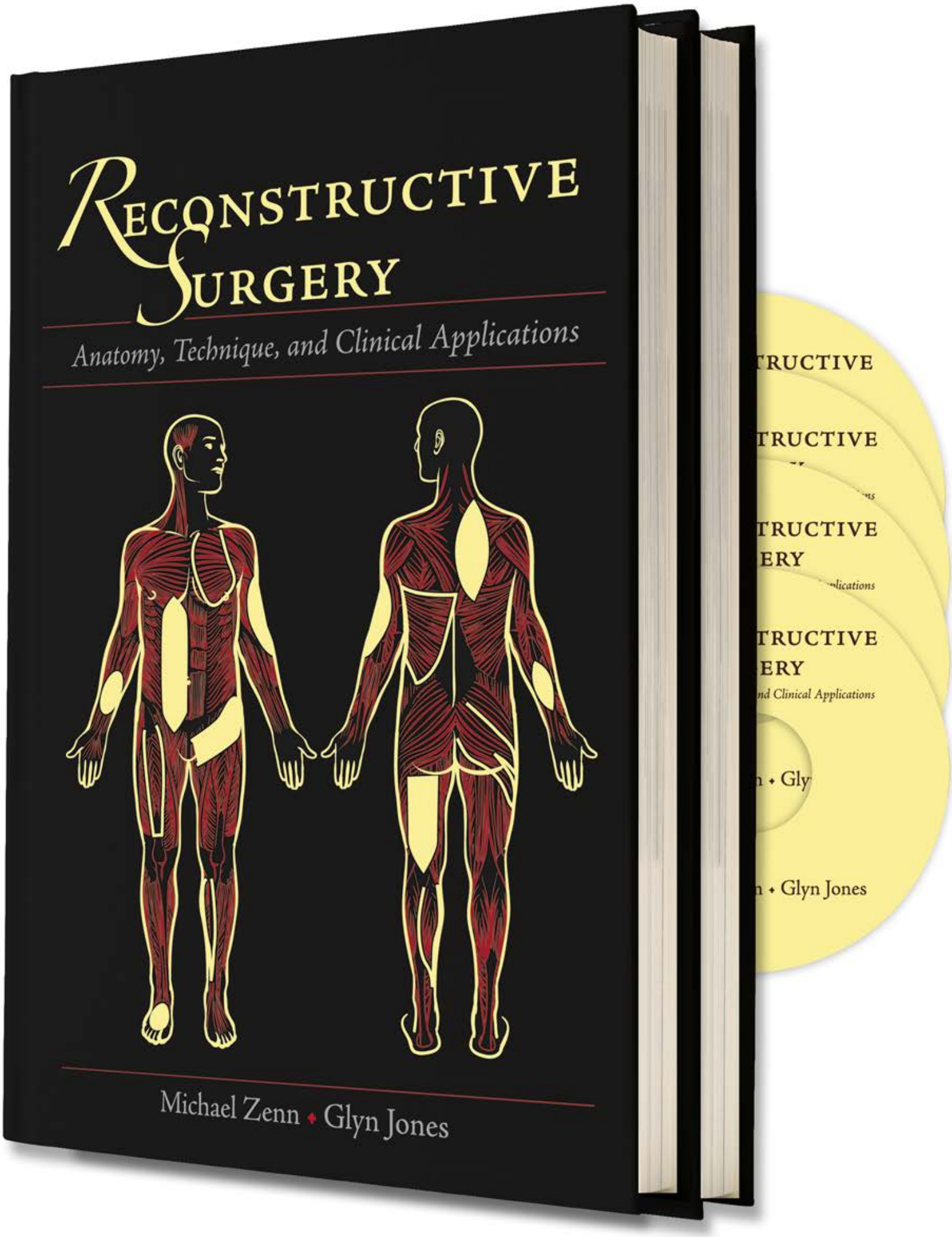
RECONSTRUCTIVE SURGERY
Anatomy, Technique, and Clinical Applications
Michael Zenn • Glyn Jones

Reconstructive Surgery

Anatomy, Technique, and Clinical Applications

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Reconstructive Surgery

Anatomy, Technique, and Clinical Applications

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To my mother, Renee Schwam,
who has inspired me to dream big, then work hard to achieve.
She came to this country at the end of World War II,
not speaking the language, in search of a new life without persecution.
Despite the barriers that confronted her, she made a life for herself in America.
Throughout my life, whenever challenges faced the family
and things seemed bleak, she was the Rock of Gibraltar
and made certain her children were her priority.
I know that without her guiding light and example,
I could not be the surgeon I am today.
For all of her sacrifice and delay of gratification,
I wish to dedicate this book to her.

Michael R. Zenn

To my wife, Hilarie, for her constant love and cheerful support,
and our treasured children, Christy, Vanessa, and Stephen,
who are the source of my greatest pride
and by far my best contribution in life.

Glyn Jones

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Foreword

This book fulfills a promise that Steve Mathes and I made in February 1987 when we planned the first edition of *Reconstructive Surgery: Principles, Anatomy, & Technique* with Karen Berger at QMP. At that time we contracted to produce a third work that would build upon the flap anatomy in the initial two-volume book while adding new techniques and specific clinical applications for each flap. In the intervening years, the project stalled when Steve became ill and I became more involved with aesthetic surgery. Now, however, I am delighted and honored to be able to write a foreword for this new book: *Reconstructive Surgery: Anatomy, Technique, and Clinical Applications,* written by two master surgeons, Michael Zenn and Glyn Jones, who have taken up the mantle and completed what we began so many years ago.

Drs. Zenn and Jones have produced a landmark work that fulfills the legacy of the first book. It captures the detailed flap anatomy, design and markings, and basic technique of the initial work while adding valuable new information on flap dissection technique, flap variants and options such as perforator flaps, clinical applications, pearls and pitfalls, and expert commentary.

This long-anticipated book does not disappoint. The artwork is rendered in a simple yet elegant style that clearly depicts key structures and techniques. Helpful icons and opening outlines enhance the learning experience, as do the summary boxes, which focus on pearls and pitfalls for each flap. The expert commentary at the conclusion of each chapter is a terrific addition; it provides valuable perspective on these flaps by leading experts in the field.

This superb text provides today's reconstructive surgeons with the tools to solve complex reconstructive problems with new surgical options. It is destined to become the standard for young and experienced surgeons alike as they seek optimal solutions for difficult reconstructive problems. We owe a debt of gratitude to the authors and to the publisher for making this book a reality after so many years and for providing our specialty with a classic textbook to guide us.

Foad Nahai, MD, FACS
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Foreword

In 1961, President Kennedy's inaugural speech referred to "the torch being passed" to a new generation. The torch of plastic surgery has been reconstructive techniques that treat myriad afflictions of the human condition: congenital deformities, traumatic injuries, oncologic conditions, and infections. Our toolbox has expanded exponentially in the past half-century.

Sixteen years ago, the first edition of *Reconstructive Surgery* became the bible for reconstructive surgeons. The ability to move tissue on vascular pedicles and perform autogenous tissue transplantation using the operating microscope welcomed the modern era of reconstructive surgery. The first edition demonstrated the anatomy of flaps and the basic techniques and applications. Now the torch has been passed from masters of modern reconstructive surgery, Foad Nahai and Stephen Mathes, to two outstanding leaders in reconstructive surgery, Michael Zenn and Glyn Jones. Dr. Michael Zenn served with distinction as my partner at Duke, and I observed his passion for reconstructive surgery, education, and clinical excellence with pride and respect. Dr. Jones's path to authorship of this book is a wonderful testimony to America and American medicine. A native of Zimbabwe, he emigrated to the United States and has made his mark in reconstructive plastic surgery and as an author/editor. For any educational event that I was fortunate to organize relating to reconstructive surgery, Glyn was always on the top of my list as a faculty member. Both authors have a keen sense of organization, clear expression of thought, and attention to detail to create excellence in everything they do. This book is a written testimony to these attributes.

It is essential that the reconstructive plastic surgery community have a definitive reference delineating anatomy, applications, and the limitations of these techniques. This new landmark publication fulfills that need; it is superbly organized, beautifully illustrated, and is authored by two reconstructive surgeons who are internationally recognized for their innovation and contributions to the field. There is such a wealth of information that this text will serve us well for the future, providing information that will allow further development of reconstructive surgery and new applications using the time-honored anatomy that is our compass in surgery. It will be embraced not only by the new generation of students, residents, and fellows, but will also inspire the practicing plastic surgeon to establish the foundation of a procedure correctly each day in the operating room by laying down the principles of reconstructive surgery.

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Preface

Progress is never achieved in isolation. To advance any field, we need to acknowledge those who have come before us and recognize how their contributions have enhanced our understanding. We must then stand on the shoulders of those giants who have preceded us and move the specialty forward. In the area of reconstructive flap surgery, there are no broader shoulders than those of Stephen Mathes and Foad Nahai. The original Mathes-Nahai text on muscle flaps was epic, ushering in a new era of reconstructive surgery. For many of us students of plastic surgery, this was the first text that we purchased in the field, guiding us on our path to becoming competent plastic surgeons. It was a detailed guide to safe flap dissection as well as an inspiration to generations of plastic surgeons.

Years ago, Glyn Jones's former partner at Emory, Foad Nahai, and colleague Steve Mathes invited Glyn to contribute to a new clinical applications book that they were planning; it was intended as a comprehensive replacement for their landmark flap book. Unfortunately, this project was shelved when Steve became ill, but the idea persisted. As time passed, it became increasingly obvious that, while the earlier book was still an invaluable resource, it was in serious need of an update, both in the scope of flaps covered and in the style that has become the standard for our times. The new text you are holding fulfills that need and the dream of the original authors.

In preparing this book, we are very much aware of how quickly plastic surgery is changing, particularly in the area of flap surgery. Advances in microsurgical techniques and applications, combined with the explosive growth of perforator surgery, make any attempt at writing a "complete" text on flap surgery daunting. These volumes are intended to be as inclusive as possible, given our current knowledge of the field and our best guess as to which flaps will prove most valuable in the future.

We have planned this text to be a helpful companion for the reconstructive surgeon, both in flap selection and in flap execution. To accomplish that goal, it is organized into two major Parts: Fundamentals and Regional Flaps (Anatomy and Techniques). Part I is introduced by a Reader's Roadmap that explains how the book's chapters and flap descriptions have been organized and helps the reader navigate its pages. Following this introduction are four key chapters. The first focuses on decision-making and surgical principles while the second by Drs. Steven Morris and Peter Davison presents invaluable information on the vascular basis and classification of flaps. Further guidance is provided in Chapter 3 with its regional treatment of flaps. This chapter outlines the possible flap options in each area of the body and serves as a useful starting place for finding the ideal flap for a particular problem. The final chapter in this section discusses complications, why they occur and what we can do to avoid them.

Part II is divided into separate chapters for each anatomic region. Within those chapters, the basic anatomy of each of the commonly used flaps is carefully outlined in a consistent format to make this text a quick and easy reference for locating critical information. Throughout, we have provided many useful dissections, pairing photographs and radiographs with detailed medical illustrations to depict dissection technique and other technical points emphasized in the text. Clinical cases demonstrate applications for each of these procedures, showing their versatility wherever possible. We are particularly grateful to the experts who have joined us in this endeavor for their sage comments and the cases they have contributed.

This enormous reservoir of pooled information and expertise will benefit us all as plastic surgeons and make a useful and timely contribution to our exciting field.

Our collaboration has been a delightful experience as we each have had a wide experience of reconstructive and aesthetic plastic surgery and we both enjoy microsurgical reconstruction. A long-standing friendship and deep personal respect for one another has fueled a collaborative effort that has made this project a particularly rewarding endeavor. Working together for several years as instructors at the renowned Duke Flap Workshop and seeing the innovative advances demonstrated by an international faculty of experts have provided further fuel for the text. It has allowed us to refine concepts and provide the most up-to-date advances and modifications to many of these flaps that have been reported by our colleagues throughout the world.

As this project comes to fruition, we sincerely hope that it will enrich the lives of our patients. We also hope that generations of plastic surgeons to come will benefit from the wealth of collective knowledge outlined in these two volumes. We are both humbled and grateful to have been given this extraordinary opportunity.

Michael R. Zenn
Glyn Jones

Acknowledgments

It was quite by accident that I was introduced to plastic surgery. I was a rotating fourth-year medical student from Cornell who signed up for a month of general surgery subinternship at the Massachusetts General Hospital with my friend, Andy Kenler. His brother-in-law, an MGH resident, got him on the premiere surgical oncology service while I got stuck on the thyroid service. After a week of seemingly endless thyroidectomies I was bored, and got my friend Andy to appeal to his brother-in-law to get me on another service. That brother-in-law was Louis Bucky, now on faculty in plastic surgery at the University of Pennsylvania; then, he was a senior general surgery resident rotating on the plastic surgery service. He got me on the service for my remaining time, and my life path was forever changed. The hustle and bustle of the plastic surgery service, the variety and complexity of the surgeries, and the iconic James W. May, Jr., were all it took to plant the seed that would take root after my training in general surgery.

Ironically, some 5 years later, I would end up at Massachusetts General again, this time as a plastic surgery resident. The intensity of that training could not be replicated today (without violating multiple ACGME rules), but the experience became the crucible that molded me into the plastic surgeon I am today. My mentors at MGH included one of the greatest teachers I have ever met and emulate daily—James W. May, Jr. I was also fortunate to train side by side with Gregory Gallico, Michael Yaremchuk, Michael Lewis, Peggy Howrigan, Matthew Donnelan, and W.P. Andrew Lee, just a first-year attending at the time. The training was intense and grounded in traditions dating back to Bradford Cannon, one of the founders of our specialty and a regular at our weekly conferences. I was heavily influenced at the time by my co-residents, who included Lou Bucky (then my chief resident), Craig Johnson (our hand fellow), Jeffrey Ditesheim, Neal Chen, Matt Concannon, and Fred Duffy.

Some early experiences at Memorial Sloan-Kettering Cancer Center while a Cornell general surgery resident introduced me to the world of microsurgery, so it only seemed appropriate that I study under the master himself, David Hidalgo, as a MSKCC microsurgery fellow. While working with David, I saw first hand the amazing power that microsurgery had to solve difficult problems and to transform lives. Most of all, it was his artistry and attention to the smallest details that stuck with me and torture my current residents on a daily basis. I was fortunate at that time to also work with Peter Cordeiro, now the chief at MSKCC, who has remained a good friend.

Early in my practice, I was fortunate to meet the man who would have the greatest influence on my career, L. Scott Levin. As Chief of Plastic Surgery, Scott welcomed me to Duke with open arms. I was not a competing microsurgeon, but a partner in what would be an incredible 10-year voyage of discovery, growth, friendship, and the creation of something special in the Duke Flap Course.

I have always known I would be an educator. Second only to operating and caring for patients, teaching residents and fellows the art and science of plastic surgery has been my life's work. It is true that the bond between teacher and student is a special one, and I would be remiss if I did not also give thanks and acknowledgment to the residents and fellows I have had the honor to train. We in academics are fortunate to be exposed to bright, energetic minds on a daily basis. One source of annoyance when training residents is their constant

questioning of the status quo. However, I must admit that it has been this pressure that has allowed my practice to evolve continually and stay at the cutting edge of plastic surgery.

It has been an incredible honor to co-author this text with Glyn Jones. As a young surgeon, I always looked up to Glyn as someone in academic surgery to emulate. He is a bright, talented surgeon who, like me, has always had a passion for teaching and enriching the lives of patients. Our long weekends at QMP in the "dungeon" will be fondly remembered. Our shared passion in creating this text has cemented a friendship for life.

I would also like to thank and congratulate the invited experts who wrote commentaries and provided additional clinical cases for a job well done. Our specialty is full of incredibly talented people, and this has been ably demonstrated through their insights.

We learn early in our surgical careers that success comes with a price. The time required to care for patients and even write this book has to come from somewhere and all too often it is our own family who suffers. I have been fortunate to have an incredible family who support my endeavors and have never complained when I have been called away or missed an event. My wife and soulmate, Susan, my son, Andrew, and my daughter, Erica, are a continual source of joy and encouragement. My other "family," my nurse of 15 years, Jo Ann Garofalo, also deserves my special thanks for helping me to hone my craft and care for our patients, many of whom are demonstrated in this book.

Last, but certainly not least, I want to thank Karen Berger at Quality Medical Publishing, without whom this text would not exist. Her decades of experience in medical publishing have given her a true understanding of the needs of the plastic surgeon and the plastic surgery educational market. Once she decides to take on a project, she has the uncanny ability to take an author's vision and make it a reality, often surpassing expectation. To know her is to love her, but make sure you meet your deadlines! The family that Karen has built at QMP is a special one and includes Amy Debrecht, Michelle Berger, Taira Keele, Andrew Berger, Suzanne Wakefield, Carolyn Reich, Brett Stone, Ngoc-Thuy Khuu, Carol Hollett, Rebecca Sweeney, and Lane Wyrick. The artistry of Brenda Bunch, Amanda Behr, Amanda Tomasikiewicz, Eric Olson, Jennifer Darcy, and Jennifer Gentry has raised the bar for medical illustration in a reconstructive text. My sincere thanks to all at QMP for your hard work and the passion you displayed creating this text. It is my hope that over the years, plastic surgeons will continue to thank you for this job well done.

Michael R. Zenn

Acknowledgments

Just over 34 years ago I completed my internship and was called up to a year of National Service during the bloody and tragic civil war in my former homeland of Rhodesia, now Zimbabwe. Committed as I was to a career in surgery, I spent a year dealing with combat casualties as well as the usual run of civilian surgical pathology. It was during that life-changing year that I was drawn repeatedly to the finesse of facial and hand reconstruction and the dilemma of closing large defects inflicted by warfare. Those early experiences were to become the stepping stones that would lead to a career in plastic surgery. Although general surgery enthralled me, a rotation through plastic surgery at the University of Cape Town convinced me that it was here where my future lay. After completing my general surgery residency in Cape Town, I was fortunate to be accepted to the plastic surgery program in Cape Town. While training there, Guy Trengrove Jones and Roger Strover inspired me to seek further fellowship training in the United States, and in 1988-1989 I spent 2 years undergoing postgraduate plastic surgical training at Norfolk, Virginia, Atlanta, Georgia, and then St. Louis, Missouri.

My time at Emory University in Atlanta was probably the most life-changing experience of my entire career. It was here that I came under the tutelage of Josh Jurkeiwicz, a born teacher and inspiration to several generations of surgeons. Josh was a man who regarded the transmission of knowledge to his residents as his life's work and a God-given responsibility, not only for the benefit of the surgeons on his watch, but for the patients those surgeons would ultimately treat. He had attracted a dynamic faculty and trained more future chairmen of plastic surgery than any other plastic surgeon in this country's history. It was as a fellow at Emory that I was exposed to the dynamism of Foad Nahai, John Bostwick, Rod Hester, and their fellow trainees John McCraw, P.G. Arnold, Steve Mathes, Luis Vasconez, and Leonard Furlow. You cannot be in the presence of these men without having your life seared by the flame of their contagious enthusiasm. They changed my entire perspective on plastic surgery, retooling the way I approached problems, and kindled within me an undying love for breast surgery and complex reconstruction that remains with me today. My relationship with John Bostwick became a lifelong friendship curtailed by his untimely death, but it allowed me the privilege of rewriting his famous text on breast surgery for future generations, a privilege I will always cherish.

While still a fellow at Emory, I spent a weekend in St. Louis with Foad Nahai and Steve Mathes, meeting Karen Berger for the first time as we discussed contributing to a clinical companion text to the original Mathes-Nahai reconstructive books. The "flap book" was a must-have text for any plastic surgeon embarking on reconstructive procedures, and despite its age, it has remained a landmark text that has helped countless surgeons better perform the reconstructions from which so many patients have benefited over the years. As time wore on and innovations emerged, however, it became clear that a companion text was needed—one that incorporated the information from the previous reconstructive work while adding important clinical applications and expert commentary. It has been a privilege to be involved in writing this monumental text. Foad Nahai has been tremendously supportive of our efforts, and I will always be grateful to him for his support, friendship, and encouragement over the years.

Karen Berger is a remarkable woman who has left an indelible mark on the plastic surgery publishing world. As Mike Zenn said in his acknowledgments, "to know her is to love her," and having known and worked with her for over 20 years, I can wholeheartedly affirm that statement. Karen is an extraordinarily motivated publisher who drives us hard as a team but delivers far more than one could have hoped for. The quality of her work and the books she produces are unmatched in the world of plastic surgical publishing. No publisher can achieve what she has without the support of an outstanding team. Karen has put together an excellent team at QMP with whom it has been both a pleasure and privilege to work. Amy Debrecht, Michelle Berger, Taira Keele, Suzanne Wakefield, Carolyn Reich, Brett Stone, Ngoc-Thuy Khuu, Carol Hollett, Rebecca Sweeney, Lane Wyrick, and Andrew Berger are a formidable publishing team who spend countless hours preparing the text for publication and marketing it to the world, and we are indebted to them for their meticulous efforts.

This book could not exist without the remarkable artistry of the medical illustrators who have infused its pages with beautiful imagery. The quality of the artwork reflects the skill of Brenda Bunch, Amanda Behr, Jennifer Gentry, Jennifer Darcy, Eric Olson, and Amanda Tomasikiewicz, whose combined efforts have created a visually stunning body of art to accompany the text. The QMP team is to be congratulated for a job well done.

In preparing something as monumental as this two-volume book, Michael Zenn and I have had to work together for hours as a team. It has been a privilege to know Michael as a colleague and a friend, and this book has been a catalyst in strengthening an enduring friendship and mutual respect. We both love to teach, and we hope that the pages of this book will help generations of plastic surgeons to come.

Works such as this do not come to fruition without considerable sacrifice. We are both busy clinical surgeons with mature practices, and time is always at a premium. In embarking upon such a project, we were acutely aware that the time commitment would be enormous. That time is garnered at night and on weekends, and it comes at the expense of time with our wives and families. I want to pay tribute to my wife, Hilarie, for her enduring support and encouragement during this second tour de force in my writing career, for without it, the project would never have matured.

It is my hope and prayer that this book will be an invaluable tool in plastic surgical training, not only as a resource for surgeons, but above all, for the benefit of our patients, without whom the need for this book would never exist.

Glyn Jones

Contents

VOLUME ONE

VOLUME TWO

Reconstructive Surgery

Anatomy, Technique, and Clinical Applications

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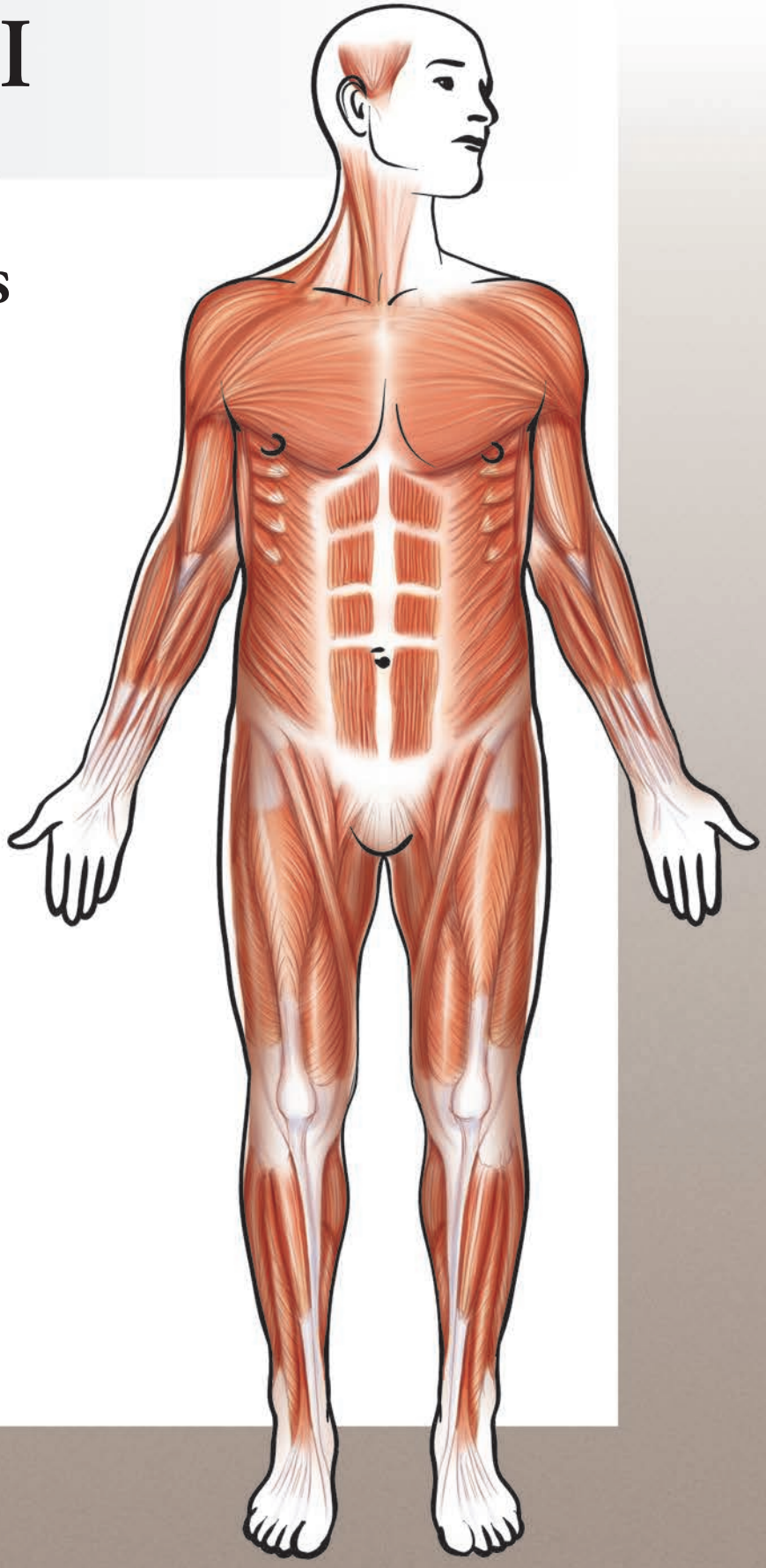
Part I

Fundamentals



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Reader's Roadmap

Successful outcomes in reconstructive surgery depend on the interplay of a number of key factors. A comprehensive understanding of anatomy is of primary importance. Once mastered, this must be combined with surgical training, clinical judgment, and technical skill. Equally important, a surgeon must be able to effectively analyze the problem at hand, identify all potential options for its solution, and select the reconstructive approach that most effectively and aesthetically restores the lost form or function while minimizing donor site deformity. Compared with our predecessors, who could not have foreseen our current concept of angiosomes or the advent of perforator flaps, our choices are greater and the range of deformity treated is wider. With this knowledge also comes complexity and an increased level of technical difficulty that our teachers never had to contend with. That said, with our improved understanding of human anatomy, coupled with advances in flap design, we are able to steadily move forward, accomplishing more with better outcomes.

This book should be thought of as a roadmap for navigating the wide range of reconstructive problems we see throughout the body. It is a tool for selecting the best solutions for these problems. It has been formatted to be a quick, easy-to-read reference guide that surgeons can use when determining options for a particular problem, delineating the appropriate anatomy, and showing the step-by-step dissection technique for the chosen flap. Clinical examples further demonstrate what is possible with each flap, and insights from invited experts ensure that you know their tricks.

Building on the systematic approach established in earlier books authored by the iconic Mathes and Nahai, our book employs a similarly structured format. The text has been organized into two distinct sections: Part I: Fundamentals, and Part II: Regional Flaps: Anatomy and Basic Techniques.

The text begins with a section on fundamentals that includes four key chapters. The first chapter is "Surgical Decision-Making: Options, Principles, and Techniques." It presents the essential building blocks for understanding and using the flap concepts and designs that follow. It also contains basic information on the subset of free tissue transfers and guidelines on flap monitoring.

The second chapter, contributed by Steven Morris, discusses the vascular basis of flaps and the justification for flap classification. As the complexity and number of flaps grow, it is important that we can communicate clearly what tissues are involved and how they are vascularized and innervated.

The third chapter in this section is entitled "Guide to Flap Selection." This unique chapter will be the one you will turn to again and again as a logical starting point when assistance is needed with clinical problem-solving. Once you know where the problem is located, a series of tables and regional maps, organized by anatomic area, will guide you to all the potential reconstructive solutions. Page numbers are keyed into these charts to quickly direct you to the appropriate chapters and the specific flaps of interest. These charts also highlight the commonly used recipient vessels in that area, which may influence the specific flap choice. This section is also ideal for determining a fall-back plan for your case or a secondary choice in addressing a complication.

Chapter 4, "Complications and Treatment," considers patient selection, surgical planning, intraoperative factors, and postoperative care.

Part II: Regional Flaps provides the detailed information on anatomy, basic technique, and clinical applications required for planning and successful execution of your reconstructive procedure. An overview of the pertinent anatomy is provided in a list format that is comprehensive yet easy to grasp. For simplicity and ease of use, this part is divided into 10 individual chapters: Head and Neck, Anterior Thorax, Posterior Trunk, Upper Extremity, Hand, Abdomen, Abdominal Viscera, Thigh, Leg, and Foot. For this atlas only the most commonly used flaps are identified in each body region. Individual sections are then dedicated to each flap, providing everything the surgeon needs to know about its execution and application. Each section in the chapter follows a distinct and consistent format, beginning with a list of clinical applications, and a succinct summary of anatomic features, as shown on p. 5.

ANATOMY

Landmarks Specific anatomic guideposts that assist the surgeon to identify all important structures to define the local anatomy and design each flap.

Composition Classification of anatomic components: (1) fascia, (2) fasciocutaneous, (3) muscle, (4) myocutaneous, (5) bone, and other specialized tissues.

Size Flap dimensions to aid in flap selection and assess whether primary closure will be possible.

Origin/Insertion Bony connections of all muscle flap origins and insertions.

Function The intended purpose and role that these tissues play in situ. This is important in selecting a flap while ensuring that as much tissue as needed is taken. Even more important, this allows the surgeon to evaluate potential morbidity from alteration of the donor site, including functional loss (range of motion or strength) and aesthetic loss after flap elevation. Synergistic muscles that retain local motor function after flap elevation are identified.

Arterial Anatomy (Pattern of Circulation)

Dominant Pedicle Source of arterial inflow to the flap and circulation to maintain tissue viability. As noted by Mathes and Nahai, different tissues have different sources of vascularization. Practically, the type of blood supply will dictate the way the flap can be used.

Regional Source Major vessel located in the region of the flap that represents the source of circulation to dominant pedicle.

Length Distance from point of entry of pedicle into flap and regional source of circulation. This information will help determine the adequacy of that flap choice based on distance to the defect or recipient site.

Diameter Measurement of external lumen diameter to assist in planning for microvascular flap transplantation and vessel match at the recipient site.

Location Anatomic site of the vascular pedicle relative to the flap and its landmarks.

Minor Pedicle Smaller pedicles in relation to dominant vascular pedicle of flap that also help to vascularize the flap but may not reliably maintain tissue viability on its own. Also listed for minor pedicles are regional source, length, diameter, and location.

Venous Anatomy

The accompanying and auxiliary vessels that provide venous drainage for the flap.

Nerve Supply

Motor Source and location of motor nerve to the muscle flaps. Important data especially for design of a functional muscle flap. Also important when muscle function is not required and the surgeon wishes to avoid undesirable muscle contractions or enhance muscle atrophy at the recipient site.

Sensory Source and location of sensory nerves that have an anatomic relationship to the flap. These data will assist in design of cutaneous components of the flap with potential for sensory innervation. This information also helps to predict potential sensory deficits at the flap donor site.

The discussion proceeds to flap design and markings, patient positioning, and operative technique. The basic flap design is described, as well as known flap variants. The principal flap design is described first; description of the common variants follows. Wherever possible, we have included technical points invaluable to achieving success. The sections on flap transfer, flap inset, and donor site closure summarize the technical aspects necessary for safe completion of the reconstructive procedure after flap elevation.

All too often, operative descriptions fail to mention key procedural tips that make or break the success of a surgery. The Pearls and Pitfalls section has been written in bulleted form with this in mind, to provide the reader with as comprehensive a list as possible, thereby reducing the potential for failure. This is also an excellent way to reinforce important flap details when returning to the chapter. Augmenting this section, our expert commentators provide further insights into the successful execution of the procedures described. Their contributions and presentation of clinical cases bring the utility of the flaps into focus, demonstrating a broad range of possible applications for each flap or variant. Although case presentations have had to be limited by space constraints, they are intended to expose the reader to the many clinical applications available and are not intended to be comprehensive or exclusive.

The annotated bibliography includes a selection of the most relevant literature on each flap. Although the articles cited are not intended to be all-inclusive, every attempt has been made to briefly summarize publications that support the use of a flap or provide data relevant to its applications in reconstructive surgery.

Each section has been liberally illustrated with high-quality anatomic drawings and cadaveric photographs. The diagrams have been rendered in a combination of black and white line and color to clearly identify key anatomic elements important to flap design and execution. Extraneous detail has been downplayed for the sake of clarity. Color correction and artistic standardization has been maintained throughout.

We hope that this text will aid trainees as well as experienced surgeons in the selection and performance of a wide range of commonly used flaps. The format has been designed for ease of use, and its visual presentation will easily imprint critical flap details on the reader's memory.

Chapter 1

Surgical Decision-Making: Options, Principles, and Techniques

Reconstructive surgery combines science, anatomic knowledge, and surgical artistry to accomplish the goals of preserving life and restoring form and function. As plastic surgeons, we are called upon to treat defects ranging from small to large that often have a significant impact on function and on the patient's sense of self-esteem. Accordingly, reconstruction of these defects may require anything from simple direct suturing to complex composite free tissue transfers in multiple stages. The selection of the most appropriate reconstructive modality requires a careful assessment of the risks and benefits of each procedure in the light of the patient's clinical status. Procedures should be tailored to the individual's needs in providing a safe and expeditious recovery with minimal morbidity. In some instances, that may require a simple skin graft, such as for a fasciotomy wound in a leg. Other defects may be solved most easily with a free composite tissue transfer, the most extreme example being a face transplant for massive facial soft tissue loss. Although complex in execution and postoperative management, the procedure provides a one-stage restoration of facial structures unparalleled by any other techniques to date.

THE RECONSTRUCTIVE PARADIGM

Surgical decision-making in general surgery has been simplified to some extent by outcomes-based algorithms that lead to clear-cut approaches and procedures suitable for dealing with a wide range of problems. By contrast, surgical decision-making in plastic surgery is complicated by the vast array of procedures suitable for a given problem, each one offering advantages and disadvantages. While this text attempts to provide the reader with an atlas of flaps to assist with the execution of a given procedure, the choice of procedure can be bewildering, especially for the neophyte.

In the past, the reconstructive ladder became a much-publicized tool to aid surgeons in decision-making.

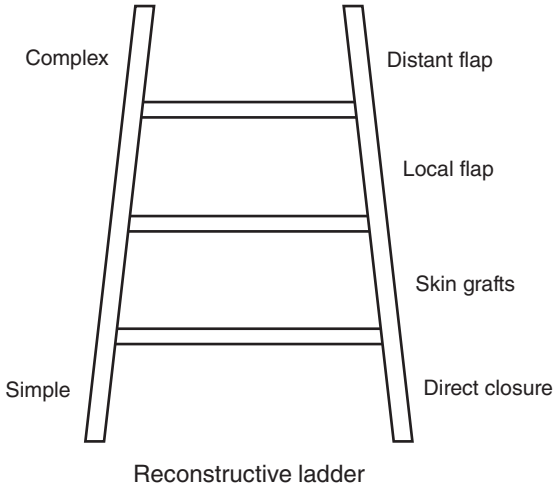


Fig. 1-1

In recent years, the ladder has been dismissed by many as being simplistic and outdated. Although this may be partially true, the ladder simply attempted to provide surgeons with a progressive approach to wound management, beginning with simple solutions such as direct wound closure, progressing to grafts, adjacent flaps, and then distant or free flaps. There is nothing inherently wrong with this approach, other than to say that it is not necessary to progress in a stepwise fashion from a simple operation to a more complex one, only to end with a free flap because the previous option failed. In other words, free flaps are not a last resort. The reconstructive ladder never attempted to suggest that. It merely suggested a progressively more complex approach, using the simplest technique possible if it was feasible and best for the patient. The problem with maintaining the hierarchy of the reconstructive ladder is that although a skin graft is appropriate management for a granulating fasciotomy wound of the leg, it is clearly not a viable proposition for a composite hemimandibulectomy defect. Similarly, while a split-thickness skin graft could be placed over viable tissues across a joint flexion crease, flexion contracture would be a certainty, and the patient would be better served with a full-thickness graft or flap procedure.

When considering reconstructive options, it is imperative to bear in mind that safe wound closure should be based on the selection of the most appropriate technique, whether simple or complex, to achieve effective wound-healing, while taking into account local wound requirements and complexity.

In an attempt to clarify some of these issues, the reconstructive triangle was proposed.

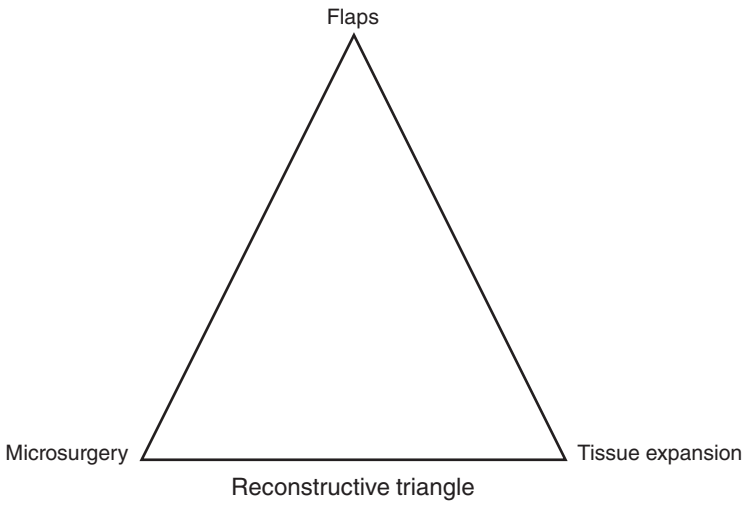


Fig. 1-2

Rather than suggesting a stepwise progression from simple to complex, the triangle concept allowed for a free flow between pedicled flaps, tissue expansion and free tissue transfer. Although attractive in some respects, this model does not give the surgeon any guidance other than to suggest that any of the above options may be useful (which we already know), and it does not allow for the use of direct closure or grafts. Also, it overstated the role of tissue expansion in daily reconstructive surgery. As such, it fails to provide a clinically useful roadmap.

Rather than this simplistic procedural triangle, it may be preferable to conceive of a triangle housing several interdependent components leading to wound closure.

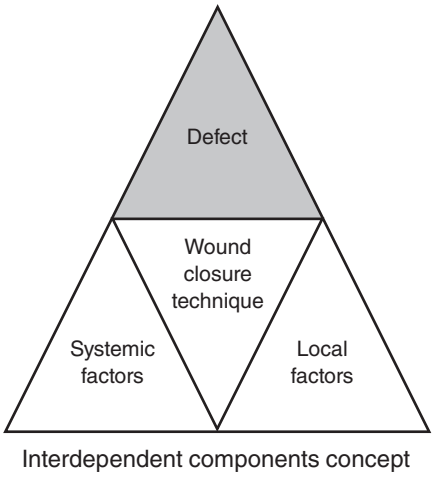


Fig. 1-3

When assessing a wound for closure, the reconstructive surgeon needs to evaluate a multiplicity of factors to determine which procedure is most appropriate. These include the patient's general health, the location and size of the defect, concomitant systemic risk factors such as tissue irradiation, and the availability of tissue donor sites.

Systemic Factors

A patient's pathology may result from either congenital or acquired conditions. Acquired problems may arise from trauma, infection, radiation therapy, neoplasia, or vascular or autoimmune causes. Defects may be stable or unstable and may range from physically deforming to life threatening. The patient's underlying health plays an important role in determining when and what, if anything, should be done. Although some procedures are simple and can be performed under local anesthesia on an outpatient basis, others require lengthy general anesthetics with postoperative intensive care. A seriously ill patient may not tolerate such a complex intervention. It should be remembered that organ failure or major medical morbidity takes precedence over defect reconstruction. In recent years the use of negative-pressure wound therapy (NPWT) has allowed temporary wound control while other more serious medical and surgical emergencies are dealt with. Once the patient's condition is stable, definitive wound closure can be performed.

A second group of patients includes those with functional disability or severe deformity without concomitant life-threatening illness. Patients may be severely incapacitated by these problems and require complex reconstructions. A patient with a grossly disfiguring facial burn may be socially stigmatized and suffer severe psychological sequelae without life-threatening consequences. The problem may be salvageable with a face transplant or a series of more standard operations.

Patients with severe neurologic impairment or a limited lifespan as a result of organ failure are not good candidates for complex reconstructions, particularly when such procedures rely on normal physiologic function as part of a successful recovery.

Systemic factors that impact wound-healing and flap survival include smoking, obesity, immunocompromised states, steroid usage, and cardiopulmonary impairment. When flaps are planned in high-risk patients, one should consider maneuvers to increase blood supply and improve the safety of the procedure.

Organ System Derangements That Contraindicate Surgery and Require Treatment Before Management of Complex Defects

Neurologic System
Space-occupying lesion with impending herniation
Acute infarction

Cardiovascular System
Acute myocardial infarction
Acute cardiac failure
Acute peripheral vascular insufficiency
Compartment syndrome

Respiratory System
Upper airway obstruction
Acute respiratory insufficiency

Gastrointestinal and Pancreaticobiliary Systems
Infarction
Obstruction
High-output fistulas

Kidney
Acute obstruction
Acute failure

Hematopoietic System
Shock (acute blood loss)
Bleeding disorder

Endocrine System
Acute adrenal insufficiency

Local Factors

Patients may be in good general health but have local wound conditions that place them at high risk for failure. Wound contamination, infection, radiation therapy, poor vascularity, extensive scarring, or exposure of underlying tissues such as bone, joint, tendons, viscera, or body cavities require widely differing approaches to reconstruction.

Defect Analysis

Analysis includes an evaluation of:

- Size
- Location
- Wound characteristics
- Adjacent tissue
- Potential donor sites

The wound bed should include an assessment of all tissue components, including:

- Tissue quality
- Skin
- Subcutaneous tissue
- Mucosa
- Vasculature
- Nerve supply
- Cartilage
- Bone

Wound characteristics include assessment of:

- Vascularity to the region
- Infection
- Desiccation
- Tissue viability and presence of slough or eschar
- Quality of granulation (if any)
- Presence or absence of radiation injury
- Degree of fibrosis and scarring
- Presence or absence of malignancy

Timing of Closure

The timing of wound closure is critical to a successful outcome. Operating on an unstable patient with hypoperfusion may result in potential flap loss. Godina demonstrated that performing a free tissue transfer to a lower extremity compound fracture 5 to 21 days after injury tends to be associated with higher flap failure rates and increased infectious complications. For severe contamination or overt infection, the wound should be adequately debrided and reassessed carefully, allowing time for inflammation to resolve before a complex reconstructive procedure is undertaken. With the advent of multidisciplinary approaches to treatment, early closure of wounds has become increasingly frequent. If surgery has to be delayed because of patient instability or organ failure, NPWT has played a major role in maintaining a temporary safe and clean environment before definitive coverage. Tumor extirpation followed by immediate reconstruction in cancer treatment has allowed primary closure with functional reconstruction in complex situations, with improvement in patient outcomes and reduced morbidity.

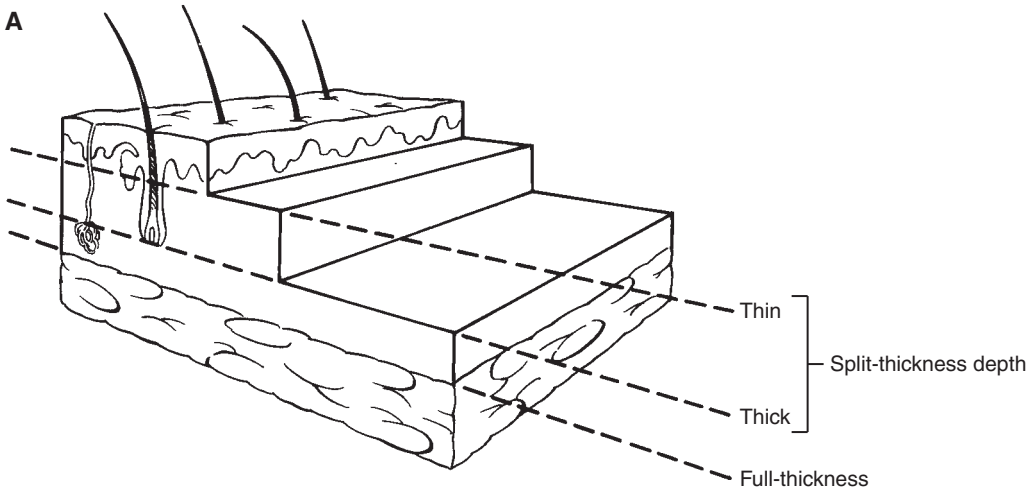
A SYSTEMATIC APPROACH TO WOUND CLOSURE: SURGICAL OPTIONS

Split-Thickness Skin Grafts

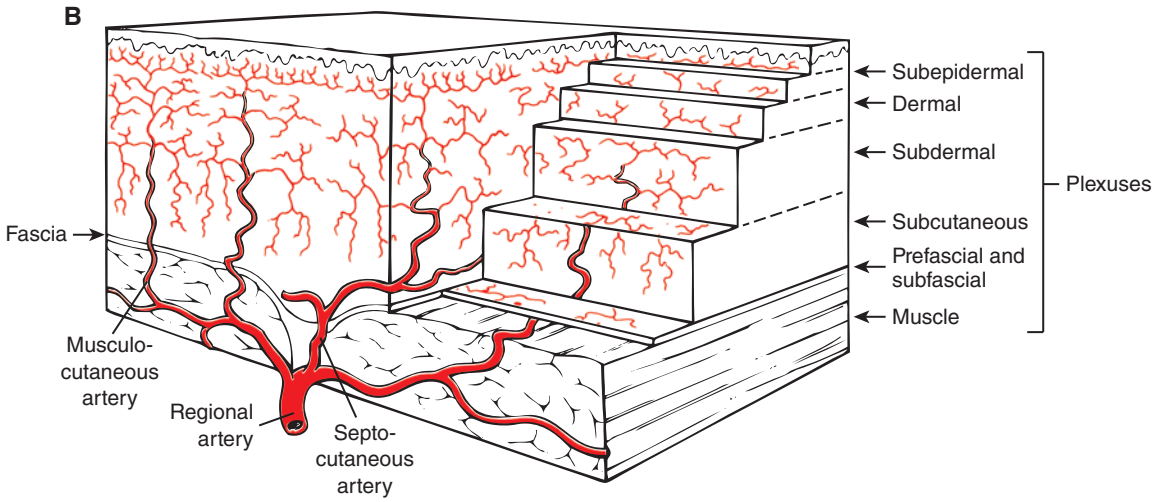
Split-thickness skin grafts are invaluable in the management of superficial, granulating clean wounds overlying stable surfaces. They are simple, easily performed, and take rapidly on a vascularized bed by imbibition and inosculation. They tend to shrink, contracting the original wound size in both area and depth, and can produce quite good aesthetic outcomes. Their inherent tendency to contract makes them a poor choice for use across joints and for correcting contractures. Because of their thin nature, they tend not to maintain their characteristic color and texture. Their donor sites are painful and leave potentially large surface area scars. Wounds with irregular surfaces often benefit from NPWT as the bolster over the skin graft to improve graft-to-bed apposition.

Full-Thickness Skin Grafts

Full-thickness grafts, by contrast, are more aesthetically pleasing and are widely used to correct or limit contractures. They provide better texture on the face and hands but produce large, full-thickness donor site defects requiring direct donor site closure, a factor precluding the harvest of very large grafts. Given their thickness, they are slower to develop a blood supply, and take is correspondingly slower. To succeed, these grafts require a freshly prepared, well-vascularized bed. Graft-to-bed apposition has to be meticulously maintained with bolster dressings to achieve complete take. Color match and contour are often better than those achieved with split-thickness grafts.



Depth of skin elevation for split-thickness and full-thickness skin graft



Skin circulation

Fig. 1-4

Local Cutaneous Flaps

Flaps are full-thickness blocks of tissue perfused by regional source vessels with varying patterns of supply. The nature of flap blood supply is the topic of Chapter 2. Traditionally, flaps were considered random in terms of blood supply, until the axial nature of the groin flap was discovered. The random concept led to complex tubed pedicle transfers in multiple stages to bring a given piece of tissue to its final destination, distant to its origin.

Random Pattern Flaps

The term *random flaps* has historically been used to refer to skin flaps raised without a known, named blood supply leading to more tenuous flap survival rates. The term has also been applied to flaps with a known blood supply at their bases, but that have been designed to include more distant areas of skin with the hope that these will survive on random extensions of the known supply into the distal tissue. This led to a somewhat hit-and-miss approach to reconstructive surgery.

With the discovery of the groin flap's axial blood flow, reconstructive surgery took a major leap forward in both predictability and creativity. *Axial pattern flaps* refers to the supply by a named, identifiable source vessel. Taylor's pioneering studies of skin vasculature, built on the concepts of Michel Salmon, demonstrated that all skin is perfused from perforators arising from or between the underlying muscles and fascial septa. As such, although these flaps are perfused by an unnamed vessel, they are in fact perforator variants of one sort or another, arising from named vessels.

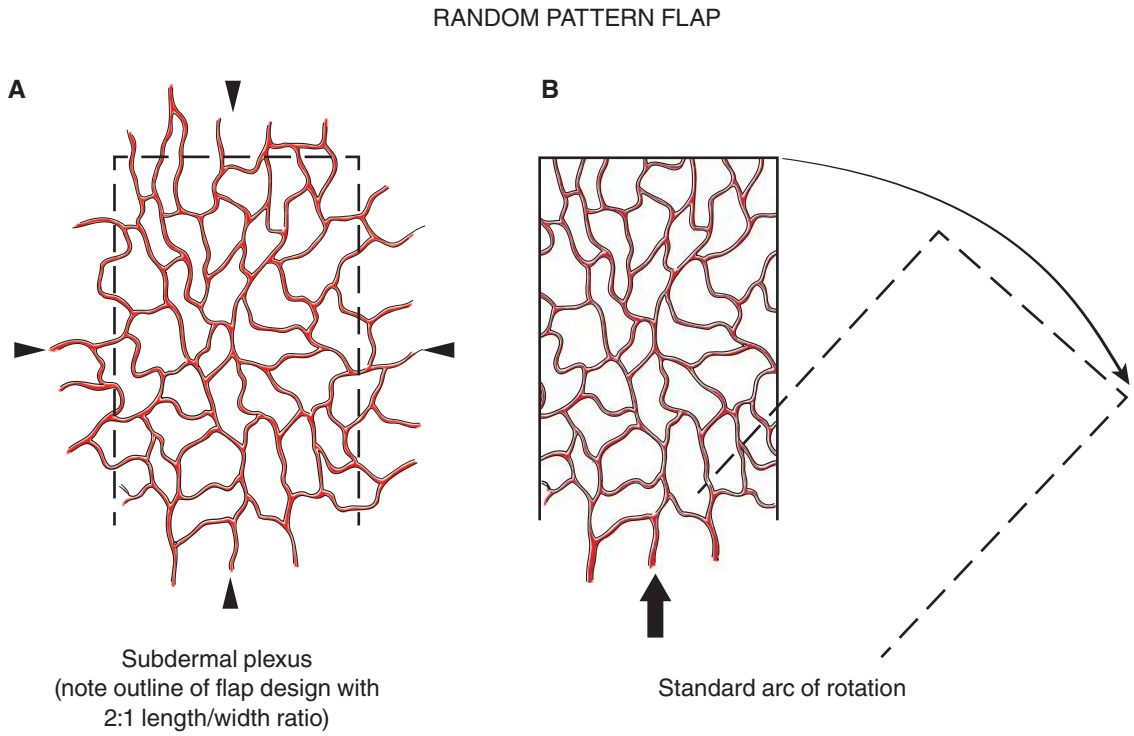


Fig. 1-5

Propeller Flaps

It is not uncommon for a surgeon to raise a flap based on Doppler identification of a small, unnamed perforator derived from a known regional source artery, which provides axial blood supply to the overlying skin island. When the design is an ellipse and the flap is transposed based on that perforator, the term *propeller flap* has come in vogue. Propeller flaps are a type of perforator flap. They are called propeller flaps because the flaps rotate around the pedicle in the same way a propeller rotates around its hub. They can be designed freestyle, meaning that the surgeon can identify a perforator and design a propeller flap based on it to cover an adjacent defect. The term also describes the technique by which the flap is rotated into the defect. Propeller flaps can be used anywhere, but are probably used most often in the lower limb. It used to be taught that a free flap was required for defects of the lower limb. Now, however, many of these defects can be closed with a propeller flap, replacing the need for a free flap and making things much simpler for the surgeon and the patient.

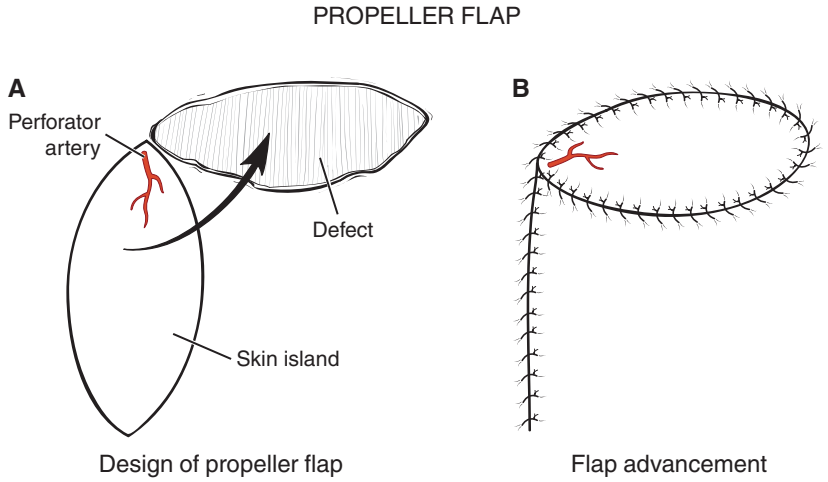


Fig. 1-6

Based on these observations, use of the word *random,* as applied to flap blood supply, is rapidly becoming obsolete. Although it is true that a flap may have a perforator in its base, so-called random flaps are usually designed with a length that may outrun the axial blood flow, thereby leaving the terminal part of the flap as a random extension. It is in this situation that length-to-breadth ratios come into play: the greater the length-to-breadth ratio, the greater the risk of necrosis. The ideal ratio is 1.5:1, with a maximum of 2:1. If an axial blood flow enters the base of the flap, ratios of 3:1 to as much as 6:1 have been described in fasciocutaneous flaps such as the supraclavicular flap. This is also related to Taylor's angiosome concept of blood flow, in which an adjacent vascular territory may be captured fairly reliably but more distant angiosomes will be more prone to necrosis. These local flaps can be either transposition or rotation advancement flaps and while invaluable in many situations, their usefulness is limited by their arc of rotation. Examples of such procedures are Limberg flaps in facial skin cancer closures and gluteal rotation advancements for pressure sore closure.

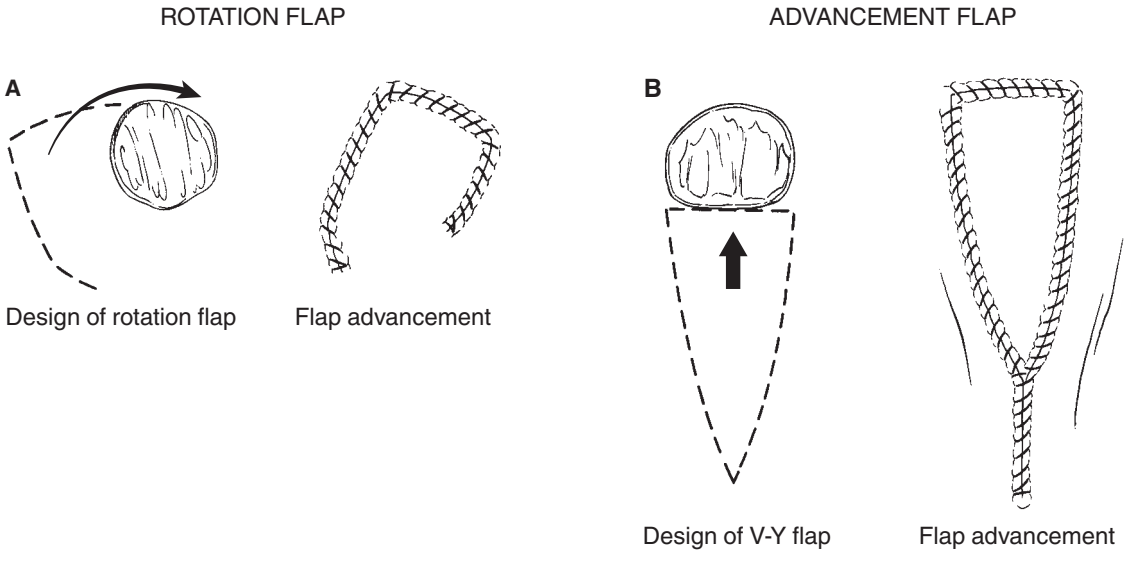


Fig. 1-7

Axial Perforator–Based Cutaneous Flaps

Cutaneous flaps with a known axial or perforator inflow often have a longer arc of rotation, and some have the option of being converted to free flaps. Typical examples include the groin, radial forearm, and supraclavicular flaps. These flaps are usually cutaneous, but some may be raised as adipofascial alternatives. The effectiveness of these flaps should not be underestimated. For example, the supraclavicular flap, an axial perforator–based flap, has often led its proponents to abandon their free flap options entirely for head and neck reconstruction in favor of this reliable and easy-to-use local pedicled flap.

Muscle and Myocutaneous Flaps

Muscle flaps are based on axial or segmental vascular supplies. This discovery in the clinical context led to the next major advance in plastic surgery after axial pattern flaps had evolved. The classification of the various blood flow patterns is described in Chapter 2. Those flaps with dominant axial inflows can be raised as pedicled or free flaps, such as the rectus abdominis or latissimus flaps, whereas those with segmental supplies, such as the sartorius, external oblique, or biceps femoris, are used only as transposition flaps. Muscle flaps are bulkier, have excellent blood flow, and can fill large defects. Many can be raised with an overlying skin paddle. Their vascularity makes them useful carriers of oxygen, growth factors, and antibiotics into the wound-healing milieu. Some are used as functional transfers, such as the latissimus dorsi, pectoralis minor, and gracilis flaps.

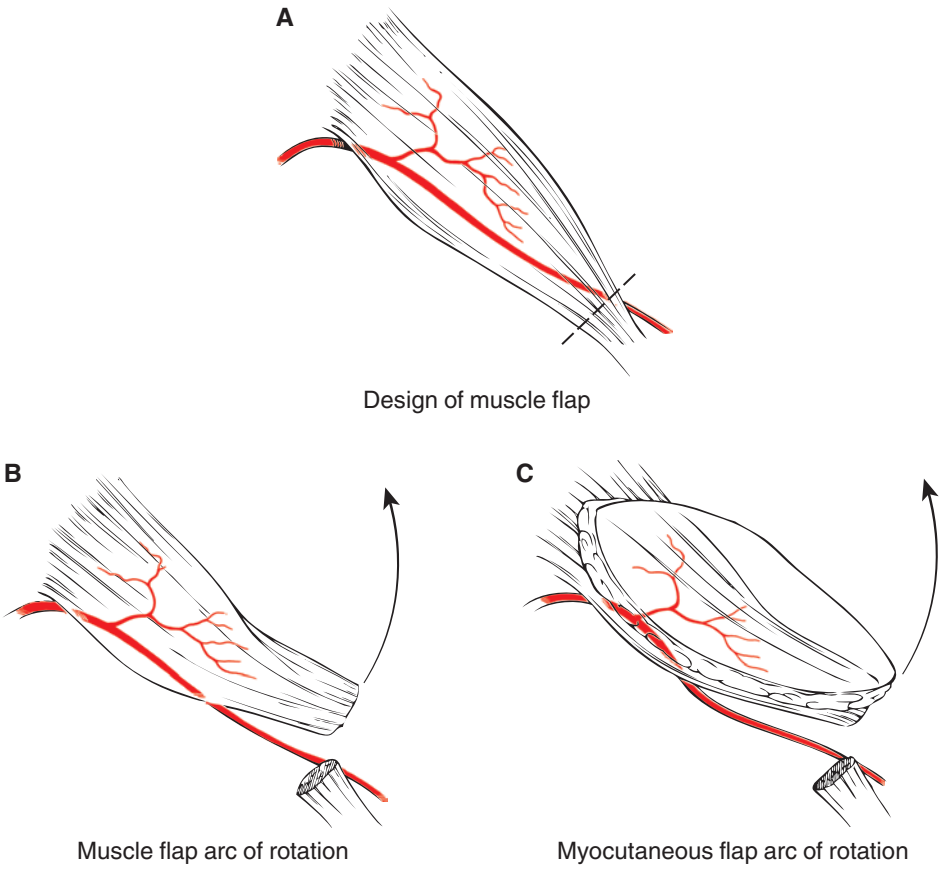


Fig. 1-8

Prediction of Arc of Rotation

The extent that a muscle may be elevated from its anatomic location and its subsequent ability to reach adjacent defects without devascularization determines its arc of rotation. The dominant vascular pedicle's entrance site into the muscle determines the point of rotation. (See Mathes and Nahai Classification, Chapter 2.)

Only muscle distal to the point of rotation is used as a transposition flap. For muscle types I, II, III, and V, the point of rotation is usually at one end or the proximal third of the muscle. For type IV, however, only the proximal or distal third of the muscle can be safely elevated because of the segmental vascular pattern; therefore type V muscle has a limited arc of rotation.

In type II muscle, the two dominant vascular pedicles are positioned at opposing ends of the muscle; thus the arc of rotation is smaller, because the whole muscle may not survive transposition on one vascular pedicle.

Type V muscle has two arcs of rotation; the total muscle can be safely elevated on the dominant vascular pedicle that enters adjacent to the muscle insertion in the shoulder girdle. Division of this dominant vascular pedicle permits safe transposition (a reverse arc of rotation) on the secondary segmental pedicles entering the muscle adjacent to the origin in the midline of the trunk.

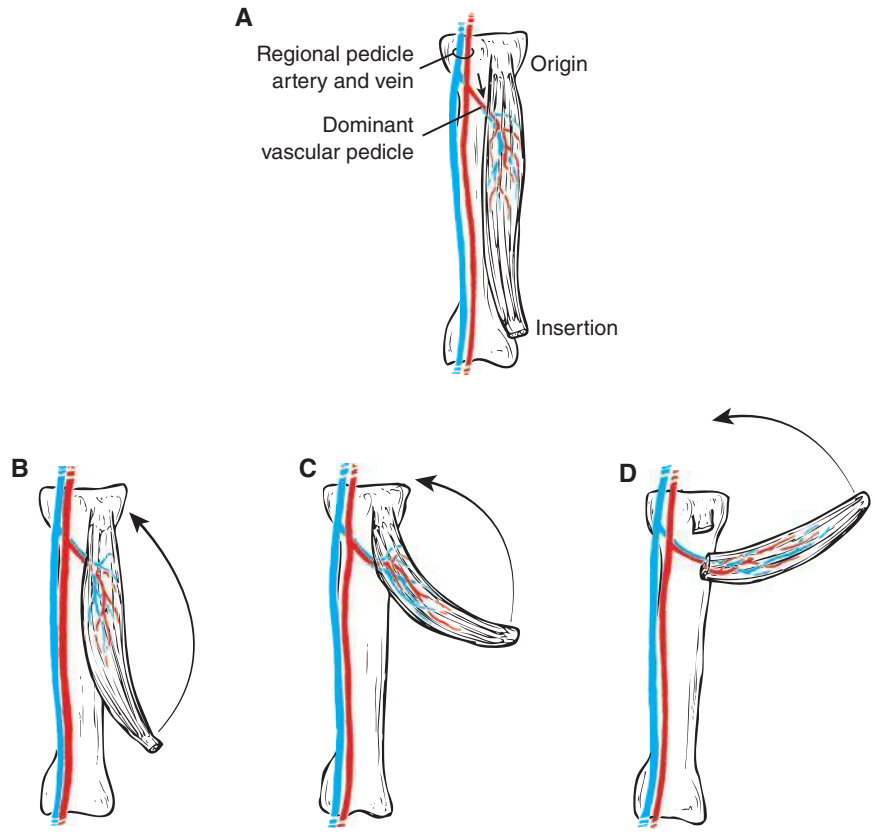


Fig. 1-9 **A,** Flap anatomy. **B,** Arc of rotation with flap elevation to the point of entrance of the vascular pedicle to the flap. Applications of the flap are based on standard arcs of rotation. **C,** Extended arc of rotation based on flap elevation with dissection of the pedicle to its regional source. **D,** Extended arc of rotation based on flap elevation with pedicle dissection and release of proximal fascia and/or muscle origin or insertion.

Fascial and Fasciocutaneous Flaps

Before the discovery of the importance of fasciocutaneous blood supply, skin flaps had been raised in the subcutaneous plane at the suprafascial level. Cormack, Lamberty, and Ponten, among others, discovered the enhanced blood flow to flaps achieved by simply incorporating the underlying fascial layer which carried with it fascial blood flow. The resulting fasciocutaneous flaps became a new vascular basis for flap design with considerably improved flap reliability. Fascial vessels were identified as running on the surface of the fascia, perforating either from the underlying muscles or from within the fascial septa between muscle groups. This important discovery, coupled with the earlier understanding of muscle flap blood supply, formed the basis of modern flap design based on an understanding of tissue perfusion and altered the entire course of modern reconstructive plastic surgery. Fascial and fasciocutaneous flaps play a major role in reconstructive surgery today. Examples of such workhorse flaps include the pedicled radial forearm flap and temporoparietal fascia flap.

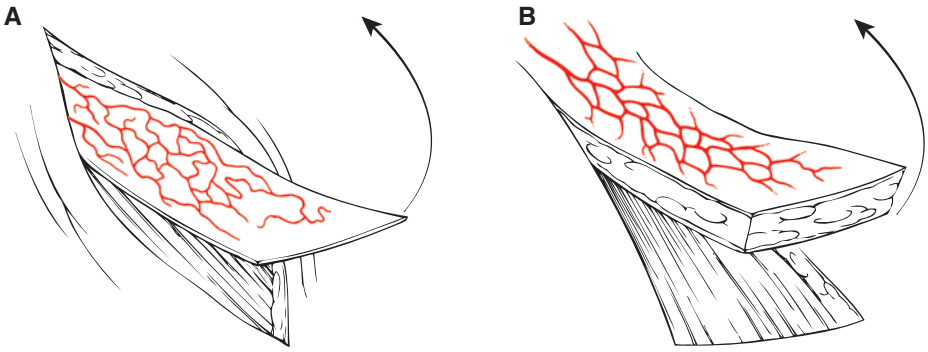


Fig. 1-10

Composite Flaps

Complex defects often require multicomponent flaps to achieve closure. A full-thickness mandibular defect may require skin, bone and intraoral lining, all of which can be supplied with a fibular or iliac crest composite free flap. Although usually used as free flaps, composite flaps can be used as pedicled procedures, as in a fibular translocation into an ipsilateral tibial defect or a pedicled iliac crest bone graft to treat osteomyelitis of the symphysis pubis.