AO CMF

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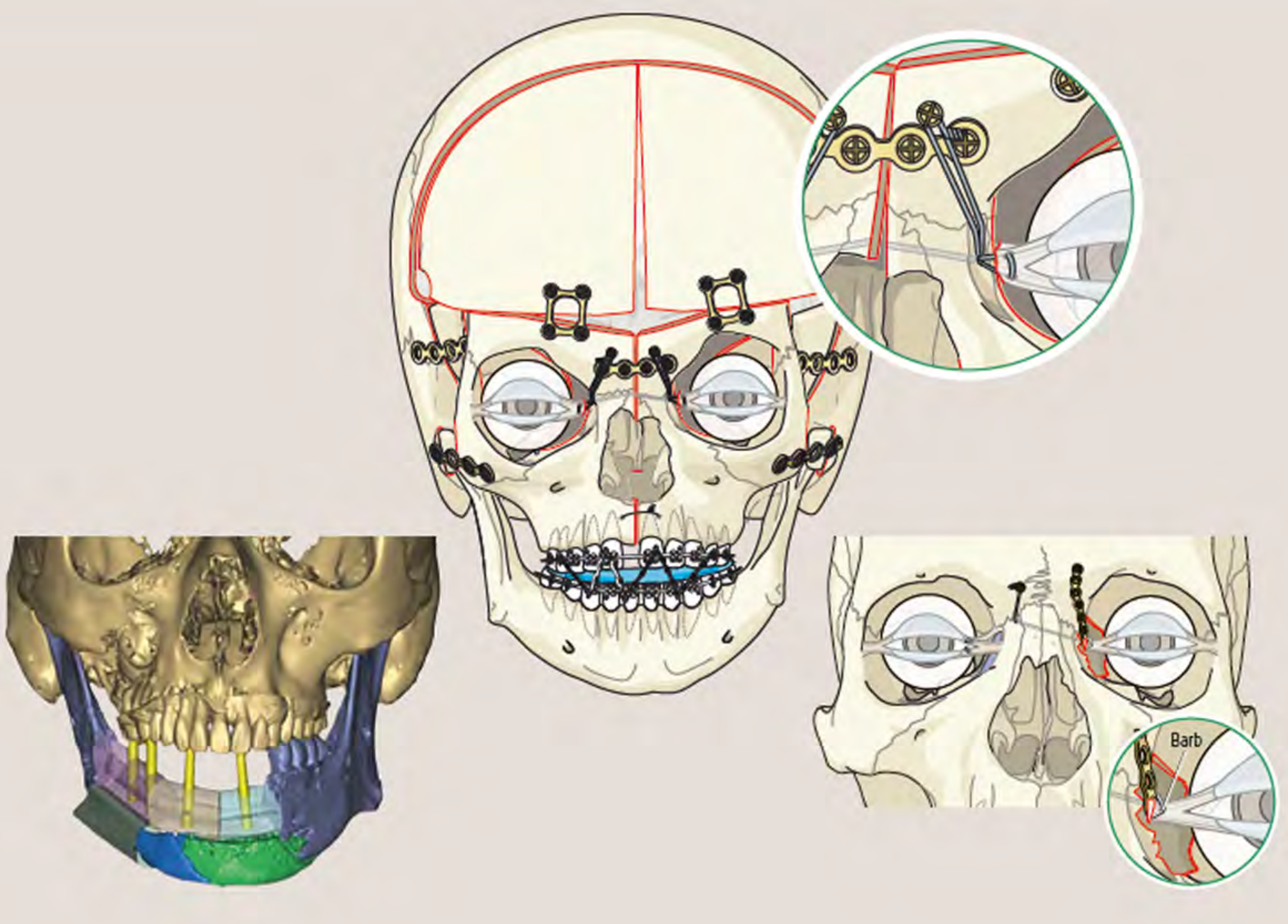
Michael Ehrenfeld, Neal D Futran,
Paul N Manson, Joachim Prein

Advanced Craniomaxillofacial Surgery

Tumor, Corrective Bone Surgery and Trauma



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Includes over 1,300 figures

Library of Congress Cataloging-in-Publication Data is available from the publisher.

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Distribution by Georg Thieme Verlag, Rüdigerstrasse 14, 70469 Stuttgart, Germany, and Thieme New York, 333 Seventh Avenue, New York, NY 10001, USA

ISBN: 9783132428393
e-ISBN: 9783132428409

1 2 3 4 5 6

Introduction

Seven years after the publication of the manual on *Principles of Internal Fixation of the Craniomaxillofacial Skeleton—Trauma and Orthognathic Surgery,* the second volume entitled *Advanced Craniomaxillofacial Surgery—Tumor, Corrective Bone Surgery and Trauma* is now available. It is a project of AOCMF, a clinical division of the AO Foundation. According to the interdisciplinary nature of AOCMF, this advanced manual includes chapters and contributions from oral and maxillofacial surgeons, plastic surgeons, otolaryngologist oculoplastic surgeons, head and neck surgeons, and researchers.

Medical knowledge is growing rapidly, and the way it is disseminated is changing from printed media toward digital presentations including video channels. On the other hand, principles of operative medicine and surgical standards remain relatively stable and do not change that fast. Therefore, the editors of this book believe that it still makes sense to produce a book that captures current aspects of advanced craniomaxillofacial bone surgery.

This advanced manual is divided into six sections. The first section presents an overview of bone grafts/flaps, bone replacement materials and techniques. Sections two and three cover various aspects of ablative and reconstructive surgery of the mandible, midface, and craniofacial junction. Section four deals with corrections of complex deformities and conditions of the craniofacial skeleton; section five with imaging and planning technologies; and the last section with principles and techniques for facial allotransplantation.

More than 1,300 figures are included to focus on practical surgical details. The combination of text and illustrations is meant to support practical training during surgical specialization, and in addition will allow the experienced surgeon to look up and refresh surgical knowledge.

This advanced manual comprises chapters from many individual surgeons, and great efforts have been made to create a consistent textbook without much overlap. We sincerely hope that the readers will find this book valuable, and we are happy to receive comments and feedback.

Michael Ehrenfeld, MD, DDS

Preface

Seven years after publication of the first volume of the manual on *Principles of Internal Fixation of the Craniomaxillofacial Skeleton—Trauma and Orthognathic Surgery,* in 2012, Professors Ehrenfeld, Prein, and Manson are joined by Professor Futran to produce volume 2 of the manual on advanced techniques in craniofacial surgery, titled *Advanced Craniomaxillofacial Surgery—Tumor, Corrective Bone Surgery and Trauma*. Renowned international experts have contributed to provide one of the most comprehensive works on sophisticated surgical analysis and treatment of complex conditions of the face, head and neck from a multidisciplinary perspective previously not possible except in a worldwide and comprehensive craniomaxillofacial faculty such as that within the interdisciplinary AO Foundation. The past 40 years have witnessed an explosion of progress in the knowledge and treatment of diseases of the head and neck and the craniofacial skeleton, with new methods of surgery, fixation, grafting and especially planning analysis and implants. These advances create new and innovative treatment concepts especially in surgery. Rigid internal fixation techniques, craniofacial exposures as well as modern planning algorithms are today applied to trauma, tumor surgery, orthognathic and craniofacial surgery for the benefit and improvement of all reconstructive and esthetic skeletal procedures in the head and neck region.

This advanced manual and companion to the *Principles of Internal Fixation of the Craniomaxillofacial Skeleton* adds to the information of the first volume sophisticated techniques in skeletal and soft-tissue analysis for the disciplines of craniofacial surgery, trauma, tumors, orthognathic, facial and esthetic skeletal surgery. This volume 2 complements the basic principles in volume 1. It covers information required to manage the challenging problems beyond the basic information and procedures presented in volume 1 and permits the acquisition of comprehensive treatment planning techniques and improvements required to achieve good results in more challenging specialty procedures throughout the entire region.

The expertise of several disciplines offers a comprehensive and unique interdisciplinary perspective necessary to create the "team" approach fundamental to achieving the progress required and expected in sophisticated medical centers: Oral and Maxillofacial Surgery, Plastic and Reconstructive Surgery, Otolaryngology and Facial Plastic and Reconstructive Surgery, Ophthalmology and Oculoplastic Surgery, Neurosurgery, and Head and Neck Surgery. The focused expertise of each discipline is assembled and combined to produce an all-inclusive volume which delivers excellent insight into the developments of the past 40 years in all techniques of facial bone surgery. Indeed, the advent of microvascular surgery, skeletal analysis, computed surgical planning, sophisticated personalized implant creation, comprehensive radiographic analysis, and thorough planning such as model surgery, patient-specific implants, detailed preoperative computerized planning and analysis have brought new principles, techniques, and possibilities that allow the individual surgical practitioner to achieve sophisticated goals more efficiently with reduced surgical time, frustration, and revolutionary outcomes.

Importantly, these new techniques of radiographic analysis and computerized planning permit a wide range of less common and highly sophisticated operations to be undertaken by all practitioners. The same techniques of analysis, when used postoperatively, generate data from results which directly translate into improvements and recommendations for new and better treatments, permitting a cycle of constant improvement which continues to generate new and better operations. The vast volume of this new material may at first seem overwhelming to the individual practitioner, but these chapters segment the knowledge into compartments which seem scalable and possible for the individual practitioner to incorporate into his or her own treatment algorithms.

It has been an enormous task to collect and to coordinate this talented group of international experts and specialty communities into this volume. The production of uniform detailed and comprehensive artwork itself is far beyond the limited quality of the usual contributions available in standard multiauthor textbooks, and the quality and numerous illustrations allow a knowledge and mastery of the principles discussed so that individual practitioners can predictably improve their knowledge and skill in any of the areas covered. The references indicate further enhancements in knowledge and practice through additional study.

Today, the wide range of surgical possibilities, implant materials, and techniques of planning and analysis allow our patients better outcomes through easier and more straightforward surgery for the practitioners who despite the added expense of the implants, analysis and techniques can even offer their patients less costly operations made possible by reduced operative time, reduced possibility of complications, reduced secondary or revisional surgery, and the improved outcomes that fully justify the results achieved.

It has been our privilege to benefit from the associations with multiple generations of surgeons worldwide in multiple disciplines through the unique structure of the AO Foundation. All specialties have been united to produce the comprehensive interdisciplinary knowledge available in these volumes. We believe we have learned as much by editing and organizing this advanced volume as anyone having this textbook.

We the editors thank the AO Foundation and its sponsors for providing the educational network that has made the interdisciplinary exchange of this knowledge advancing progress possible.

Good luck and good learning as you appreciate the special treat offered by this international multidisciplinary effort of the AOCMF.

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Acknowledgment

The editors express their appreciation to the authors for contributing chapters to this book and sharing their knowledge and experience with the reader. We are convinced that this effort will contribute significantly to the education of craniomaxillofacial surgeons. We are also grateful to the authors for understanding that the editors needed to update the original manuscripts in order to exclude overlap and ensure consistency throughout the book.

Special thanks go to Almuth Nussbaumer who has been of invaluable help to the editors in the coordination of this book project.

The AO Education Institute team has provided significant resources and expertise without which this book would not have been possible. We thank Vidula H Bhoyroo for the overall planning and management of this project, as well as Urs Rüetschi, Robin Greene, Carl Lau, and Jecca Reichmuth for their dedicated support.

Many thanks to all illustrators, especially the main illustrator Marcel Erismann. And our appreciation to Roman Kellenberger who did a tremendous job in typesetting the book.

We convey our appreciation and deep gratitude to Prof Hans F Zeilhofer and Prof Christoph Kunz for their logistical support to Prof Prein in the production of this project by generously providing the infrastructure within their unit.

We are also grateful to the former and current Executive Directors of AOCMF, Tobias Hüttl and Erich Roethlisberger for their unwavering support of this very important project.

Finally, we thank our families for their patience, help, and support during the production of this book.

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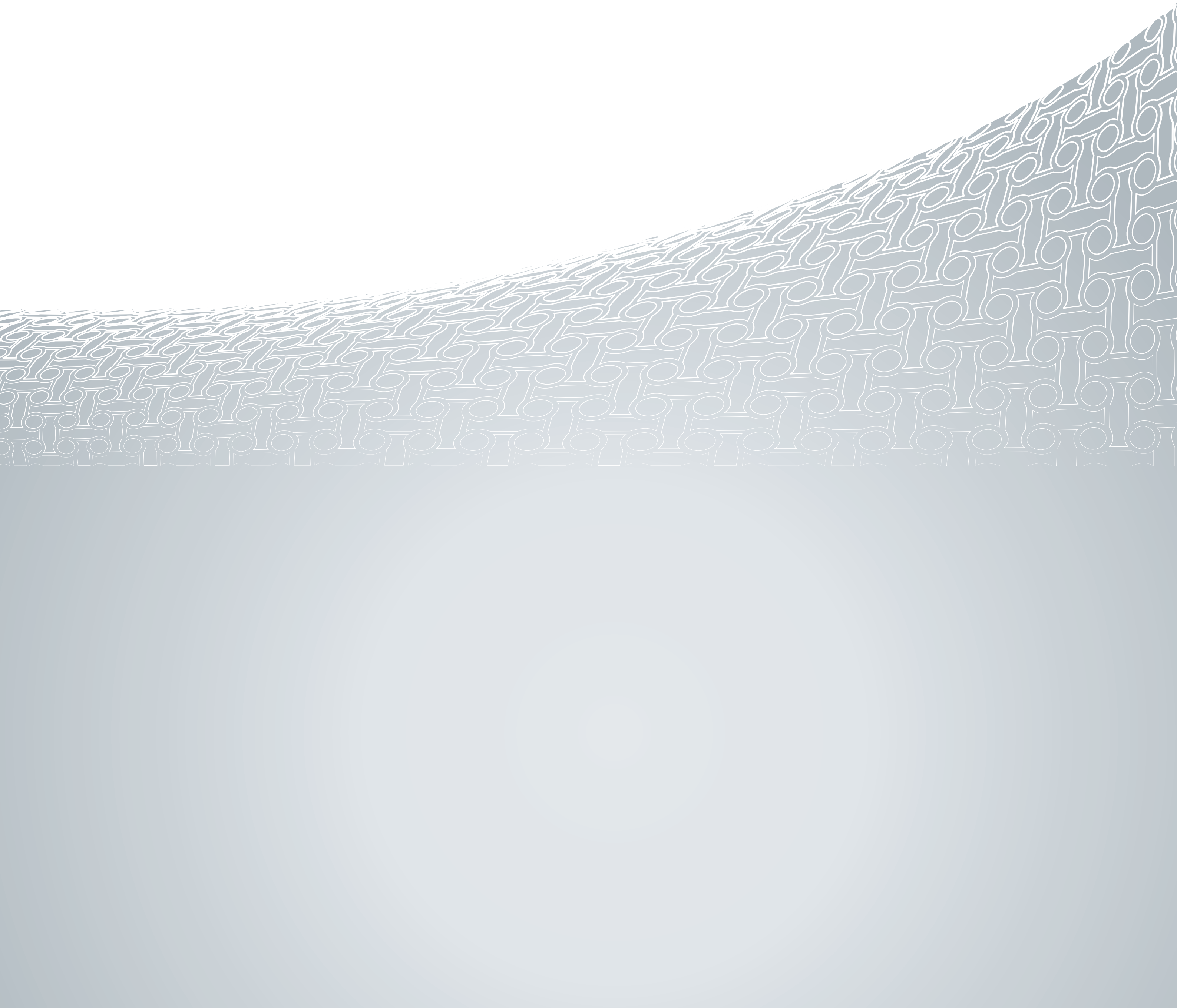
Table of Contents



1.1 Types and harvest of bone grafts and bone flaps

Michael Ehrenfeld, Christine Hagenmaier, Remy H Blanchaert Jr

1 Introduction

In craniomaxillofacial (CMF) surgery bone grafts and bone flaps are used to replace missing bone. Bone deficits or defects may result from congenital malformations and developmental disorders, or originate from tumor surgery, trauma, medication-related bone diseases, irradiation or infections. Bone grafts may also be indicated in esthetic surgery.

Today fresh autogenous bone is still the gold standard among all available bone replacement materials [Axhausen, 1962; Schweiberer, 1970; Tessier et al, 2005]. However, nonresorbable alloplastic materials (eg, porous polyethylene, silastic, ceramic materials) are preferred for contour augmentation procedures because they do not undergo the unpredictable initial remodeling and resorption seen with nonvascularized autogenous bone grafts. Bone graft harvest itself may be associated with complications and undesired adverse effects [Tessier et al, 2005].

Fresh autogenous bone in principle can be harvested as nonvascularized bone grafts, pedicled bone grafts, and microvascular bone flaps [Bardenheuer, 1892; Sykoff, 1900; Krause, 1907; Axhausen, 1908; Lexer, 1908; Rydygier, 1908; Lindemann, 1916; Matti, 1932; Converse, 1945; Conley, 1972; Boyne, 1973; Taylor et al, 1975; O'Brien, 1977; Taylor et al, 1979; Quillen, 1979; Ariyan, 1980; Swartz et al, 1986]. Pedicled bone grafts today are rarely used in CMF reconstructive surgery; thus they are not further discussed in this chapter. Nonvascularized autogenous bone can be harvested as cancellous bone and marrow, cortical bone, corticocancellous bone, and so-called bone dust, which is small particles of cortical bone.

In the preoperative planning phase, the surgeon must assess the patient carefully to determine the needed type of bone based on the characteristics of the defect, the quality and quantity of the surrounding soft tissues, and the specific clinical indication for surgery. Potential donor sites must then be considered and a surgical plan developed that balances the risk-benefit ratio of each of the suitable donor sites and graft/flap types. This chapter reviews the most commonly used bone graft and bone flap donor sites used in CMF reconstruction. The intent is to provide the surgeon with a review of the potential donor sites and an outline of the techniques used for bone graft/flap harvest and donor site management.

2 Nonvascularized bone grafts

Nonvascularized bone grafts are typically harvested from certain preferred donor sites. In the recipient site the bone must be revitalized mainly via tissue ingrowth. Therefore, the recipient site must be of good biological quality, especially well perfused, and allow for complete 360° coverage of the bone graft(s) to avoid exposure, contamination, and healing disturbances [Axhausen, 1962; Schweiberer, 1970; Axhausen, 1951; Axhausen, 1952; Chalmers, 1959; Williams, 1962; Heiple et al,1963; Ray, et al, 1963; Burwell, 1965]. Revitalization of a nonvascularized bone graft goes along with a process of resorption, remodeling, and maturation, which is typically associated with a loss of bone volume. The amount of resorption depends on many factors, such as the dimensions and the density of the grafted material (it takes longer to revitalize large and more dense bone grafts, and therefore they show a greater percentage of bone loss), the type of the bone (cortical, cancellous, corticocancellous, bone dust), tissue qualities at the recipient site (vascularization), biomechanical properties (functional loading), and fixation of the bone graft to surrounding bone [Lexer, 1908; Lentrodt et al, 1976; Eitel et al, 1980; Schweiberer et al, 1981; Lentrodt et al, 1987]. The amount of bone loss after nonvascularized bone transplantation is unpredictable.

Indications for nonvascularized bone grafts

Nonvascularized bone grafts are indicated for filling bone defects, for example, after extirpation of large cysts (see chapter 2.3). Another widespread indication is for ridge augmentation procedures in preprosthetic surgery and dental implantology (see chapter 4.4). Small mandibular or maxillary continuity defects can be treated with nonvascularized bone grafts; other indications include osteotomy gaps in orthognathic surgery, defect zones in fractures, and facial clefts (see chapters 4.6 and 4.7) [Steinhäuser, 1968]. Nonvascularized bone grafts have been used for augmentation procedures in esthetic surgery (malar augmentation, chin augmentation), but because of the potential loss of bone volume nonresorbable grafting materials like ceramic implants or porous polyethylene should be considered instead [Reuther, 1979; Bell, 1992].

2.1 Cancellous bone and marrow

Cancellous bone and marrow is commonly used in CMF reconstruction of small defect areas. It may be harvested from either the ilium or tibia using a trocar, when only small amounts of bone graft are needed, or via open techniques. Grafts obtained by trocar may be suitable for small defects, such as in a fracture nonunion or for sinus floor elevation procedures. Harvest of the bone graft is generally simple; however, proper selection of the most appropriate donor site and careful execution of the harvest are required to minimize donor site morbidity and potential complications. Recipient site preparation for cancellous grafting is perhaps more critical. Development of a well-vascularized, appropriately sized pocket of soft tissue is critical to containment of the graft and a prerequisite for revascularization. Avoidance of oral exposure and therefore bacterial contamination is also vital. Grafted sites, which require extensive soft-tissue dissection and creation of potential dead space, should be drained with a closed suction technique to avoid hematoma and seroma formation. Perioperative antibiotics are administered in the standard fashion. Compressed cancellous bone and marrow can be handled nicely and can be shaped and molded to achieve anatomically adequate filling of appropriate defects.

This chapter outlines the most commonly used donor sites for maxillofacial bone graft reconstruction, which are the ilium and tibia. General characteristics of each site are described. A description of open harvesting techniques for the anterior and posterior ilium and the tibia are provided in the subsequent sections of this chapter.

2.1.1 Ilium

The ilium is a common donor site for autogenous cancellous bone used in CMF reconstruction. Bone can be harvested from either the anterior or posterior ilium. The anterior site is most often used because of its ease of access in comparison with the posterior ilium that requires the patient to be placed in a prone position. However, when large amounts of cancellous bone (> 35 cc compressed) are required, the posterior ilium is a more suitable donor site and a viable alternative to bilateral anterior harvests. The character of the bone is different from these two locations, which is, however, more important for the harvest of corticocancellous grafts. Major CMF reconstruction procedures typically require open techniques for harvest of appropriate and adequate amounts of bone. The posterior ilium provides a thin monocortical element and cancellous material, which often contains visible fat in adult patients. The anterior ilium may be harvested as either cancellous bone and marrow, or as a monocortical or bicortical graft. It has a much thicker cortical component and a less fatty appearing cancellous bone and marrow component.

2.1.1.1 Ilium—anterior technique (medial harvest)

The patient is positioned supine. In some cases, a folded sheet under the ipsilateral hip may make medial visualization easier. The ilium should be outlined on the skin with a surgical marker from the anterior superior iliac spine (ASIS) to the iliac tubercle. The site should be widely prepared and draped. The length of the incision depends on the volume of the harvest required. In general, a 2–6 cm incision is made parallel to the iliac crest either over or slightly lateral to the crest (**Fig 1.1-1**).

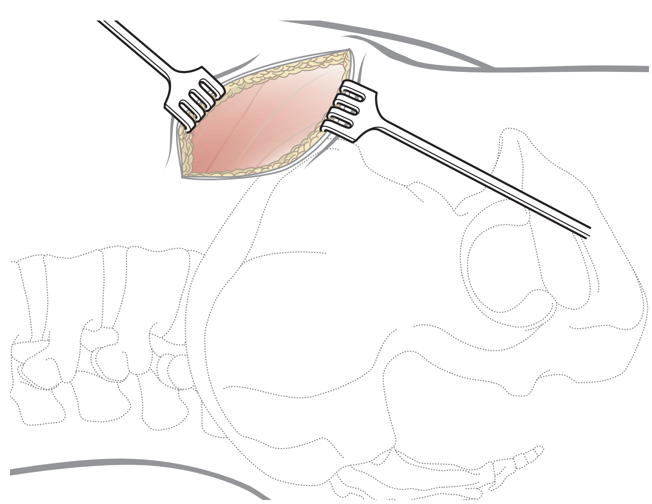


Fig 1.1-1 Approach to the anterior ilium.

The incision should be no closer than 1 cm to the ASIS to minimize injury to the lateral cutaneous femoral nerve. Incision is made through the skin and subcutaneous tissue, then through Scarpa fascia. Dissection is continued to the aponeurosis overlying the iliac crest (**Fig 1.1-2**).

Being careful to incise the aponeurosis minimizes bleeding and facilitates reapproximation. Careful subperiosteal dissection allows excellent exposure. Avoid overzealous soft-tissue retraction, as this is the likely cause of injury to the lateral femoral cutaneous nerve. For the harvest of cancellous material only, the crest may be split with chisels and the cancellous material removed with gouges and/or curettes (**Fig 1.1-3**).

In pediatric patients the iliac crest is still covered with cartilage. The cartilage can be easily separated from the bone with a scalpel and reflected medially pedicled on the adjacent soft tissues to allow access to the bone. The collected cancellous bone can be placed in a 30 cc syringe and compressed to better delineate the volume harvested (**Fig 1.1-4**).

The syringe can then be placed in a lap sponge moistened with chilled saline solution and set aside. This simplifies the collection of the bone, reveals the actual volume obtained, and facilitates the delivery of the bone to the recipient site. However, it must be noted that cancellous bone and marrow should never be placed in saline solution or similar or washed out with saline solution to avoid loss of cells and proteins.

Placement of a resorbable hemostatic agent in the harvest site often controls hemorrhage such that there is no need for a closed suction drain. The wound is then closed in layers.

2.1.1.2 Ilium—posterior technique

The patient is positioned prone. Extreme care in positioning with placement of appropriate lateral chest support and careful rotation of the arms is important to avoid elevated ventilation pressures and nerve injury. The bed is flexed, and reverse Trendelenburg applied to keep the upper body parallel to the floor (**Fig 1.1-5**).

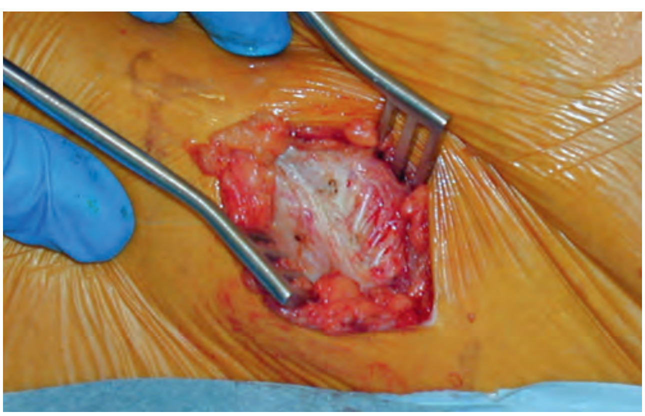


Fig 1.1-2 After incision of the skin and subcutaneous tissue, the fascia is exposed.

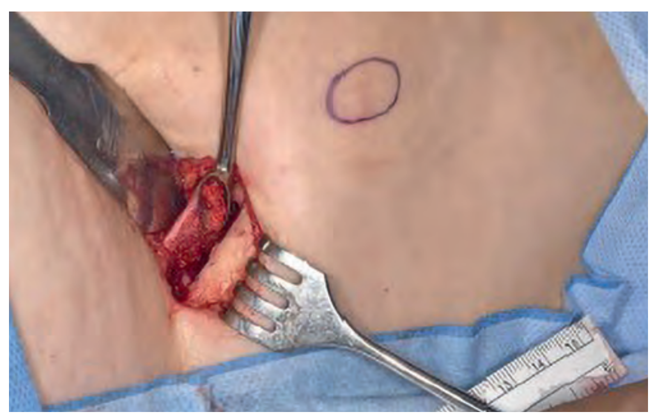


Fig 1.1-3 Harvesting of cancellous bone and marrow with a curette.

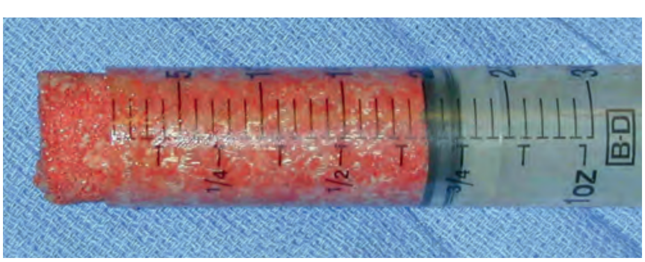


Fig 1.1-4 The cancellous bone graft material has been placed in a 30 cc syringe and compacted.

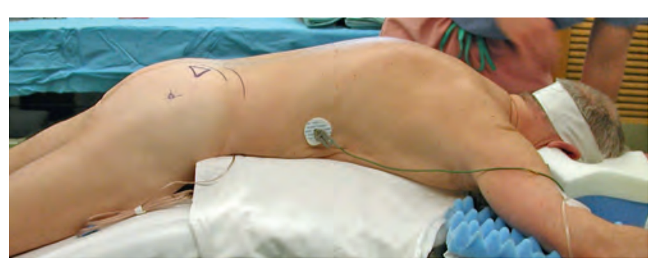


Fig 1.1-5 Proper positioning for harvest of bone from the posterior ilium is critical. Note the lateral padding.

The surgical anatomical landmarks are then outlined with a marker to include the iliac crest, sacrum, and the insertion of the gluteus maximus muscle (**Fig 1.1-6**). Next, the operative field is scrubbed and then prepared and draped excluding the anal region from the field.

A curvilinear incision inferior to and parallel to the posterior iliac crest is then created. The incision should be placed 1–2 cm lateral to the sacroiliac joint to avoid the cluneal nerve. The dissection is deepened through fascia to the insertion of the gluteus maximus muscle. The periosteum is then incised and elevated exposing a triangular protuberance at the site of the muscle insertion. It is recommended that the location of the sciatic notch be determined by manual palpation to assure that no retractor is placed in its vicinity. A retractor is then placed to facilitate harvest. The lateral iliac cortex is removed with a saw and/or chisel and the underlying cancellous material collected with gouges and/or curettes (**Fig 1.1-7**).

Avoid violation of the medial cortex and the sacroiliac joint. If pure cancellous bone and marrow are needed, the cortical bone may be replaced and fixed with miniplates. Often times, the application of a resorbable hemostatic agent obviates the need for a closed suction drain. The wound is closed in layers using resorbable sutures.

2.1.2 Tibia

The proximal tibial metaphysis has reemerged in recent years as an alternative site for the harvest of cancellous bone. After description of the harvest procedure and its applications in CMF surgery, the tibia has become an accepted and frequent alternative to the anterior ilium for defects requiring only small amounts of bone. The major reported advantage is decreased morbidity. Reports of tibial bone harvest with local anesthesia and deep sedation demonstrate the simplicity of the procedure and the utility of the technique in CMF surgery. Cancellous harvests of 15–25 mL uncompressed bone have been reported. This volume is perfectly suited for dentoalveolar reconstructions in preparation for implant placement (sinus augmentation, etc) and management of fracture nonunion where only cancellous material is needed [Herford et al, 2003].

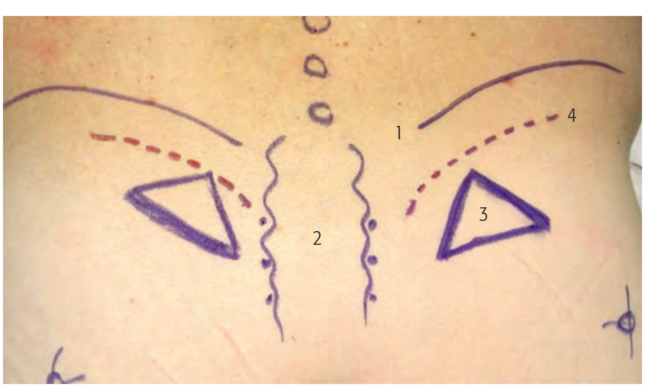


Fig 1.1-6 Upper borders, iliac crest, sacrum, and tubercle where musculus gluteus maximus inserts. Incision line (4).
1 = upper border
2 = sacrum
3 = tubercle
4 = incision line

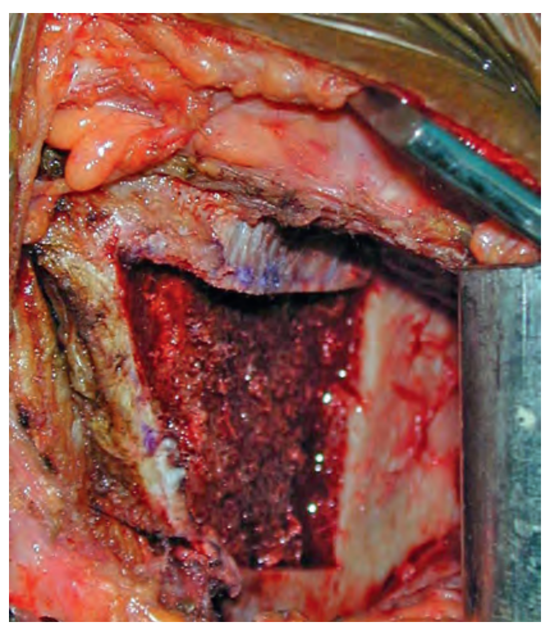


Fig 1.1-7 After removal of a portion of the lateral cortex, excellent access to the cancellous bone and marrow is provided.

2.1.2.1 Harvest technique

Approaches lateral or medial to the patellar tendon are possible. The anatomy of the proximal lower leg should be outlined with a surgical marker to include the insertion of the patellar tendon and the tibial plateau (**Fig 1.1-8**).

The incision length depends on the harvest technique. A small stab is required if a trocar is used. Otherwise the incision is carried down to the periosteum which is incised and reflected. A bone window is then created with a sagittal saw or piezotome and removed (**Fig 1.1-9**).

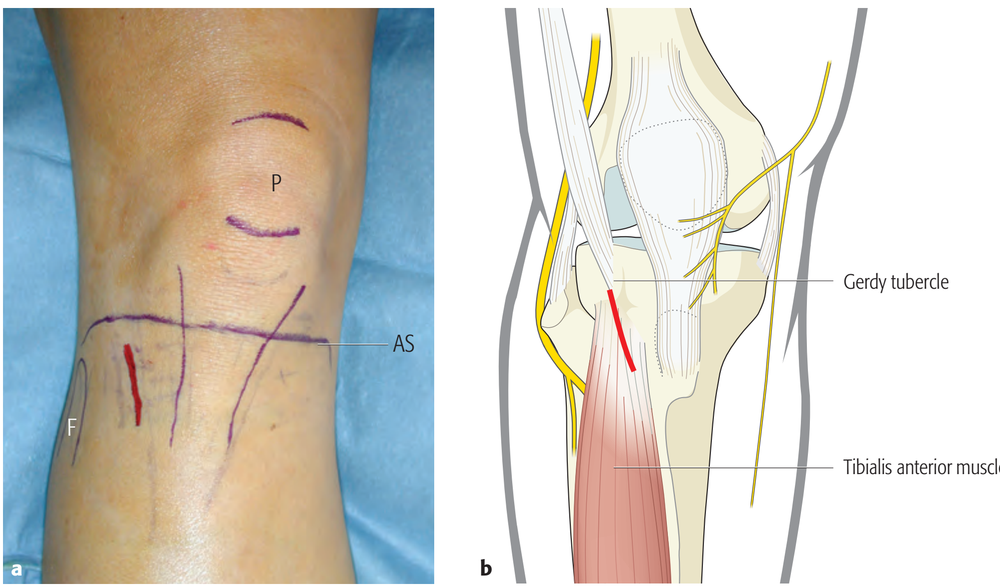


Fig 1.1-8a–b Planning for a lateral bone harvest from the tibial head. The incision line (red) is obliquely orientated to the joint plane and is placed just above and over Gerdy tubercle. P indicates patella; AS, articulation surface, plane of the femoral tibial joint; and F, fibular head.

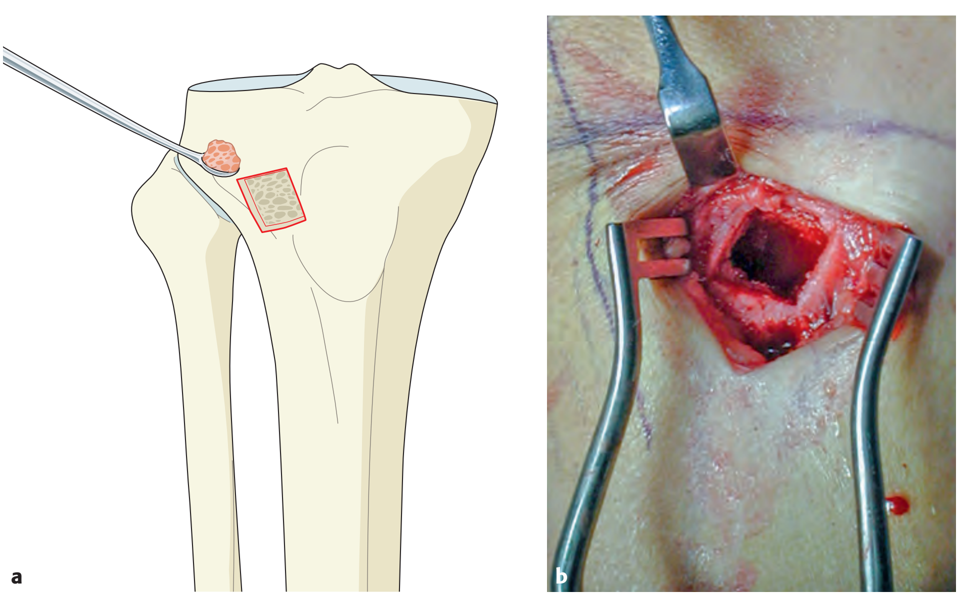


Fig 1.1-9a–b After osteotomy of the tibial cortex, cancellous bone and marrow can be harvested.

The cancellous bone is harvested with a curette, placed in a small container, and set aside. Operative site hemostasis is facilitated by the placement of a topical hemostatic agent. The wound is then closed in layers. After application of a wound dressing, the leg is covered in a soft roll and a gently compressive elastic bandage is applied. Ambulation is allowed immediately with a rapid return to normal exercise activities in a few weeks.

2.2 Cortical bone

Cortical bone grafts are used in CMF reconstruction for structural support and onlay augmentation. Examples of use of these grafts for structural support include maxillary lengthening with loss of bone contact and for restoration of the pillars of the facial skeleton in high-energy CMF trauma. In orthognathic surgery, cortical bone grafts are often available from the distal portion of the proximal segments after sagittal ramus osteotomies. These bone grafts can be used to augment the maxilla and to bridge gaps after maxillary advancements or maxillary lengthening procedures in bimaxillary cases. Cortical outer table bone grafts from the cranial vault or hip are alternatives, among others. Cortical bone grafts may be used for onlay augmentation in dentoalveolar reconstruction, for instance, after atrophy or traumatic bone loss, to allow placement of osseointegrated implants.

Cortical bone grafts require rigid fixation for optimal results. Whenever possible, a lag screw technique should be used for stabilization of the grafts after appropriate contouring. Miniplate/microplate fixation is an alternative. Failure to fixate the graft can result in migration, movement, infection, and rapid resorption.

2.2.1 Mandible

The harvest of cortical bone from the mandible is used for the purpose of onlay bone grafting in preparation for dental implant placement. The procedure is commonly performed with the patient under local anesthesia or local anesthesia and sedation. Patient acceptance of an oral donor site is high in comparison to a distant donor site.

Cortical bone from the mandible is typically harvested from either the ramus or symphysis (**Fig 1.1-10**).

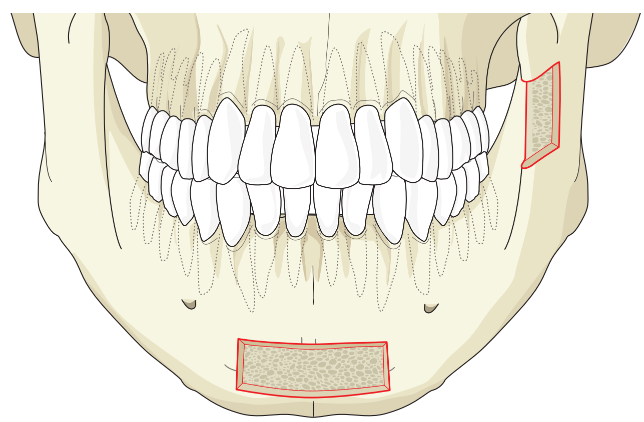


Fig 1.1-10 Potential mandibular bone harvest sites.

2.2.1.1 Ramus

The ramus of the mandible is exposed through a standard posterior vestibular access identical to that used for orthognathic surgery. The mucosa is incised along the external oblique line and the soft tissues are reflected by subperiosteal dissection. Thus, a wide exposure is obtained. A small drill bit, a specially designed right-angle rotating saw or a piezotome is used to outline the graft harvest along the lateral portion of the ramus. A small curved chisel allows elevation of the graft. The graft is then immediately placed at the recipient site and rigidly stabilized or placed in a saline moistened sponge and placed aside. The site is thoroughly irrigated and closed in a single layer. A gentle compressive dressing can be placed on the face to assist in closure of the dead space created by the dissection.

2.2.1.2 Symphysis

The symphysis of the mandible is exposed through a standard vestibular access incision. It is important to maintain a suitable cuff of the unattached tissue by placing the incision labial to the junction of the attached and unattached mucosa. The mentalis muscles must be elevated, and the dissection completed widely to obtain adequate exposure. It is often best to dissect circumferentially around the mental nerve and release the periosteum at the mental foramina to avoid traction injury to the mental nerves. The bone harvest is then outlined with either a small fissure bur, a piezotome, or a specially designed rotating saw. Care must be taken to stay a few millimeters below the apices of the teeth. A curved osteotome is required to elevate the bone graft. For wound closure suturing in two layers, ie, muscle and mucosa, is required. Proper support of the mentalis muscles is necessary to achieve an esthetic outcome. If the mentalis muscle is not resuspended, chin ptosis will likely occur. Additional support of the mentalis muscle and closure of the dead space can be provided with tape or compressive dressing support of the chin. It appears that postoperative pain and local wound complications are more common when the symphysis is used to obtain cortical bone from the mandible.

2.2.2 Maxilla

From the maxilla small amounts of mostly cortical bone can be taken from the nasal aperture (**Fig 1.1-11**) or from the tuber maxillae. The maxilla is approached via transoral incisions in the upper vestibular mucosa.

Other than swelling and pain for a few days, there is no significant donor site morbidity. The bone volume is sufficient for small defects, such as localized ridge augmentations in dental implantology.

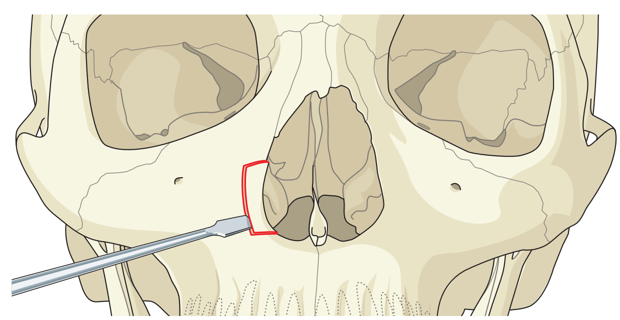


Fig 1.1-11 Bone harvest from the nasal aperture.

2.2.3 Cranial bone

In adult patients the harvest of split thickness calvarium is typically accomplished by removal of the outer cortex; however, the inner cortex may also be separated from a previously elevated full thickness calvarial bone flap as it is commonly performed in craniofacial surgery. The description here will focus on the former technique (**Fig 1.1-12**). The well-developed diploe allows for easy harvest of the outer table. Donor site morbidity is low with proper technique [Jackson et al, 1986]. Younger children typically do not have a layered skull with outer table, diploe, and inner table. Here, harvest of outer table bone grafts is not possible; however, full thickness cortical bone grafts may be taken and split in two layers. One layer is usually replanted to maintain skull continuity for brain protection.

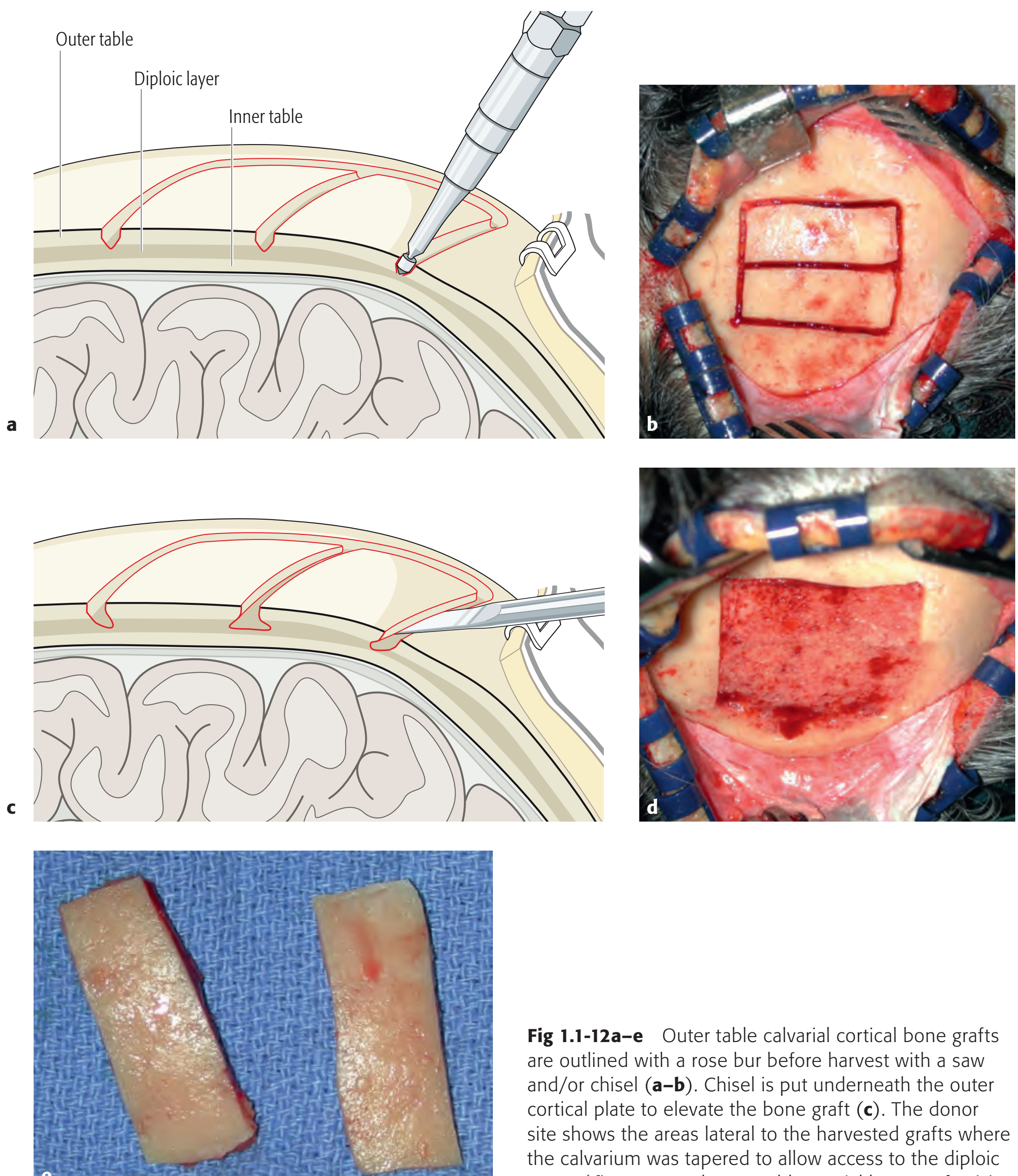


Fig 1.1-12a–e Outer table calvarial cortical bone grafts are outlined with a rose bur before harvest with a saw and/or chisel (**a–b**). Chisel is put underneath the outer cortical plate to elevate the bone graft (**c**). The donor site shows the areas lateral to the harvested grafts where the calvarium was tapered to allow access to the diploic space (**d**). Harvested outer table cranial bone grafts (**e**).