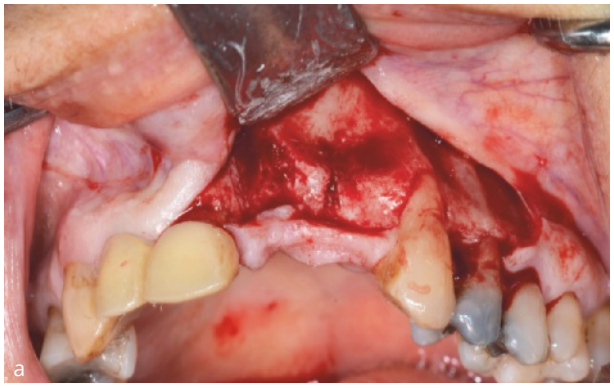
Bone harvesting from the anterior iliac crest

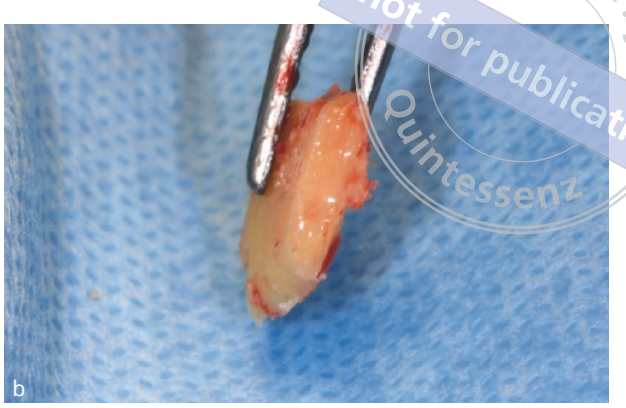
The prerequisites for graft removal from the iliac crest are a sterile operating room, surgical skin disinfection, sterile draping, and a procedure that follows the rules of aseptic surgery.

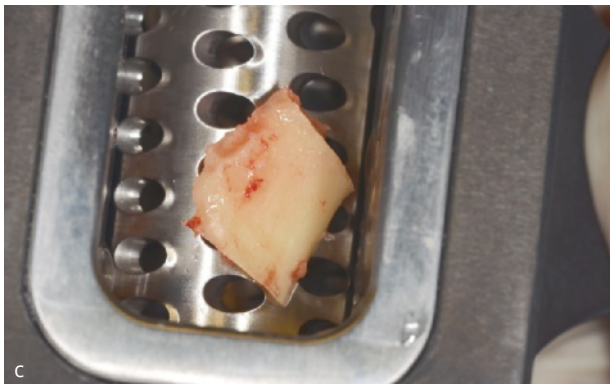
The incision is approximately 4 cm long and is located within the iliac crest clearly dorsal to the anterior iliac spine (Fig 6-18). The incision is made medial to the iliac crest because one does not want to place the scar in the areas directly on the bony crest that would be in contact with a belt worn on the waist of pants. After dissection through the skin fat slightly laterally, one exposes the white aponeurosis between the gluteus and external oblique abdominal muscles and separates them in the middle of the crista. With this technique, painless or at least minimally painful removal is possible without injury to the musculature.

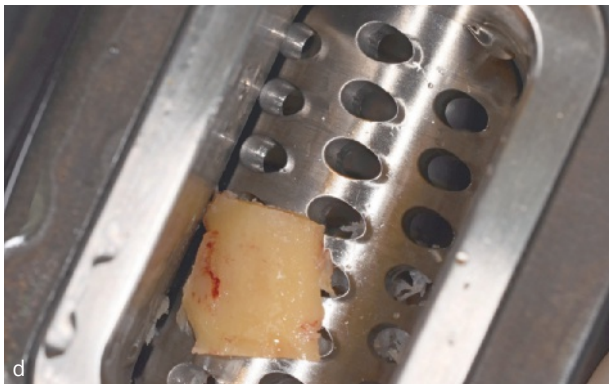
Now the periosteum of the inner side of the pelvis and from the medial part of the iliac crest is detached. Different parts of the bone can be viewed by moving the overlying soft tissue. As a rule, monocortical chips are taken from the inner side, along the inner half of the curve of the crest. The inner curve is removed by a Lindemann cutter or oscillating saw in several longitudinal pieces that measure approximately 1 × 1 cm in cross section. From this defect, monocortical strips can now be cut like piano keys toward the center of the pelvic blade with the oscillating saw. They are detached from the outer cortical bone by sliding a broad chisel along it. It is necessary to know that the outer cortex approximates the inner cortex relatively quickly and can fuse with this a few centimeters below the crest. One should avoid perforation of the outer cortex (bicortical harvesting) for implantology purposes.

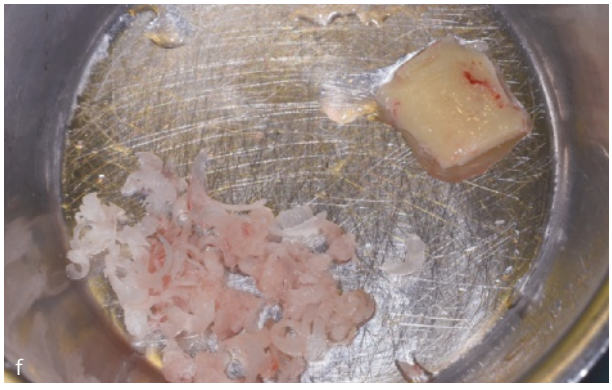
Finally, infiltration with bupivacaine 0.5%, drainage without suction, and an elastic bandage to support the soft tissues are recommended.











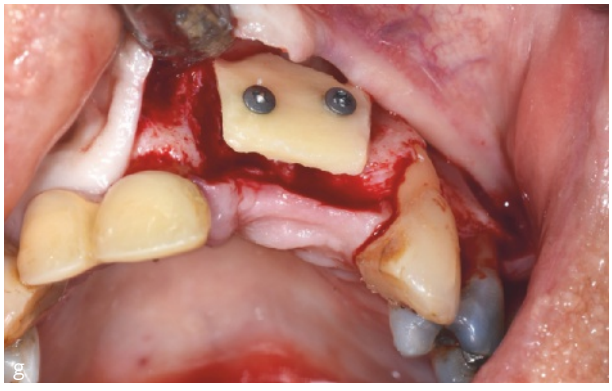
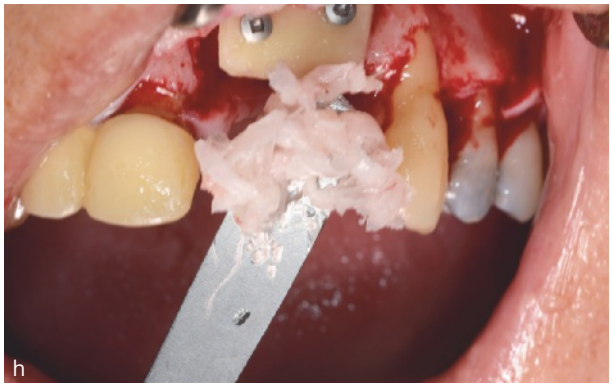
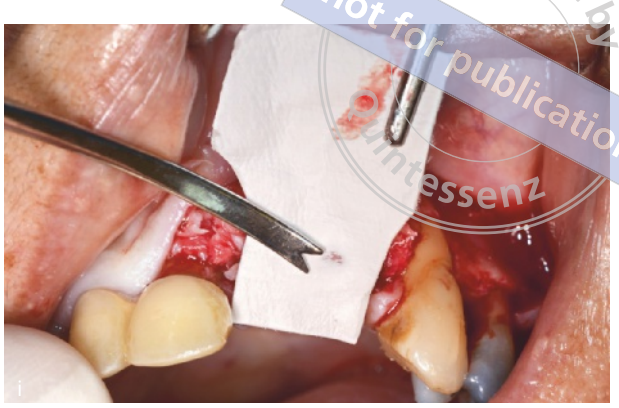
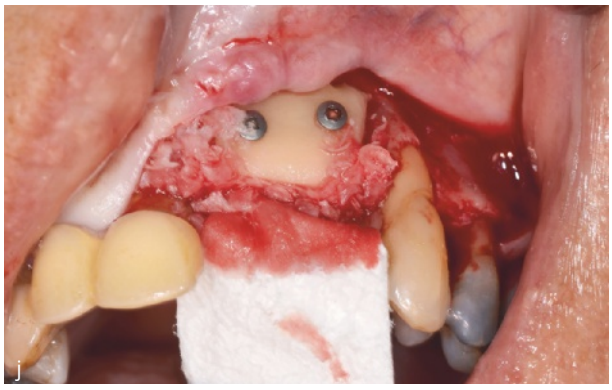
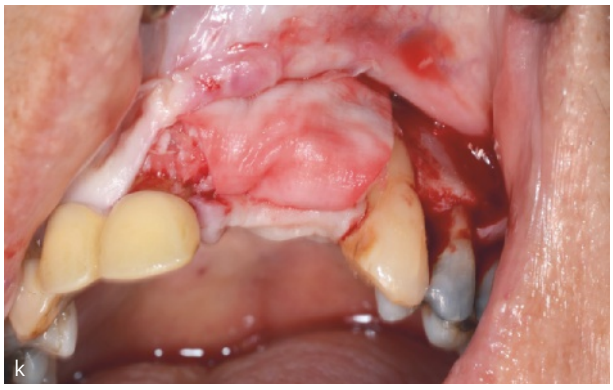


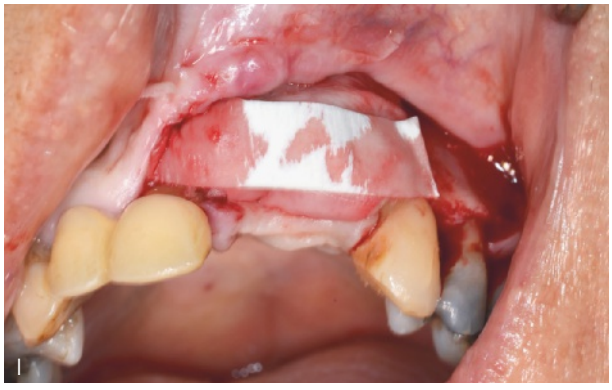
Fig 6-17 Bone block grafting using a shell technique. a. Initial situation with horizontal ridge defect (1/2 according to the quarter rule; see Fig 1-11) in the maxillary left central and lateral incisor region. **b.** Bone block from the external oblique ridge. **c.** In a bone mill (Ustomed, Ulrich Storz), the block is ground thin to form a shell. **d.** This is done in several stages until the desired thickness of 1 mm is reached. **e.** The cortical chips collect in the drum of the bone mill. **f.** All autogenous bone materials are temporarily stored moist until use. **g.** In the defect the shell defines the future outer contour of the alveolar process with an allowance for resorption of about 1 mm in width and height. It is secured with two positioning screws (1.5-mm system, KLS Martin).

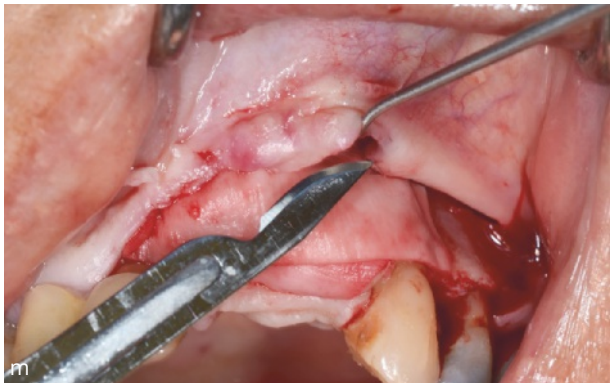












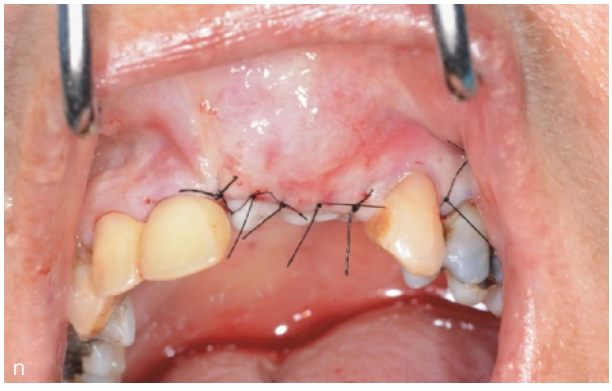


Fig 6-17 Bone block grafting using a shell technique. h. The shell is backfilled exclusively with autogenous chips. **i.** A membrane made of native collagen (Bio-Gide, Geistlich) is cut into a tongue shape and adapted with a Luniatschek gauze packer. **j.** The tongue of the membrane is placed under the palatal flap. **k.** The membrane is moistened with a few drops of saline and is self-adaptive. **l.** A section of the membrane is applied as a double layer in the area of the highest resorption. **m.** The flap mobilization takes place by means of a single hook retractor and 15c scalpel. **n.** Wound closure is very tight with a few interrupted sutures because the gingival margin incision and the midline incision of the alveolar ridge can be well adapted due to the rigid marginal gingiva.

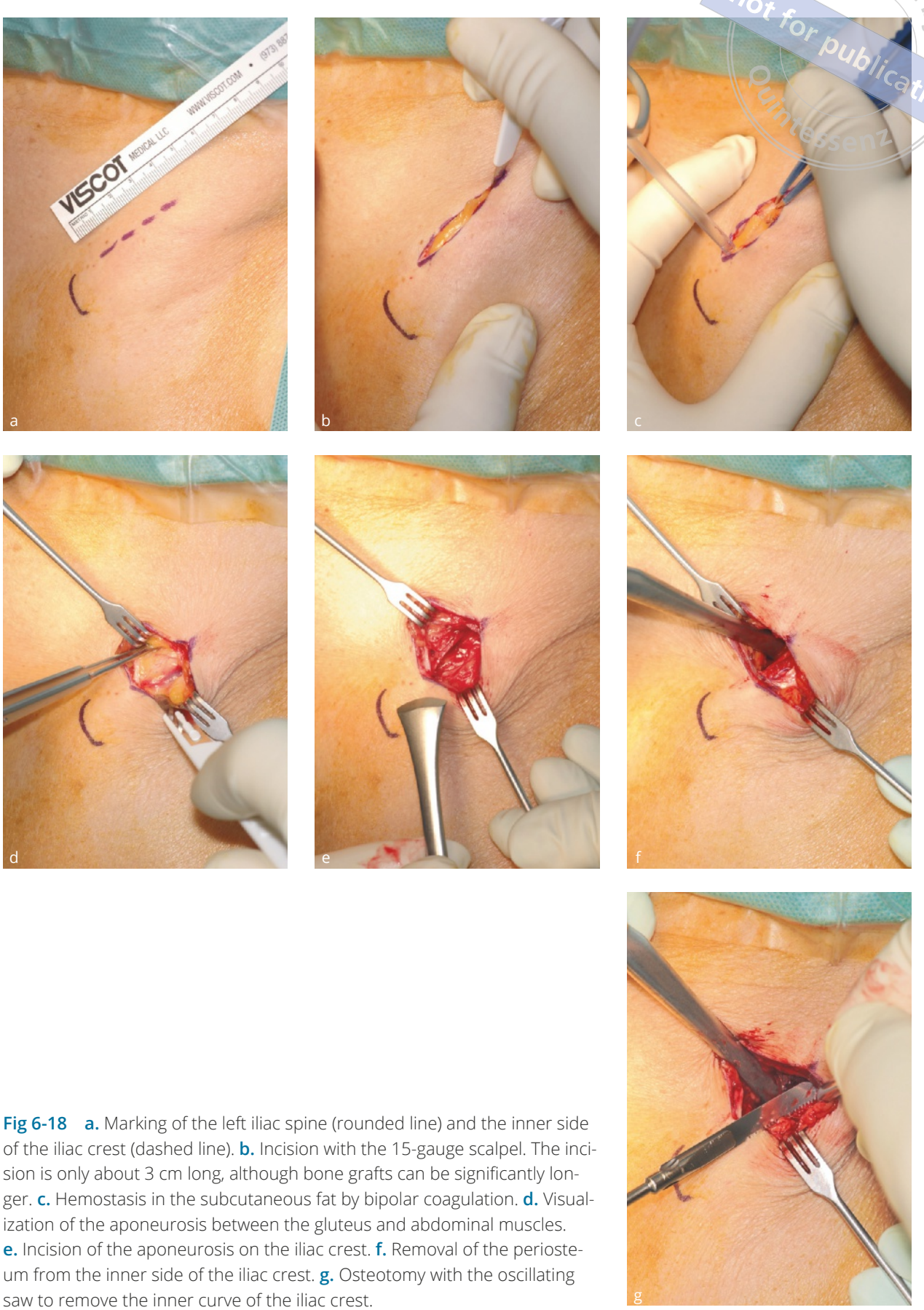


Fig 6-18 **a.** Marking of the left iliac spine (rounded line) and the inner side of the iliac crest (dashed line). **b.** Incision with the 15-gauge scalpel. The incision is only about 3 cm long, although bone grafts can be significantly longer. **c.** Hemostasis in the subcutaneous fat by bipolar coagulation. **d.** Visualization of the aponeurosis between the gluteus and abdominal muscles. **e.** Incision of the aponeurosis on the iliac crest. **f.** Removal of the periosteum from the inner side of the iliac crest. **g.** Osteotomy with the oscillating saw to remove the inner curve of the iliac crest.

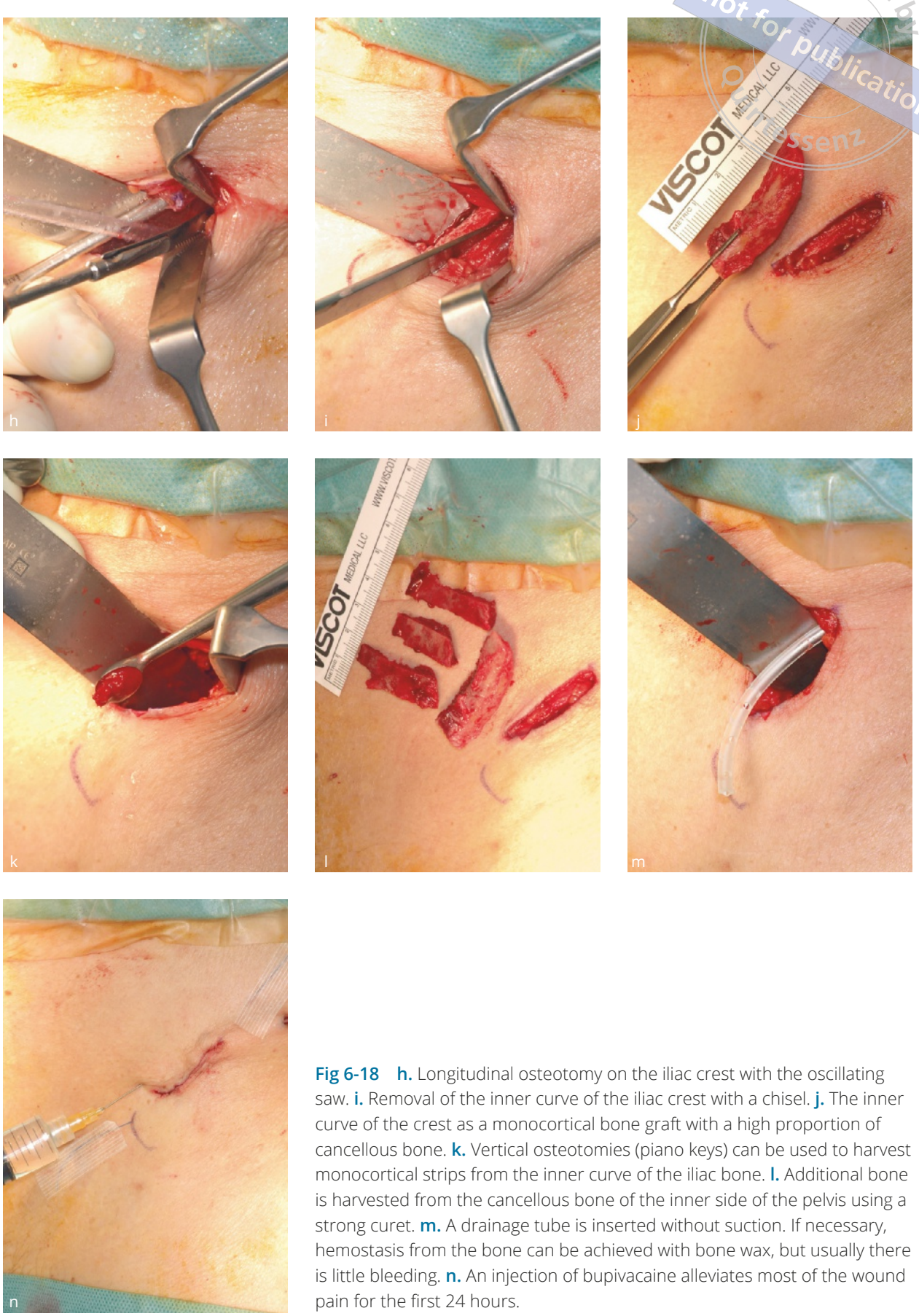


Fig 6-18 **h.** Longitudinal osteotomy on the iliac crest with the oscillating saw. **i.** Removal of the inner curve of the iliac crest with a chisel. **j.** The inner curve of the crest as a monocortical bone graft with a high proportion of cancellous bone. **k.** Vertical osteotomies (piano keys) can be used to harvest monocortical strips from the inner curve of the iliac bone. **l.** Additional bone is harvested from the cancellous bone of the inner side of the pelvis using a strong curet. **m.** A drainage tube is inserted without suction. If necessary, hemostasis from the bone can be achieved with bone wax, but usually there is little bleeding. **n.** An injection of bupivacaine alleviates most of the wound pain for the first 24 hours.

Complications of iliac bone harvesting include impaired sensation of the lateral femoral cutaneous nerve, which runs medial to the anterior iliac spine and is at risk here. In bicortical harvest, the superior gluteal nerve is at risk, which innervates the tensor fasciae latae muscle and can cause gait disturbance if it fails. Particularly in patients with osteoporosis and with heavy use of chisels, a fracture of the pelvic rim may occur, which can usually be treated conservatively. To avoid this, the ends of the saw cuts should be rounded by a ball cutter so as not to set a predetermined fracture point by notch action. Bruising can occur and should be avoided by good hemostasis of the bone marrow cavity using bone wax if necessary. Infection almost never occurs when the above requirements of antisepsis are met.

Transplantation of a bone block of a retromolar bone block graft

First, the recipient defect is exposed subperiosteally by means of a full-length flap and measured with a caliper or ruler. Then the bone is freed from soft tissue remnants with a ball bur and multiply perforated with a small rose bur. The bone trap runs alongside during this work. The surface of the recipient bone can be removed with the scraper to obtain chips and to remove the cambium layer. Now the external oblique ridge block is elevated instead according to the measured length transferred with the calipers (see chapter 3), closing the recipient wound with some temporary sutures in the meantime to give access to as few bacteria as possible. The block is tried in to the defect. It is then trimmed by breaking sharp edges with the diamond ball bur. In most cases, a groove must be milled apically in the recipient bone so that the block is as flush as possible with the ridge. The block is vertically positioned so that it stands 3 mm below the prospective gingival height of the planned restoration. Horizontally, it should lie slightly outside the envelope. Osteosynthesis is then performed. To increase precision, resorption protection can be provided by applying fine-grained bone substitute material (Bio-Oss, Geistlich). It is important to compensate for contour gaps on the alveolar ridge in the mesiodistal direction and on the alveolar ridge with a mixed bone graft so that no grooves or bulges are created later. It is also important to break sharp edges and palpate them with the finger, otherwise flap necrosis may occur. An absorbable collagen membrane acts as protection against dehiscence by cushioning the block against the flap.

6.6 One- or Two-Stage Implant Placement with Bone Grafting

In principle, the two-stage procedure, first augmentation and then implant placement after successful bony healing of the augmentation, is the safer alternative compared to simultaneous implant placement.

The two-stage procedure is safer because in this case the implant is placed in an already vascularized bone bed and is therefore more likely to heal without problems. In addition, the alignment of the implant is usually more successful in the already regenerated bone bed than in a bone bed in the atrophy stage. In the single-stage procedure, the implant surface is adjacent to the temporarily devitalized augmentation material, which must first heal before bone can attach to the implant surface. Simply put, dead bone material does not function well on a dead implant surface. The advantage of the one-stage procedure is the shorter overall treatment time and the lower surgical and cost burden on the patient. With the one-stage procedure, there must still be sufficient bone to stabilize the implant, which is usually only the case with the 1/4 defect. With sinus elevation surgery, the required residual bone height at the maxillary sinus floor depends on the implant system used. Implants with particularly sharp threads or a press-fit design in the cervical portion may well have primary stability even with 1 to 2 mm of residual bone height.

6.7 References

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Bone and soft tissue augmentation of the alveolar ridge is fairly unique in medicine, because true biologic regeneration of lost alveolar bone is achievable. With this book, the author makes a fine contribution to knowledge management and clinical judgment in this dynamic field. The book begins with the basics of jaw atrophy, biology of bone regeneration, and wound healing, as well as grafts and materials. Subsequent chapters cover standard augmentation techniques such as bone grafting and soft tissue management, fully explaining available augmentation techniques for even the most demanding surgeons. The final third of the book is dedicated to a clinical decision-making scheme for different situations, challenges in the esthetic region, posterior jaws, and fully edentulous ridges. The chapters are supplemented with step-by-step clinical cases that illustrate the respective topic in a clear and comprehensible way. The book aims to introduce general dentists to the field of bone and soft tissue augmentation. It also offers more experienced colleagues, including oral and maxillofacial surgeons, many practical tips, particularly with regard to complication management.

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