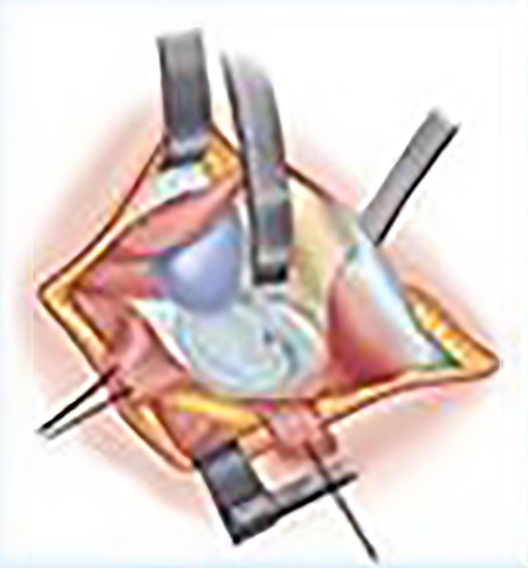
MD

CAMPBELL'S OPERATIVE ORTHOPAEDICS

THIRTEENTH EDITION



S. TERRY CANALE
JAMES H. BEATY
FREDERICK M. AZAR

INTERNATIONAL EDITION

ELSEVIER

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IN MEMORY

Lee W. Milford, MD
1922–2013

Robert E. Tooms, MD
1933–2013

Since the last edition of this text, we have lost two of our friends and mentors, Dr. Lee Milford and Dr. Robert Tooms, both of whom made important contributions to several editions of *Campbell's Operative Orthopaedics*. Dr. Milford was responsible for the first chapter in the book to focus on surgery of the hand. In the 7th edition of *Campbell's Operative Orthopaedics* (1987), he established the format for the hand section of the text by dividing the enormous amount of information from one chapter into 18 more focused chapters. His hand surgery chapters formed the basis of three monographs (*The Hand*). Dr. Tooms also expanded his area of expertise, taking amputation from a single chapter to multiple, anatomy-based chapters. His compassion for and dedication to amputees, especially children, are evident in his work. He was an early adopter of total joint arthroplasty and contributed some of the first chapters on total knee and total ankle arthroplasty. The experience and expertise of these two staff members added immensely to the value of our book, and we hope subsequent editions have remained true to their example.

DEDICATION

This 13th edition of *Campbell's Operative Orthopaedics* is dedicated to all of the contributors, present and past, without whose knowledge and dedication this text would be impossible. Over the years, nearly 100 authors have freely shared their time and knowledge with their colleagues, residents, fellows, and medical students. Their varied areas of expertise have allowed our text to cover a wide array of orthopaedic conditions and procedures and to keep information current. The willingness of these experts in their respective fields to take the time and make the effort to contribute well thought out and well-written chapters is a large part of the ability of *Campbell's Operative Orthopaedics* to remain relevant and useful for almost 80 years.

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PREFACE

Over the past four years, our authors have exhaustively reviewed a multitude of new techniques, new equipment, and new information in the world literature to produce a comprehensive update of our textbook. This edition reflects the growing numbers of less-invasive surgical techniques and devices that are being described, with promising results reported, and many arthroscopic and endoscopic techniques that continue to expand their indications. Over the last several years, ambulatory surgery centers have become an important part of orthopaedic surgery—from ligament repair to total joint arthroplasty—and outpatient orthopaedic surgery is now more frequently performed than standard hospital-based surgery in many centers. With knowledge and technology expanding and evolving at an ever-increasing speed, we have attempted to include the latest orthopaedic procedures while retaining as a foundation many of the classic techniques.

As always, the Campbell Foundation staff—Kay Daugherty and Linda Jones, editors; Shawn Maxey, graphics; and Tonya Priggel, librarian—were essential in the production of this edition. Thanks to Kay and Linda for taking sometimes illegible notes on a napkin and translating them into eloquent English, to Shawn for keeping track of the hundreds of illustrations, and to Tonya for always locating the latest information on any topic. As many of our orthopaedic colleagues who have visited our institution can affirm, the piles of references, rough drafts, and jammed-full file folders that occupy the office floor are a testament to this monstrous undertaking. Our thanks, too, to Taylor Ball, Content Development Editor; Dolores Meloni, Executive Content Strategist; and John Casey, Senior Project Manager, at Elsevier publishing, who provided much guidance, encouragement, and assistance and who, while they may have doubted that we would get material in on time, never expressed anxiety. We also are most appreciative of the worldwide community of orthopaedic surgeons for their expertise and innovation without which our book would not be possible. Without their zeal to learn, teach, and contribute to the body of orthopaedic knowledge, our purpose would be compromised.

We are most grateful to our families, especially our wives, Sissie Canale, Terry Beaty, and Julie Azar, who patiently endured our total immersion in the publication process.

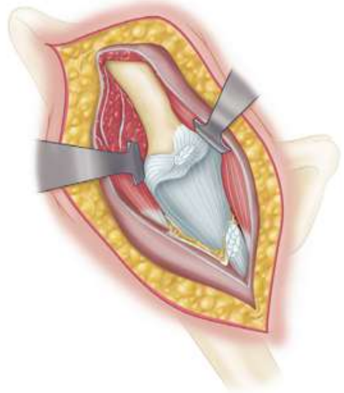
Technology has made the exchange of information easier and faster, but, as noted by one pundit, we can "drown in technology" and the "fog of information can drive out knowledge." We have attempted to take advantage of current technology while presenting information in a consistent and concise manner that clears the "fog" and adds to knowledge. Dr. Campbell noted many years ago, "The purpose of this book is to present to the student, the general practitioner, and the surgeon the subject of orthopedic surgery in a simple and comprehensive manner." We hope that this edition continues to live up to his standards.

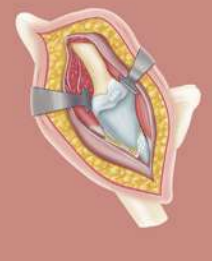
Frederick M. Azar, MD
James H. Beaty, MD
S. Terry Canale, MD

VIDEO CONTENTS

PART I

GENERAL PRINCIPLES





CHAPTER 1

SURGICAL TECHNIQUES AND APPROACHES

Andrew H. Crenshaw Jr.

SURGICAL TECHNIQUES

There are several surgical techniques especially important in orthopaedics: use of tourniquets, use of radiographs and image intensifiers in the operating room, positioning of the patient, local preparation of the patient, and draping of the appropriate part or parts. Operative techniques common to many procedures, fixation of tendons or fascia to bone, and bone grafting also are described.

TOURNIQUETS

Operations on the extremities are made easier by the use of a tourniquet. The tourniquet is a potentially dangerous instrument that must be used with proper knowledge and care. In some procedures a tourniquet is a luxury, whereas in others, such as delicate operations on the hand, it is a necessity. A pneumatic tourniquet is safer than an Esmarch tourniquet or the Martin sheet rubber bandage.

A pneumatic tourniquet with a hand pump and an accurate pressure gauge probably is the safest, but a constantly regulated pressure tourniquet is satisfactory if it is properly maintained and checked. A tourniquet should be applied by an individual experienced in its use.

Several sizes of pneumatic tourniquets are available for the upper and lower extremities. The upper arm or the thigh is wrapped with several thicknesses of smoothly applied cast padding. Rajpura et al. showed that application of more than two layers of padding resulted in a significant reduction in the actual transmitted pressure. When applying a tourniquet on an obese patient, an assistant manually grasps the flesh of the extremity just distal to the level of tourniquet application and firmly pulls this loose tissue distally before the cast padding is placed. Traction on the soft tissue is maintained while the padding and tourniquet are applied, and the latter is secured. The assistant's grasp is released, resulting in a greater proportion of the subcutaneous tissue remaining distal to the tourniquet. This bulky tissue tends to support the tourniquet and push it into an even more proximal position. All air is expressed from the sphygmomanometer or pneumatic tourniquet before application. When a sphygmomanometer cuff is used, it should be wrapped with a gauze bandage to prevent its slipping during inflation. The extremity is elevated for 2 minutes, or the blood is expressed by a sterile sheet rubber bandage or a cotton elastic bandage. Beginning at the fingertips or toes, the extremity is wrapped proximally to within 2.5 to 5 cm of the tourniquet. If a Martin sheet rubber bandage or an elastic bandage is applied up to the level of the tourniquet, the latter tends to slip distally at the time of inflation. The tourniquet should be inflated quickly to prevent filling of the superficial veins before the arterial blood flow has been occluded. Every effort is made to decrease tourniquet time; the extremity often is prepared and ready before the tourniquet is inflated. The conical, obese, or muscular lower extremity presents a special challenge. If a curved tourniquet is not available, a straight tourniquet may be used but is difficult to hold in place because it tends to slide distally during skin preparation. Application of adhesive drapes, extra cast padding, and pulling the fat tissue distally before applying the tourniquet generally works. A simple method has been described to keep a tourniquet in place on a large thigh. Surgical lubricating jelly is applied circumferentially to the thigh, and several layers of 6-inch cast padding are applied over the jelly. The tourniquet is then applied. The cast padding adheres to the lubricating jelly-covered skin and reduces the tendency of the tourniquet to slide.

The exact pressure to which the tourniquet should be inflated has not been determined (Table 1-1). Evidence indicates that pressures greater than necessary have been used for many years. The correct pressure depends on the age of the patient, the blood pressure, and the size of the extremity. Reid et al. used pneumatic tourniquet pressures determined by the pressure required to obliterate the peripheral pulse (limb occlusion pressure) using a Doppler stethoscope; they then added 50 to 75 mm Hg to allow for collateral circulation and

TABLE 1-1

Published Recommendations on Tourniquet Use

ORGANIZATION/STUDY	PRESSURE	DURATION (MIN)	REPERFUSION INTERVAL
Association of Surgical Technologists	Upper extremity, 50 mm Hg above SBP; lower extremity, 100 mm Hg above SBP	Upper extremity, 60; lower extremity 90	15 min
Association of Perioperative Registered Nurses	40 mm Hg above LOP for LOP <130 mm Hg; 60 mm Hg above LOP for LOP <131-190 mm Hg; 80 mm Hg above LOP for LOP > 190 mm Hg	Upper extremity, 60; lower extremity 90	15 min deflation after every 1 h of tourniquet time
Wakai et al.	General recommendation, 50-75 mm Hg above LOP; upper extremity, 50-75 mm Hg above SBP; lower extremity, 90-150 mm Hg above SBP	120	30 min at 2-h point in surgery lasting >3 h
Kam et al.	50-150 mm Hg above SBP, using the lower end of the range for the upper extremity and the higher end for the lower extremity	120	10 min at the 2-h point for surgery lasting < 2 h
Noordin et al.	Use LOP. No margin specified	120	NR

From Fitzgibbons PG, DiGiovanni C, Hares S, Akelman E: Safe tourniquet use: a review of the literature. J Am Acad Orthop Surg 20:310, 2012.
LOP, Limb occlusion pressure; *NR,* no recommendation; *SBP,* systolic blood pressure.

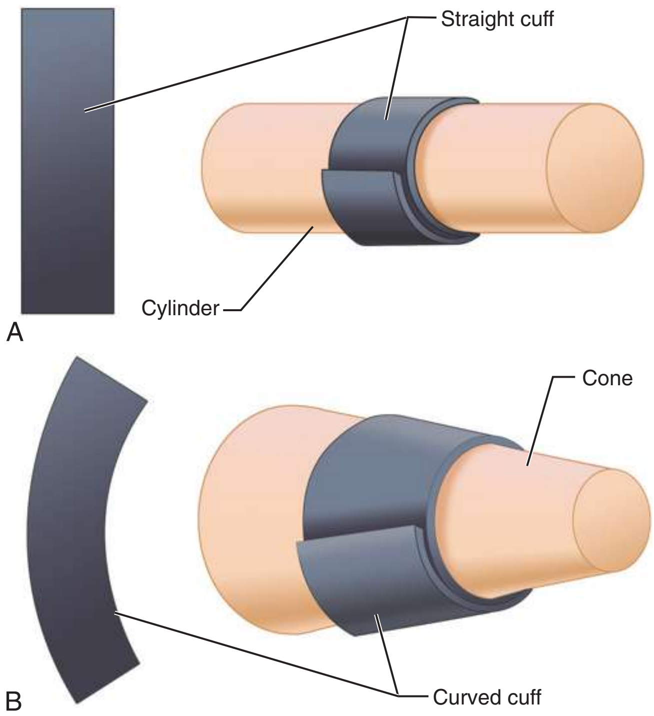


FIGURE 1-1 **A, Straight (rectangular) tourniquets fit optimally on cylindrical limbs. B, Curved tourniquets best fit conical limbs.** (From Pedowitz RA, Gershuni DH, Botte MJ, et al: The use of lower tourniquet inflation pressures in extremity surgery facilitated by curved and wide tourniquets and integrated cuff inflation system, *Clin Orthop Relat Res* 287:237, 1993.)

blood pressure changes. Tourniquet pressures of 135 to 255 mm Hg for the upper extremity and 175 to 305 mm Hg for the lower extremity were satisfactory for maintaining hemostasis.

According to Crenshaw et al., wide tourniquet cuffs are more effective at lower inflation pressures than are narrow ones. Pedowitz et al. showed that curved tourniquets on conical extremities require significantly lower arterial occlusion pressures than straight (rectangular) tourniquets (Fig. 1-1). The use of straight tourniquets on conical thighs should be avoided, especially in extremely muscular or obese individuals.

Any solution applied to skin must not be allowed to run beneath the tourniquet, or a chemical burn may result. A circumferential adhesive-backed plastic drape applied to the skin just distal to the tourniquet prevents solutions from running under the tourniquet. Sterile pneumatic tourniquets are available for operations around the elbow and knee. The limb may be prepared and draped before the tourniquet is applied. Rarely, a superficial slough of the skin may occur at the upper margin of the tourniquet in the region of the gluteal fold. This slough usually occurs in obese individuals and is probably related to the use of a straight, instead of a curved, tourniquet.

Pneumatic tourniquets should be kept in good repair, and all valves and gauges must be checked routinely. The inner tube should be completely enclosed in a casing to prevent the tube from ballooning through an opening, allowing the pressure to fall or causing a "blowout." The cuff also should be inspected carefully. Single-use sterile disposable tourniquets are preferable because reusable tourniquets must be thoroughly decontaminated after each use to prevent microbial colonization.

Any aneroid gauge must be calibrated frequently. Newer gauges carry instruction cards with them. They are sold with test gauges so that the gauges on the tourniquets can be tested for proper calibration. Many automatic tourniquet control units will self-test when turned on. If there is a discrepancy, the unit must be manually checked with a test gauge. If the discrepancy is more than 20 mm Hg, the unit should be repaired or replaced. One of the greatest dangers in the use of a tourniquet is an improperly registering gauge; gauges have been found to be 300 mm off calibration. In many tourniquet injuries, the gauges were later checked and found to be grossly inaccurate, allowing excessive pressure.

Tourniquet paralysis can result from (1) excessive pressure; (2) insufficient pressure, resulting in passive congestion of the part, with hemorrhagic infiltration of the nerve; (3) keeping the tourniquet on too long; or (4) application without consideration of the local anatomy. There is no rule as to how long a tourniquet may be safely inflated. The time may vary with the age of the patient and the vascular supply of the extremity. In an average healthy adult younger than 50 years of age, we prefer to leave the tourniquet inflated for no more than 2 hours. If an operation on the lower extremity takes longer than 2 hours, it is better to finish it as rapidly as possible than to deflate the tourniquet for 10 minutes and then reinflate it. It has been found that 40 minutes is required for the tissues to return to normal after prolonged use of a tourniquet. Consequently, the previous practice of deflating the tourniquet for 10 minutes seems to be inadequate. Posttourniquet syndrome, as first recognized by Bunnell, is a common reaction to prolonged ischemia and is characterized by edema, pallor, joint stiffness, motor weakness, and subjective numbness. This complication is thought to be related to the duration of ischemia and not to the mechanical effect of the tourniquet. Posttourniquet syndrome interferes with early motion and results in increased requirement for narcotics. Spontaneous resolution usually occurs within 1 week.

Compartment syndrome, rhabdomyolysis, and pulmonary emboli are rare complications of tourniquet use. One study, using transesophageal echocardiography during arthroscopic knee surgery, showed that asymptomatic pulmonary embolism can occur within 1 minute after tourniquet release. The number of small emboli depended on the duration of tourniquet inflation. Vascular complications can occur in patients with severe arteriosclerosis or prosthetic grafts. A tourniquet should not be applied over a prosthetic vascular graft.

Pneumatic tourniquets usually are applied to the upper arm and thigh, and a well-padded proximal calf tourniquet is safe for foot and ankle surgery. General guidelines for the safe use of pneumatic tourniquets are outlined in Table 1-2.

The Esmarch tourniquet is still in use in some areas and is the safest and most practical of the elastic tourniquets. It is never used except in the middle and upper thirds of the thigh. This tourniquet has a definite, although limited, use in that it can be applied higher on the thigh than can the pneumatic tourniquet. The Esmarch tourniquet is applied in layers, one

TABLE 1-2

Braithwaite and Klenerman's Modification of Bruner's Ten Rules of Pneumatic Tourniquet Use

APPLICATION	Apply only to a healthy limb or with caution to an unhealthy limb
SIZE OF TOURNIQUET	Arm, 10 cm; leg, 15 cm or wider in large legs
SITE OF APPLICATION	Upper arm; mid/upper thigh ideally
PADDING	At least two layers of orthopaedic felt
SKIN PREPARATION	Occlude to prevent soaking of wool. Use 50-100 mm Hg above systolic for the arm; double systolic for the thigh; or arm 200-250 mm Hg, leg 250-350 mm Hg (large cuffs are recommended for larger limbs instead of increasing pressure)
TIME	Absolute maximum 3 h (recovers in 5-7 days) generally not to exceed 2 h
TEMPERATURE	Avoid heating (e.g., hot lights), cool if feasible, and keep tissues moist
DOCUMENTATION	Duration and pressure at least weekly calibration and against mercury manometer or test maintenance gauge; maintenance every 3 months

Modified from Kutty S, McElwain JP: Padding under tourniquets in tourniquet controlled surgery: Bruner's ten rules revisited, Injury 33:75, 2002.

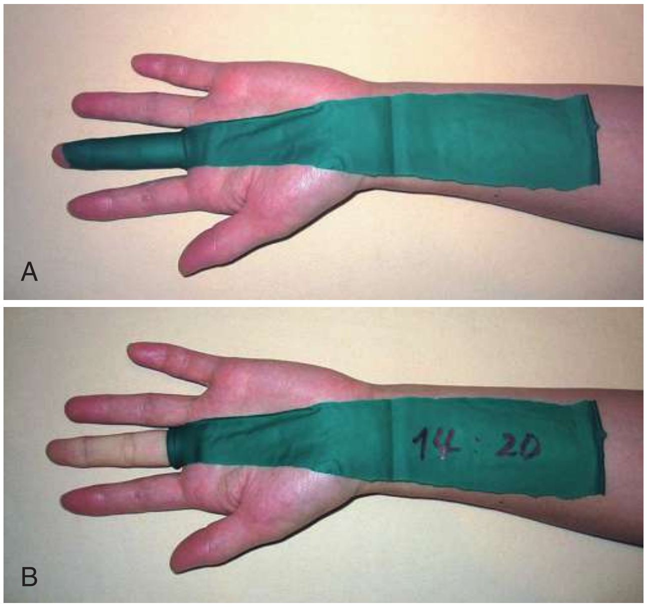


FIGURE 1-2 **A,** Cut 1 cm from the end of the corresponding glove finger, then cut through the palm half of the glove finger at the base and extend both ends of the cut longitudinally along the back side of the glove. Remove the remaining glove and finger and apply it to the palm side of the hand. **B,** Roll the glove finger back to serve as a tourniquet. Tourniquet start time can be written on the glove flap. (From Osanai T and Ogino T: Modified digital tourniquet designed to prevent the tourniquet from inadvertently being left in place after the end of the surgery. J Orthop Trauma 24:387, 2010.)

on the top of the other; a narrow band produces less tissue damage than does a wide one.

A Martin rubber sheet bandage can be safely used as a tourniquet for short procedures on the foot. The leg is elevated and exsanguinated by wrapping the rubber bandage up over the malleoli of the ankle and securing it with a clamp. The distal portion of the bandage is released to expose the operative area.

Special attention should be given when using tourniquets on fingers and toes. A rubber ring tourniquet or a tourniquet made from a glove finger that is rolled onto the digit should not be used because it can be inadvertently left in place under a dressing, resulting in loss of the digit. A glove finger or Penrose drain can be looped around the proximal portion of the digit, stretched, and secured with a hemostat. A modified glove finger with a volar flap will help prevent inadvertently leaving the tourniquet in place after surgery (Fig. 1-2).

It is difficult to include a hemostat inadvertently in a digital dressing.

Sterile disposable rubber ring tourniquets are now available for use on the upper and lower extremities. These tourniquets are wrapped in stockinette and are applied by rolling the rubber ring and stockinette up the extremity, which exsanguinates the extremity. The stockinette is then cut away at the operative site. Rubber ring tourniquets are not indicated in the presence of malignancy, infections, significant skin lesions, unstable fractures or dislocations, poor peripheral blood flow, edema, or deep venous thrombosis. Sizing of these tourniquets is based on systolic blood pressure.

The use of preoperative prophylactic antibiotics in orthopaedic operations has been accepted practice for over 30 years and decreases the likelihood of postoperative infection. Most believe that these antibiotics should be given prior to inflation of the tourniquet to ensure that the antibiotic is present in the tissues before the incision is made. There has been no consensus as to the interval between antibiotic administration and tourniquet inflation, with variations in time from 5 to 20 minutes being reported. Our institution requires administration of cephazolin within 1 hour of tourniquet inflation. Studies have shown that a 1-minute interval resulted in cephazolin concentration in soft tissue and bone at or greater than the minimum inhibitory concentrations for microorganisms encountered in orthopaedic surgery. A prospective randomized study found that the administration of antibiotics 1 minute after tourniquet inflation resulted in a significantly lower infection rate than the administration of antibiotics 5 minutes before tourniquet inflation, suggesting that administration before tourniquet inflation does not give better results.

RADIOGRAPHS IN THE OPERATING ROOM

Often it is necessary to obtain radiographs during an orthopaedic procedure. Radiography technicians who work in the operating room must wear the same clothing and masks as the circulating personnel. These technicians must have a clear understanding of aseptic surgical technique and draping to avoid contaminating the drapes in the operative field. Portable radiograph units used in the operating room should be cleaned regularly and ideally are not used in any other area of the hospital.

When an unsterile radiograph cassette is to be introduced into the sterile field, it should be placed inside a sterile double pillowcase or sterile plastic bag that is folded over so that the exterior remains sterile. The pillowcase or plastic bag is covered by a large sterile towel, ensuring at least two layers of sterile drapes on the cassette. The operative wound should be covered with a sterile towel when anteroposterior view radiographs are made to avoid possible contamination from the machine as it is moved into position.

Portable C-arm image intensifier television fluoroscopy allows instantaneous evaluation of the position of fracture fragments and internal fixation devices. Many of these machines have the ability to make permanent radiographs. When used near the sterile field, the C-arm portion of the machine must be draped in a sterile fashion (Fig. 1-3A). Every time the C-arm is brought to the lateral position (Fig. 1-3B), a fresh drape should be applied over the end of the C-arm and dropped off the field when complete. This prevents the potentially contaminated lower half of the drape from getting near the patient and operating surgeon.

As with any electronic device, failure of an image intensifier can occur. In this event, backup plain radiographs are necessary. Two-plane radiographs can be made, even of the hip when necessary, using portable equipment (Fig. 1-3C and D). Closed intramedullary nailing or percutaneous fracture fixation techniques may need to be abandoned for an open technique if the image intensifier fails.

All operating room personnel should avoid exposure to radiographs. Proper lead-lined aprons should be worn beneath sterile operating gowns. Thyroid shields, lead-impregnated eyeglasses, and rubber gloves are available to decrease exposure. C-arm imaging should be used as a 1- to 2-second pulse to produce a still image for viewing. Active fluoroscopy with the C-arm should be avoided to prevent excessive radiation exposure.

POSITIONING OF THE PATIENT

Before entering the operating room, the surgeon and the awake, alert patient should agree on the surgical site, and the surgeon should mark this clearly to prevent a "wrong-site" error. The position of a patient on the operating table should be adjusted to afford maximal safety to the patient and

FIGURE 1-3 **A** and **B,** Portable C-arm image intensifier television fluoroscopy setup for fracture repair. C-arm rotates 90 degrees to obtain lateral view. **C** and **D,** Technique for two-plane radiographs during hip surgery with a portable machine for anteroposterior and lateral views. Film cassette for lateral view is positioned over superolateral aspect of hip.

convenience for the surgeon. A free airway must be maintained at all times, and unnecessary pressure on the chest or abdomen should be avoided. This is of particular importance when the patient is prone; in this position, sandbags are placed beneath the shoulders, and a thin pillow is placed beneath the symphysis pubis and hips to minimize pressure on the abdomen and chest. Large, moderately firm chest rolls extending from the iliac crests to the clavicular areas may serve the same purpose.

When the patient is supine, the sacrum must be well padded; and when the patient is lying on his or her side, the greater trochanter and the fibular neck should be similarly protected. When a muscle relaxant drug is used, the danger of stretching a nerve or a group of nerves is increased. Figure 1-4 shows traction on the brachial plexus from improper positioning of the arm. The brachial plexus can be stretched when the arm is on an arm board, particularly if it is hyperabducted to make room for the surgeon or an assistant or for administration of intravenous therapy. The arm should never be tied above the head in abduction and external rotation while a body cast is applied because this position may cause a brachial plexus paralysis. Rather, the arm should be suspended in flexion from an overhead frame, and the position should be changed frequently. Figure 1-5 shows the position of the arm on the operating table that may cause pressure on the ulnar nerve, particularly if someone on the operating team leans against the arm. The arm must never be allowed to hang over the edge of the table. Padding should be placed over the area where a nerve may be pressed against the bone (i.e., the radial nerve in the arm, the ulnar nerve at the elbow, and the peroneal nerve at the neck of the fibula).

LOCAL PREPARATION OF THE PATIENT

Superficial oil and skin debris are removed with a thorough 10-minute soap-and-water scrub. We prefer a skin cleanser containing 7.5% povidone-iodine solution that is diluted approximately 50% with sterile saline solution. Hexachlorophene-containing skin cleanser is substituted when allergy to shellfish or iodine is present or suspected. After scrubbing, the skin is blotted dry with sterile towels. This scrub can be performed in the patient's room just before surgery or in the operating room. If performed outside the operating room, the extremity must be wrapped securely with sterile sheets.

After a tourniquet has been placed, if one is required, the sterile sheets applied during the earlier preparation should be removed. Care should be taken that the operative field does not become contaminated because the effectiveness of the preparation would be partially lost. With the patient in the proper position, the solutions are applied, each with a separate sterile sponge stick, beginning in the central area of the site of the incision and proceeding peripherally. Tincture of iodine containing 85% alcohol is still widely used as a skin preparation. Once painted on, it is allowed to dry and then is taken off with plain alcohol. Some surgeons routinely use povidone-iodine solution, especially when the risk of a chemical burn from tincture of iodine is significant. The immediate operative field is prepared first; the area is enlarged to include ample surrounding skin. The sponges used to prepare the lumbar spine are carried toward the gluteal cleft and anus rather than in the opposite direction. Sponges should not be saturated because the solution would extend beyond the operative field and must be removed. Excessive iodine, even in the operative field, should be removed with alcohol to prevent chemical dermatitis. If the linen on the table or the sterile drapes become saturated with strong antiseptic solutions, they should be replaced by fresh linen or drapes. Solutions should not be allowed to flow underneath a tourniquet. Pooled alcohol-based solutions should be removed from the field because they can be ignited by a spark from a cautery unit.

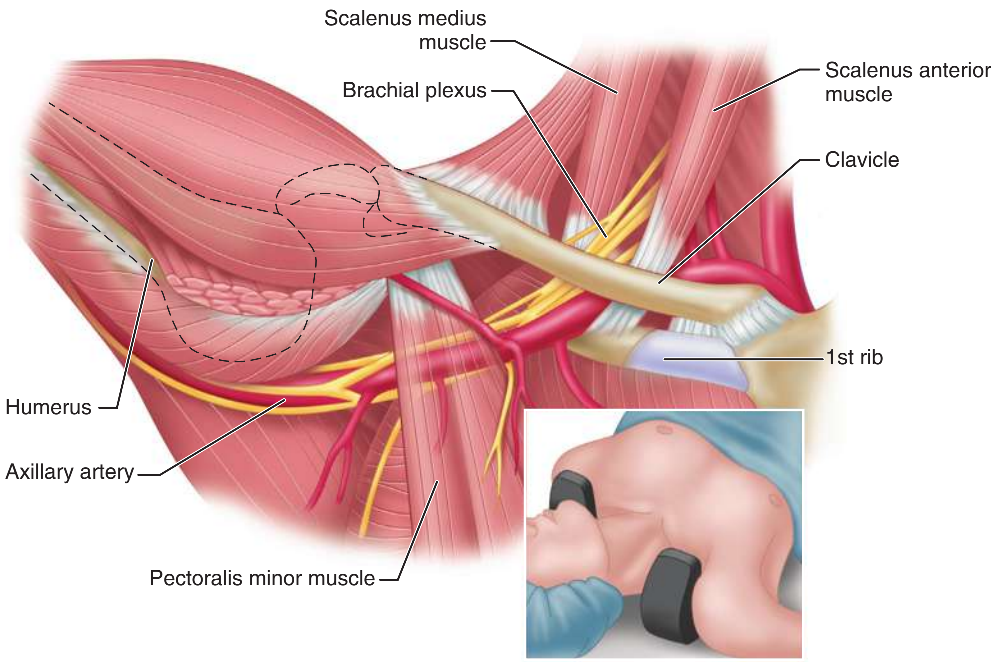


FIGURE 1-4 Anatomic relationships of brachial plexus when limb is hyperabducted. *Inset,* With patient in Trendelenburg position, brace at shoulder is in poor position because limb has been abducted and placed on arm board.

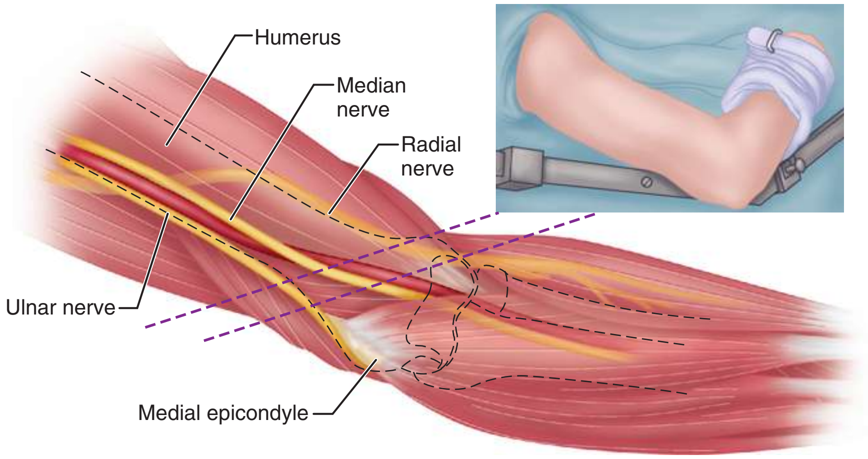


FIGURE 1-5 Points at which nerves of arm may be damaged by pressure (dashed lines). *Inset,* Pressure is applied to medial side of arm because patient is poorly positioned on operating table.

If a patient is allergic to iodine, plain alcohol can be used as a skin preparation. Colored proprietary antiseptics, commonly used in abdominal surgery, are not suitable in surgery of the extremities when preparation of the toes or fingernails is involved. Most of these solutions are difficult to remove, and the residual red, pink, or orange color makes evaluation of the circulation difficult after surgery.

When traumatic wounds are present, tincture of iodine and other alcohol-containing solutions should not be used for antiseptic wound preparation. Povidone-iodine or hexachlorophene solutions without alcohol should be used instead to avoid tissue death.

In operations around the upper third of the thigh, the pelvis, or the lower lumbar spine in male patients, the genitalia should be displaced and held away from the operative field with adhesive tape. A long, wide strip of tape similarly helps cover the gluteal cleft, from which there is the potential of infection. In female patients, the genital area and gluteal cleft also are covered longitudinally by strips of adhesive tape. Adherent, sterile, plastic drapes can be used for these purposes.

Before the operative field in the region of the lower lumbar spine, sacroiliac joints, or buttocks is prepared, the gluteal cleft is sponged with alcohol and sterile dry gauze is inserted around the anus so that iodine or other solutions are prevented from running down to this region, causing dermatitis.

Brown et al. and others recommended that before total joint arthroplasty the extremity should be held by a scrubbed and gowned assistant because this reduces bacterial air counts by almost half. They also recommended that instrument packs not be opened until skin preparation and draping are completed.

When these preparations are done in haste, the gown or gloves of the sterile assistant preparing the area may become contaminated without the assistant's knowledge. To prevent this, a nurse or anesthetist should be appointed to watch this stage of preparation.

WOUND IRRIGATING SOLUTIONS

At our institution, we routinely irrigate clean surgical wounds to keep them moist with sterile isotonic saline or lactated Ringer solution. Occasionally, if the risk of wound contamination is high, antimicrobial irrigating solutions are used. Dirschl and Wilson recommended a triple antibiotic solution of bacitracin, neomycin, and polymyxin because it provides the most complete coverage in clean and contaminated wounds. Antibiotic solutions should remain in the wound for at least 1 minute. Pulsatile lavage systems and basting-type syringes blow debris into the soft tissues and are being replaced with cystoscopy tubing for irrigation and curettage for debridement, especially in treatment of open fractures and infections.

DRAPING

Draping is an important step in any surgical procedure and should not be assigned to an inexperienced assistant. Haphazard draping that results in exposure of unprepared areas of skin in the middle of an operation can be catastrophic. Considerable experience is required in placing the drapes, not only to prevent them from becoming disarranged during the operation but also to avoid contamination of the surgeon and the drapes. If there is the least doubt as to the sterility of the drapes or the surgeon when draping is complete, the entire process should be repeated. Unless assistants are well trained, the surgeon should drape the patient.

In the foundation layer of drapes, towel clips or skin staples are placed not only through the drapes but also through the skin to prevent slipping of the drapes and exposure of the contaminated skin. In every case, the foundation drapes should be placed to overlap the prepared area of skin at least 3 inches (7.5 cm). During draping, the gloved hands should not come in contact with the prepared skin.

Cloth drapes are being replaced with disposable paper and plastic drape packages specifically designed for the area to be draped (Figs. 1-6 and 1-7). A disposable drape package should have at least one layer made of waterproof plastic to prevent fluids from soaking through to unprepared areas of the body. Drape packages for bilateral knee and foot surgery also are available. Paper drapes give off lint that collects on exposed horizontal surfaces in the operating room if those surfaces are not cleaned daily.

FIGURE 1-6 Disposable drape package for knee surgery.

FIGURE 1-7 Disposable drape package for hip surgery.

DRAPING THE EDGES OF THE INCISION

The gloved hand should not come in contact with the skin before the incision is made. For the extremities, a section of sterile stockinette is drawn proximally over the operative field. The stockinette is grasped proximally and distally and cut with scissors to uncover the area of the proposed incision. Its cut edges are pulled apart, and the area is covered by a transparent adhesive-coated material (Fig. 1-8). A large transparent plastic adhesive drape may be wrapped entirely around the extremity or over the entire operative field so that the stockinette is not needed. The incision is made through the material and the skin at the same time. The edges of the incision are neatly draped, and the operative field is virtually waterproof; this prevents the drapes in some areas from becoming soaked with blood, which can be a source of contamination. The plastic adhesive drape minimizes the need for towel clips or staples around the wound edge and allows the entire undraped field to be seen easily. Visibility is especially important when there are scars from previous injuries or surgery that must be accommodated by a new incision.

FIGURE 1-8 Iodoform-impregnated plastic adhesive drape.

PREVENTION OF HUMAN IMMUNODEFICIENCY VIRUS AND HEPATITIS VIRUS TRANSMISSION

At our institution, we follow the American Academy of Orthopaedic Surgeons (AAOS) Task Force recommendations on acquired immunodeficiency syndrome (HIV), hepatitis B virus (HBV), and hepatitis C virus (HCV), which go beyond those recommended for health care personnel by the Centers for Disease Control and Prevention (CDC) and the American Hospital Association. Every effort should be made to prevent further transmission of these diseases in all areas of medical care. For specific recommendations, the reader is referred to the AAOS Task Force guidelines. We strongly agree with the following AAOS recommendations regarding HIV, HBV, and HCV precautions in the operating room:

1. Do not hurry an operation. Excess speed results in injury. The most experienced surgeon should be responsible for the surgical procedure if the risk of injury to operating room personnel is high.
2. Wear surgical garb that offers protection against contact with blood. Knee-high, waterproof, surgical shoe covers, water-impervious gowns or undergarments, and full head covers should be worn.
3. Double gloves should be worn at all times.
4. Surgical masks should be changed if they become moist or splattered.
5. Protective eyewear (goggles or full face shields) that covers exposed skin and mucous membranes should be used.
6. To avoid inadvertent injury to surgical personnel, the surgeon should:
   - Use instrument ties and other “no-touch” suturing and sharp instrument techniques when possible.
   - Avoid tying with a suture needle in hand.
   - Avoid passing sharp instruments and needles from hand to hand; instead they should be placed on an intermediate tray.
   - Announce when sharp instruments are about to be passed.
   - Avoid having two surgeons suture the same wound.

- Take extra care when performing digital examinations of fracture fragments or wounds containing wires or sharp instrumentation.
- Avoid contact with osteotomes, drill bits, and saws.
- Use of full protective gowns, hoods, and surgical facemasks with eyeshields when splatter is inevitable, such as when irrigating large wounds or using power equipment.
- Routinely check gowns, masks, and shoe covers of operating room personnel for contamination during the surgical procedure and change as necessary.

7. Incidents of exposure of healthcare personnel to potentially infected fluids should be reported to a person designated by the health care facility to be responsible for managing occupational exposures. Relevant histories and incident information should be documented, and the source patient and exposed health care worker appropriately tested within applicable laws as recommended by the CDC. Follow-up testing of exposed personnel should be performed as recommended by the CDC. Patients exposed to a potentially infected health care provider should be immediately informed of the incident and the above recommendations for exposed health care providers be followed.
8. Postexposure prophylaxis for HBV and HIV should be provided as recommended by the U.S. Public Health Service. There is no postexposure prophylaxis for HCV.
9. Protective gowns and full hoods with surgical facemask should be routinely used for total joint arthroplasty and for large trauma and elective cases. Blood spatter should be avoided and at a minimum protective eyewear and gloves should be worn by all members of the team including observers.

PREVENTING MISTAKES

The operative site should be marked before entering the operating room by at least one member of the operative team, preferably the surgeon, to avoid operation on the wrong site.

Once the patient is under anesthesia, a designated member of the team should state the name of the patient, the procedure, and the correct site. All members of the team should be in agreement. This statement should be clear, concise, and not contain unnecessary information. A short statement is more likely to be closely heard. This statement should be preferably made after draping.

SPECIAL OPERATIVE TECHNIQUES

Special operative techniques are used in a variety of procedures and are described here so that repetition in other chapters will be unnecessary. The methods of tendon or fascia fixation and bone grafting are discussed here. The methods of tendon suture are discussed in Chapter 66.

METHODS OF TENDON-TO-BONE FIXATION

The principles of tendon suture are described in Chapter 66 on the hand; in Chapter 48, in which disorders of muscles and tendons are discussed; and under the discussion of tendon transfers in Chapter 71. The following discussion deals only with the methods of attaching a tendon to bone.

Attaching tendon to bone can be a fairly easy task. Healing of tendon to bone with something close to biologically normal tissue is the challenge. Multiple modalities such as osteoinductive growth factors, periosteal grafts, osteoconductive factors, platelet-rich plasma, biodegradable scaffolds, ultrasound, and extracorporeal shockwave therapy are being studied in the laboratory. Controlled level-1 human trials are necessary before these procedures become commonplace in clinical practice.

FIXATION OF TENDON TO BONE

TECHNIQUE 1-1

- Scarify the apposing surfaces of bone and tendon to hasten attachment by incising the periosteum and elevating it enough to expose the bony surface. After completion of the tendon fixation, an attempt should be made to close the periosteum over the tendon, although this usually is impossible. Instead, the periosteum may be sutured to the edges of the tendon.
- Place a suture in the end of the tendon by one of the techniques described in Chapter 71. With this suture, pull the tendon distally, removing all slack, and determine the point of attachment.
- Drill a hole transversely into the bone just distal to this point.
- Pass the sutures on each side of the tendon through this hole in opposite directions and tie them tightly over the shaft of the bone (Fig. 1-9A).
- If the tendon is long enough, pass the end through the hole in the bone and suture the tendon to itself (Fig. 1-9B). If passing the tendon or piece of fascia through the hole drilled in bone is difficult, construct a homemade Chinese finger trap from two pieces of suture woven around the tendon (Fig. 1-10).

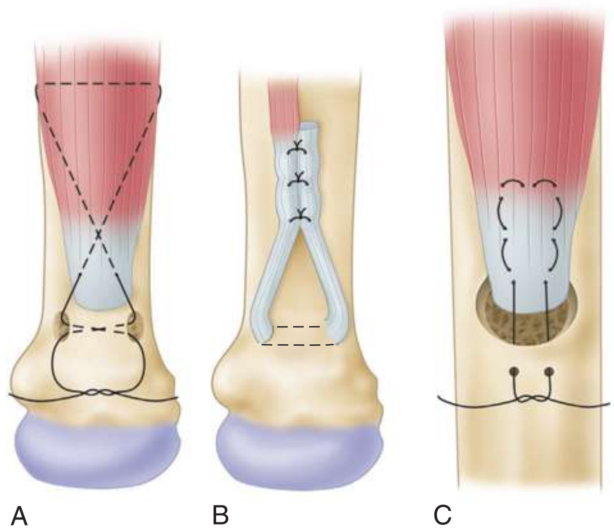


FIGURE 1-9 A-C, Fixation of tendon to bone. **SEE TECHNIQUES 1-1 AND 1-5.**

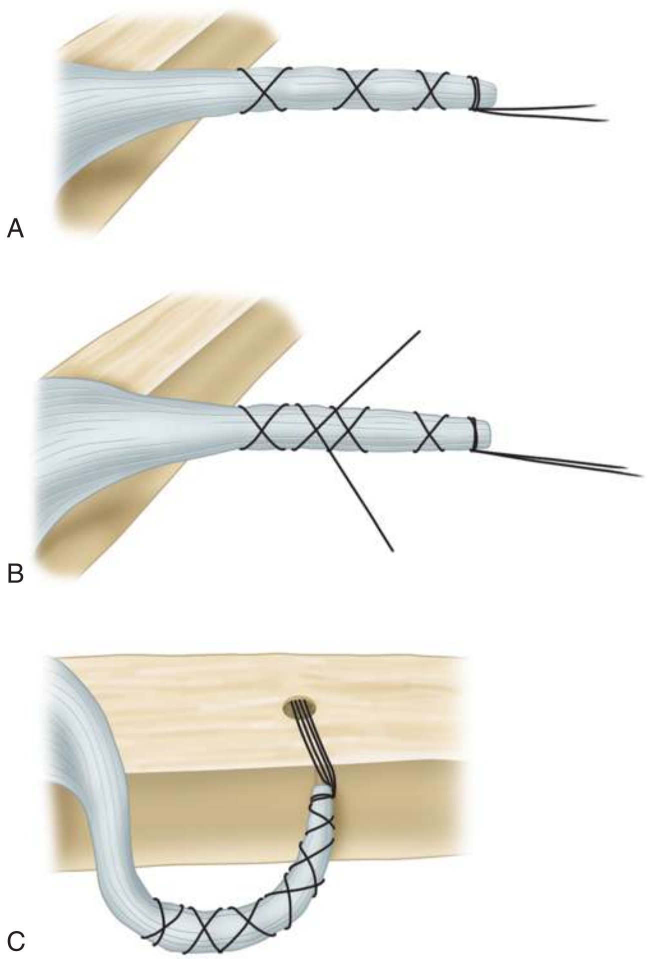


FIGURE 1-10 Krackow and Cohn technique for passing tendon or fascia through hole in bone. **A,** Suture is wrapped in crisscross fashion around the distal end of the tendon or fascia and is tied in a knot, leaving the ends of the suture long. **B,** A second suture is wrapped in similar fashion but out of phase with the first suture. **C,** A Chinese finger-trap suture fits tightly around the tendon or fascia and allows it to enter the hole without difficulty. (Redrawn from Krackow KA, Cohn BT: A new technique for passing tendon through bone: brief note, J Bone Joint Surg 69A:922, 1987.) **SEE TECHNIQUE 1-1.**

- If a distally based strip of iliotibial band is to be inserted into bone, roll the part of the band that is to be inserted into a cylindrical shape and wrap a suitable length of strong, nonabsorbable suture around the fascia in a crisscross fashion, beginning about 4 cm proximal to the end of the strip. At the end of the strip, tie the suture into a knot, leaving the ends long (Fig. 1-10A).
- Wrap a second piece of suture around the fascia in the same way but out of phase with the first piece of suture (Fig. 1-10B) and tie it at the end.
- Pass the ends of the suture through the hole in the bone (Fig. 1-10C), followed by the rolled up fascial strip.
- Finally, cut the sutures just proximal to the knots at the apex of the finger trap and remove them one at a time.

For larger muscles, a broad, firm, bony attachment must be ensured (Fig. 1-9C). The advantage of this method is that drilling a transverse hole through the shaft of the bone is unnecessary; such a procedure is sometimes difficult in deep wounds, and exposure requires considerable stripping of soft tissues from the bone.

TENDON FIXATION INTO THE INTRAMEDULLARY CANAL

TECHNIQUE 1-2

- After placing the suture in the end of the tendon and leaving two long, free strands, create a trapdoor in the bone, exposing the medullary canal at the predetermined point of attachment.
- Just distal to the trapdoor, drill two holes through the cortex into the medullary canal.
- Pass the free ends of the suture through the trapdoor and out through the two holes.
- Pull the sutures taut and draw the end of the tendon through the trapdoor into the medullary canal.
- Partially replace the trapdoor or break into small fragments and pack it into the defect as grafts.

TENDON TO BONE FIXATION USING LOCKING LOOP SUTURE

Krackow et al. have devised a locking loop suture that is relatively simple to use and is especially suited to attaching flat structures, such as the tibial collateral ligament, joint capsule, or patellar tendon, to bone. It allows the application of tension to the structure, resists pulling out, and does not cause major purse-stringing or bunching. A doubled suture of strong suture material is nearly twice as strong as staple fixation to bone. When the suture is used in combination with a staple, fixation is significantly improved.

TECHNIQUE 1-3 *Figure 1-11*

(KRACKOW, THOMAS, JONES)

- Approach the tendon or ligament from the raw end, and place three or more locking loops along each side of the structure.
- Apply tension during the procedure to remove excess suture material within the locking loops. This suture may be reinforced proximal to the first suture.
- Attach the tendon or ligament and the suture to bone through holes drilled in the bone, or tie the suture over a screw or staple fixed in the bone.

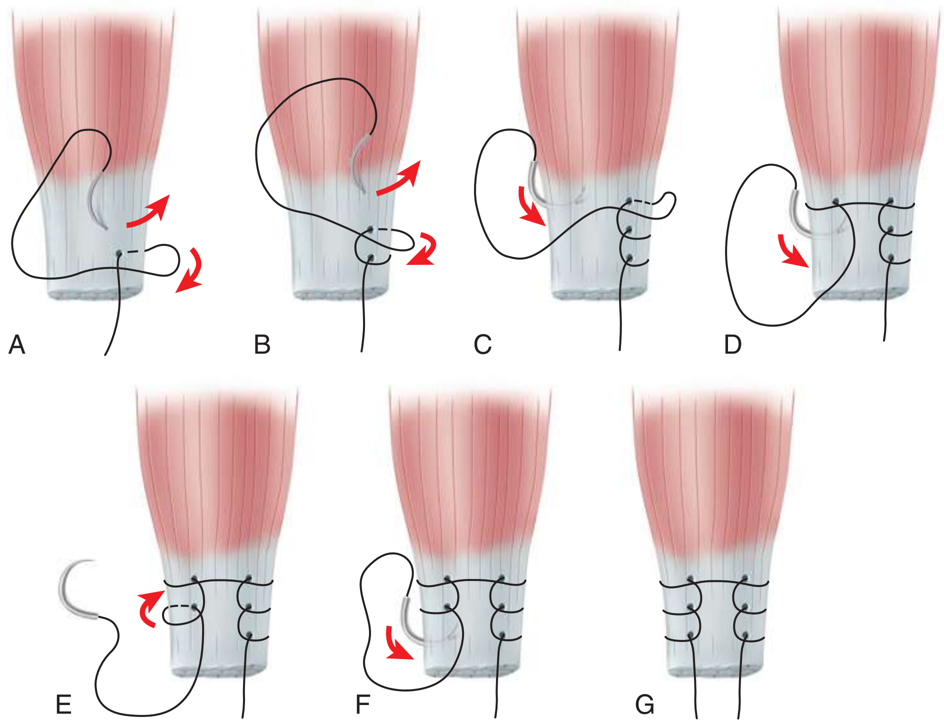


FIGURE 1-11 Krackow, Thomas, and Jones technique for ligament or tendon fixation to bone. **A-G,** Detail of placement of suture in wide tendon. (Redrawn from Krackow KA, Thomas SC, Jones LC: Ligament-tendon fixation: analysis of a new stitch and comparison with standard techniques, Orthopedics 11:909, 1988.) **SEE TECHNIQUE 1-3.**

TENDON TO BONE FIXATION USING WIRE SUTURE

Because of the scarcity of surrounding soft tissue and the nature of the bone, Cole's method is especially applicable to the fixation of tendons to the dorsum of the tarsus, to the calcaneus, or to the phalanges of the fingers.

TECHNIQUE 1-4

Figure 1-12

(COLE)

- Prepare the tendon and place a pull-out suture in the end of the tendon, as described for end-to-end sutures (Chapter 66).
- Reflect a small flap of bone with a chisel, and at the apex of the flap drill a tunnel through the bone.
- Place both ends of the wire suture on a long, straight skin needle.
- Pass the needle through the hole in the bone and out through the skin on the opposite side, drawing the end of the tendon into the tunnel.
- Anchor the wire snugly over a loop of gauze or a padded button. If considerable tension is necessary, as in Achilles tendon, the skin should be padded with heavy felt.
- Apply a cast with the wires protruding through the bottom of the cast. After the plaster sets, anchor the wire over a button on the outside of the cast.

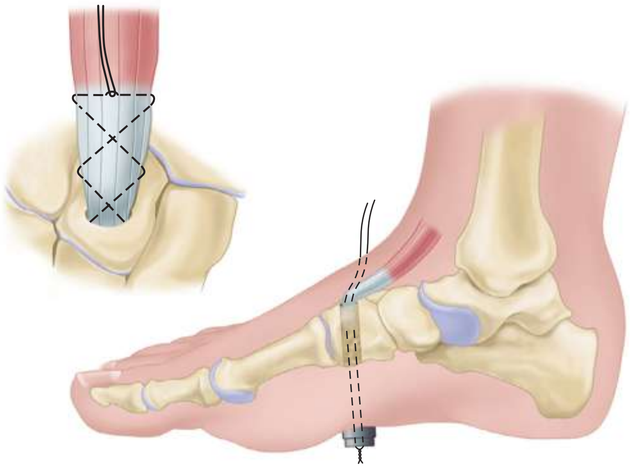


FIGURE 1-12 The Cole method of anchoring tendons to bone. Ends of wire suture are passed on a straight skin needle through a hole drilled in bone. The needle is drawn through the skin on the opposite side. Wire sutures are anchored over a rubber tube or button. To prevent necrosis of the skin when the suture is under considerable tension, ends of wire may be passed through the bottom of the cast. Subsequently, wire is anchored over the button on the outside of the cast. **SEE TECHNIQUE 1-4.**

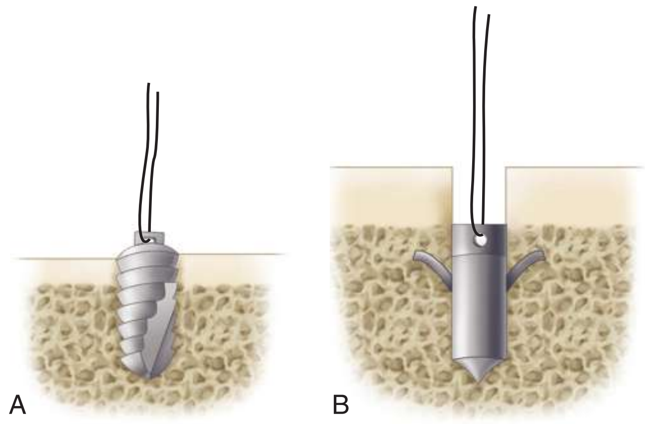


FIGURE 1-13 Suture-anchoring implants. **A,** Statak (Zimmer) suture-anchoring device is drilled into bone. **B,** QuickAnchor (Mitek) suture anchor consists of a hook device with suture that is anchored into drill hole in the bone.

SUTURE ANCHORS

Suture-anchoring devices also are useful in securing tendon, ligament, or capsule to bone (Fig. 1-13). The pull-out strength of these devices is at least equal to that of a suture passed through drill holes in bone, and these devices are especially useful in deep wounds with limited room, such as in the shoulder. Tingart et al. found that metal suture anchors withstand a significantly higher load to failure than biodegradable anchors. Bottoni et al. found that the suture used usually failed before the suture anchor in an animal model. Suture anchors made from methyl methacrylate cement are useful in osteopenic bone (Fig. 1-14). Giori et al. found that augmenting suture anchors with methyl methacrylate greatly improved pull-out strength in osteopenic cadaver bone.

A tendon or ligament also can be secured to bone through a drill hole using a screw for an interference fit as in anterior cruciate ligament reconstruction procedures (Chapter 45). Allograft cortical bone is now being commercially machined into screws for such a purpose.

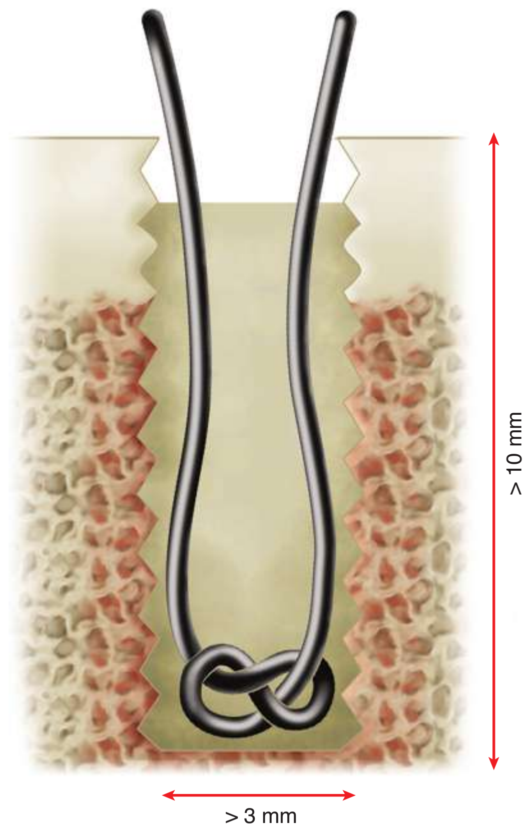


FIGURE 1-14 Methyl methacrylate suture anchor. Figure-of-eight knot increases load to failure.

FIXATION OF OSSEOUS ATTACHMENT OF TENDON TO BONE

When larger muscles are transferred, such as the quadriceps or the abductor muscles of the hip, better fixation is secured if the tendon is removed with a portion of its bony attachment.

TECHNIQUE 1-5

- Remove sufficient bone to ensure a cancellous surface.
- Draw the bony segment distally and determine the location of its reattachment.
- Elevate the periosteum, scarify the surface of the shaft, and fix the attachment of the tendon to the raw area by two threaded pins inserted obliquely or by a screw (Fig. 1-15A). Staples also are useful for anchoring a ligament or a tendon to bone (Figs. 1-16 and 1-17), and wire

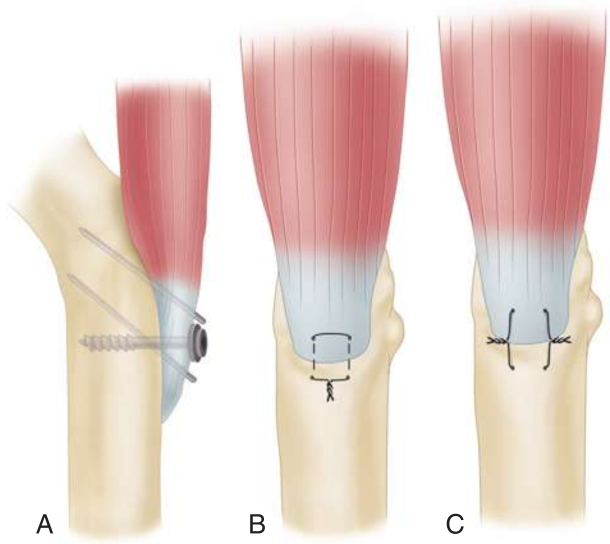


FIGURE 1-15 Fixation of osseous attachment of tendon to bone. **A,** Fixation by screw or threaded pins. **B,** Fixation by mattress suture of wire through holes drilled in bone. **C,** Fixation by wire loops. **SEE TECHNIQUE 1-5.**

FIGURE 1-16 Stone staple, used most frequently for anchoring tendinous tissue to bone. **SEE TECHNIQUE 1-5.**

FIGURE 1-17 Arthrex low-profile bridge staple. (Courtesy Arthrex, Naples, FL). **SEE TECHNIQUE 1-5.**

loops passed through holes drilled into the bone (Fig. 1-15B and C) are efficient. Heavy sutures may be used instead of metal for fixation of tendons in the less powerful muscles.

- If desired, create a trapdoor in the shaft of the bone, and countersink the osseous attachment of the tendon into the defect and hold with a suture, as illustrated in Figure 1-9.

SUTURE BUTTONS

Suture-button devices are now available for minimally invasive tendon-to-bone, ligament-to-bone, and fracture fixation. The Endobutton (Smith and Nephew, York, UK) and the TightRope Fixation System (Arthrex, Naples, Florida) can be inserted through a single incision and drill hole. These devices have been successfully used in acromioclavicular joint dislocations, Neer II distal clavicular fractures, ankle syndesmosis

FIGURE 1-18 TightRope Syndesmosis Buttress Plate Kit (Arthrex, Naples, Florida). One suture strand is used to "flip" the medial button so a second incision is unnecessary.

disruptions, and high-energy os calcis fractures with compromised skin (Fig. 1-18).

BONE GRAFTING

The indications for bone grafting are to:

- Fill cavities or defects resulting from cysts, tumors, or other causes
- Bridge joints and provide arthrodesis
- Bridge major defects or establish the continuity of a long bone
- Provide bone blocks to limit joint motion (arthroereisis)
- Establish union in a pseudarthrosis
- Promote union or fill defects in delayed union, malunion, fresh fractures, or osteotomies

STRUCTURE OF BONE GRAFTS

Cortical bone grafts are used primarily for structural support, and cancellous bone grafts are used for osteogenesis. Structural support and osteogenesis may be combined; this is one of the prime advantages of using bone graft. These two factors vary, however, with the structure of the bone. Probably all or most of the cellular elements in grafts (particularly cortical grafts) die and are slowly replaced by creeping substitution, the graft merely acting as a scaffold for the formation of new bone. In hard cortical bone, this process of replacement is considerably slower than in spongy or cancellous bone.

Although cancellous bone is more osteogenic, it is not strong enough to provide efficient structural support. When selecting the graft or combination of grafts, the surgeon must be aware of these two fundamental differences in bone structure. When a graft has united with the host and is strong enough to permit unprotected use of the part, remodeling of the bone structure takes place commensurate with functional demands.

SOURCES OF BONE GRAFTS

AUTOGENOUS GRAFTS

When the bone grafts come from the patient, the grafts usually are removed from the tibia, fibula, or ilium. These three bones provide cortical grafts, whole bone transplants, and cancellous bone. Rarely is a resected rib appropriate.

When internal or external fixation appliances are not used, which is currently rare, strength is necessary in a graft used for bridging a defect in a long bone or even for the treatment of pseudarthrosis. The subcutaneous anteromedial aspect of the tibia is an excellent source for structural autografts. In adults, after removal of a cortical graft, the plateau of the tibia supplies cancellous bone. Apparently, leaving the periosteum attached to the graft has no advantage; however, suturing to the periosteum over the defect has definite advantages. The periosteum seems to serve as a limiting membrane to prevent irregular callus when the defect in the tibia fills in with new bone. The few bone cells that are stripped off with the periosteum can help in the formation of bone needed to fill the defect.

Disadvantages to the use of the tibia as a donor area include (1) a normal limb is jeopardized; (2) the duration and magnitude of the procedure are increased; (3) ambulation must be delayed until the defect in the tibia has partially healed; and (4) the tibia must be protected for 6 to 12 months to prevent fractures. For these reasons, structural autografts from the tibia are now rarely used.

A good source for bulk cancellous autogenous graft is material from a reamer-irrigator-aspirator (RIA) used in the canal of the femoral and tibial shafts. A complication rate of less than 2% has been reported in approximately 200 patients with a mean volume harvested of 47±22 mL. Debris harvested during RIA and bone graft harvested from iliac crest have similar RNA transcriptional profiles for genes that act in bone repair and formation, suggesting that material harvested by RIA is a viable alternative to iliac crest autogenous cancellous graft.

The entire proximal two thirds of the fibula can be removed without disabling the leg. Most patients have complaints and mild muscular weakness after removal of a portion of the fibula. The configuration of the proximal end of the fibula is an advantage. The proximal end has a rounded prominence that is partially covered by hyaline cartilage and forms a satisfactory transplant to replace the distal third of the radius or the distal third of the fibula. After transplantation, the hyaline cartilage probably degenerates rapidly into a fibrocartilaginous surface; even so, this surface is preferable to raw bone.

The middle one third of the fibula also can be used as a vascularized free autograft based on the peroneal artery and vein pedicle using microvascular technique. Portions of the iliac crest also can be used as free vascularized autograft. The use of free vascularized autografts has limited indications, requires expert microvascular technique, and is not without donor site morbidity. The management of segmental bone loss can be difficult. Taylor et al. described a two-stage induced membrane technique using a methyl methacrylate spacer. The spacer is placed into the defect to induce the formation of a bioactive membrane. Four to 8 weeks later the spacer is removed and cancellous autograft is placed in the now membrane surrounded defect. The membrane helps prevent graft resorption, promote revascularization, and consolidation of new bone.

ALLOGENIC GRAFTS

An allogenic graft, or allograft, is one that is obtained from an individual other than the patient. In small children, the usual donor sites do not provide cortical grafts large enough to bridge defects or the available cancellous bone may not be enough to fill a large cavity or cyst; the possibility of injuring a physis also must be considered. Allograft is preferred in this situation. Allografts are also indicated in the elderly, patients who are poor operative risks, and patients from whom not enough acceptable autogenous bone can be harvested. Larger structural allografts have been used successfully for many years in revision total joint surgery, periprosthetic long bone fractures, and reconstruction after tumor excision. Osteochondral allografts are now being used with some success in a few centers to treat distal femoral osteonecrosis. Large osteochondral allografts, such as the distal femur, are used in limb salvage procedures after tumor resection. Autogenous cancellous bone can be mixed in small amounts with allograft bone as “seed” to provide osteogenic potential. Mixed bone grafts of this type incorporate more rapidly than allograft bone alone. Increased allograft union rates and less resorption have been noted in large acetabular defects when allografts were loaded with bone marrow derived mesenchymal stem cells. The various properties of autogenous and allogenic bone grafts are summarized in Table 1-3.

HETEROGENEOUS GRAFTS

The use of heterogeneous graft material (bone from another species) is not recommended and is not commercially available.

BONE BANK

To provide safe and useful allograft material efficiently, a bone banking system is required that uses thorough donor screening, rapid procurement, and safe, sterile processing. Standards outlined by the U.S. Food and Drug Administration (FDA) and American Association of Tissue Banks must be followed. Donors must be screened for bacterial, viral (including HIV and hepatitis), and fungal infections. Malignancy (except basal cell carcinoma of the skin), collagen vascular disease, metabolic bone disease, and the presence of toxins are all contraindications to donation. No system is perfect, and the transmission of disease by allograft material has been reported from single donors to multiple recipients.

Bone and ligament and bone and tendon are now banked for use as allografts. The use of allograft ligaments and tendons in knee surgery is discussed in Chapter 45. Bone can be stored and sterilized in several forms. It can be harvested in a clean, nonsterile environment; sterilized by irradiation, strong acid, or ethylene oxide; and freeze-dried for storage. Bone under sterile conditions can be deep frozen (–70°C to –80°C) for storage. Fresh frozen bone is stronger than freeze-dried bone

TABLE 1-3

Bone Graft Activity by Type

GRAFT	OSTEOGENESIS	OSTEOCONDUCTION	OSTEOINDUCTION	MECHANICAL PROPERTIES	VASCULARITY
AUTOGRAFT					
Bone marrow	++	±	+	–	–
Cancellous	++	++	+	+	–
Cortical	+	+	±	++	–
Vascularized	++	++	+	++	++
ALLOGRAFT					
Cancellous	–	++	+	+	–
Cortical	–	±	±	++	–
Demineralized	–	++	+++	–	–

From Kahn SN, et al: The biology of bone grafting, J Am Acad Orthop Surg 13:80, 2005.

and better as structural allograft material. Articular cartilage and menisci also can be cryopreserved in this manner. Cancellous allografts incorporate to host bone, as do autogenous cancellous grafts. These allografts are mineralized and are not osteoinductive, although they are osteoconductive. Cancellous allografts can be obtained in a demineralized form that increases osteogenic potential but greatly decreases resistance to compressive forces.

Enneking and Mindell observed that cortical allografts are invaded by host blood vessels and substituted slowly with new host bone to a limited degree, especially in massive allografts. This probably accounts for the high incidence of fracture in these grafts because dead bone cannot remodel in response to cyclic loading and then fails.

CANCELLOUS BONE GRAFT SUBSTITUTES

Interest in bone graft substitutes has mushroomed in recent years. Dozens of products are in general use or in clinical trials. To understand better the properties of these products, the following bone synthesis processes need to be understood (see Table 1-3). *Graft osteogenesis* is the ability of cellular elements within a graft that survive transplantation to synthesize new bone. *Graft osteoinduction* is the ability of a graft to recruit host mesenchymal stem cells into the graft that differentiate into osteoblasts. Bone morphogenetic proteins and other growth factors in the graft facilitate this process. *Graft osteoconduction* is the ability of a graft to facilitate blood vessel ingrowth and bone formation into a scaffold structure.

Bone graft substitutes can replace autologous or allogenic grafts or expand an existing amount of available graft material. Autologous cancellous and cortical grafts are still the "gold standards" against which all other graft forms are judged. Bone graft substitutes are classified based on properties outlined in Table 1-4. FDA-approved applications for these products are variable and ever changing. Table 1-5 lists bone graft substitutes that are FDA approved with published, peer-reviewed, level I or II human studies as burden of proof. Surgeons must carefully review the manufacturers' stated indications and directions for use. For more in-depth discussions of the biologic events in bone graft incorporation, see the reviews by Khan et al. and Gardiner and Weitzel. The

TABLE 1-4

Classification of Bone Graft Substitutes

PROPERTY	DESCRIPTION	CLASSES
Osteoconduction	Provides a passive porous scaffold to support or direct bone formation	Calcium sulfate, ceramics, calcium phosphate cements, collagen, bioactive glass, synthetic polymers
Osteoinduction	Induces differentiation of stem cells into osteogenic cells	Demineralized bone matrix, bone morphogenic proteins, growth factors, gene therapy
Osteogenesis	Provides stem cells with osteogenic potential, which directly lays down new bone	Bone marrow aspirate
Combined	Provides more than one of the above mentioned properties	Composites

From Parikh SN: Bone graft substitutes in modern orthopedics, Orthopedics 25:1301, 2002.

Orthopaedic Trauma Association Orthobiologics Committee (DeLong et al.) reported a review of the literature on bone grafts and bone graft substitutes and provided recommendations to the orthopaedic community based on levels of evidence. Kurien et al. reviewed 59 bone graft substitutes available for use in the United Kingdom, only 22 of which had peer-reviewed published clinical literature. They questioned the need for so many products and called for more prospective randomized trials. They also provided a good review of uses of various bone graft substitutes.

Bone graft substitutes are not without complications, however. Recombinant human bone morphogenic protein-Z

TABLE 1-5

Commercially Available FDA-Approved Bone-Graft Substitutes with Peer-Reviewed Published Level I-II Human Studies as Burden of Proof (2010)

PRODUCT	COMPOSITION AND MECHANISM OF ACTION	FDA STATUS
HEALOS DePuy Spine	Mineralized collagen matrix in strips of varying sizes Mechanisms of action: osteoinduction/conduction, creeping substitution, osteogenesis when mixed with autogenous bone graft	Cleared as bone filler but must be used with autogenous bone marrow
Vitoss Orthovita	100% beta TCP; 80% beta TCP/20% collagen; 70% beta TCP/20% collagen/10% bioactive glass as putt, strip, flow, morsels, or shapes Mechanism of action: osteoconduction/bioresorbable, bioactive, osteostimulation, osteogenesis and osteoinduction when mixed with bone marrow aspirate	Cleared as bone void filler
NovaBone NovaBone/MTF	Bioactive silicate in particulate or putty or morsel form Mechanism of action: osteoconduction, bioresorbable, osteostimulation	Cleared as a bone void filler
GRAFTON A-FLEX, Flex, Matrix Scoliosis Strips, Putty Osteotech	DBM fiber technology in flexible sheets of varying shapes and sizes or moldable or packable graft Mechanism of action: osteoinduction/conduction, incorporation, osteogenesis when mixed with autogenous bone graft or bone marrow aspirate	Cleared as bone graft substitute, bone graft extender, and bone void filler
GRAFTON Crunch Orthoblend Large Defect Orthoblend Small Defect Osteotech	DBM fibers with demineralized cortical cubes or crushed cancellous chips as packable or moldable graft Mechanism of action: osteoinduction/conduction, incorporation, osteogenesis when mixed with autogenous bone graft or bone marrow aspirate	Cleared as bone graft substitute, bone graft extender, and bone void filler
GRAFTON Gel Osteotech	DBM in a syringe for MIS and percutaneous injectable graft Mechanism of action: osteoinduction/conduction, incorporation, osteogenesis when mixed with autogenous bone graft or bone marrow aspirate	Cleared as bone graft substitute, bone graft extender, and bone void filler
GRAFTON Plus Paste Osteotech	DBM in a syringe for MIS injectable graft that resists irrigation Mechanism of action: osteoinduction/conduction, incorporation, osteogenesis when mixed with autogenous bone graft or bone marrow aspirate	Cleared as bone graft substitute, bone graft extender, and bone void filler

DBM, Demineralized bone matrix; *MIS,* minimally invasive surgery; *TCP,* tricalcium phosphate.

(rh BMP-2) has been associated with an increased cancer risk. Data from a randomized trial involving over 500 patients who had spine fusion with single-level lumbar fusion using rh BMP-2 in a compression-resistant material showed a significant increase of cancer events in the rh BMP-2 group. A 16% complication rate involving soft-tissue inflammation also was noted in another study of 31 patients after the use of tricalcium phosphate and calcium sulfate. An increased risk for retrograde ejaculation also has been reported after anterior lumbar interbody fusion using rhBMP-2.

INDICATIONS FOR VARIOUS BONE GRAFT TECHNIQUES

ONLAY CORTICAL GRAFTS

Until relatively inert metals became available, the onlay bone graft (see Chapter 59) was the simplest and most effective treatment for most ununited diaphyseal fractures. Usually the cortical graft was supplemented by cancellous bone for osteogenesis. The onlay graft is still applicable to a limited group of fresh, malunited, and ununited fractures and after osteotomies.

Cortical grafts also are used when bridging joints to produce arthrodesis, not only for osteogenesis but also for fixation. Fixation as a rule is best furnished by internal or external metallic devices. Only in an extremely unusual situation would a cortical onlay graft be indicated for fixation, and then only in small bones and when little stress is expected. For osteogenesis, the thick cortical graft has largely been replaced by thin cortical and cancellous bone from the ilium. Dual onlay bone grafts are useful when treating difficult and unusual nonunions or for bridging massive defects (see Chapter 59). The treatment of a nonunion near a joint is difficult because the fragment nearest the joint is usually small, osteoporotic, and largely cancellous, having only a thin cortex. It often is so small and soft that fixation with a single graft is impossible because screws tend to pull out of it and wire sutures cut through it. Dual grafts provide stability because they grip the small fragment-like forceps.

The advantages of dual grafts for bridging defects are as follows: (1) mechanical fixation is better than fixation by a single onlay bone graft; (2) the two grafts add strength and stability; (3) the grafts form a trough into which cancellous bone may be packed; and (4) during healing, the dual grafts, in contrast to a single graft, prevent contracting fibrous tissue from compromising transplanted cancellous bone. A whole fibular graft usually is better than dual grafts for bridging defects in the upper extremity except when the bone is osteoporotic or when the nonunion is near a joint.

The disadvantages of dual grafts are the same as those of single cortical grafts: (1) they are not as strong as metallic fixation devices; (2) an extremity usually must serve as a donor site if autogenous grafts are used; and (3) they are not as osteogenic as autogenous iliac grafts, and the surgery necessary to obtain them has more risk.

INLAY GRAFTS

By the inlay technique, a slot or rectangular defect is created in the cortex of the host bone, usually with a power saw. A graft the same size or slightly smaller is fitted into the defect. In the treatment of diaphyseal nonunions, the onlay technique is simpler and more efficient and has almost replaced the inlay graft. The latter still is occasionally used in arthrodesis, particularly at the ankle (see Chapter 11).

MULTIPLE CANCELLOUS CHIP GRAFTS

Multiple chips of cancellous bone are widely used for grafting. Segments of cancellous bone are the best osteogenic material available. They are particularly useful for filling cavities or defects resulting from cysts, tumors, or other causes; for establishing bone blocks; and for wedging in osteotomies. Being soft and friable, this bone can be packed into any nook or crevice. The ilium is a good source of cancellous bone; and if some rigidity and strength are desired, the cortical elements may be retained. In most bone grafting procedures that use cortical bone or metallic devices for fixation, supplementary cancellous bone chips or strips are used to hasten healing. Cancellous grafts are particularly applicable to arthrodesis of the spine because osteogenesis is the prime concern. Iliac crest cancellous grafts can be easily harvested from the anterior crest, using an acetabular reamer as described by Dick with excellent results and no graft-related complications as reported by Brawley and Simpson.

Large-volume cancellous bone grafts can be harvested from the femoral canal using a reamer-irrigator-aspirator as described by Newman et al.

HEMICYLINDRICAL GRAFTS

Hemicylindrical grafts are suitable for obliterating large defects of the tibia and femur. A massive hemicylindrical cortical graft from the affected bone is placed across the defect and is supplemented by cancellous iliac bone. A procedure of this magnitude has only limited use, but it is applicable for resection of bone tumors when amputation is to be avoided.

WHOLE-BONE TRANSPLANT

The fibula provides the most practical graft for bridging long defects in the diaphyseal portion of bones of the upper extremity, unless the nonunion is near a joint. A fibular graft is stronger than a full-thickness tibial graft. When soft tissue is scant, a wound that cannot be closed over dual grafts can be closed over a fibular graft. Disability after removing a fibular graft is less than after removing a larger tibial graft. In children, the fibula can be used to span a long gap in the tibia, usually by a two-stage procedure (see Chapter 59). The shape of the proximal end of the fibula makes it a satisfactory substitute for the distal end of the fibula or distal end of the radius.

A free vascularized fibular autograft has greater osteogenic potential for incorporation but is technically much more demanding to use. Bone transplants consisting of whole segments of the tibia or femur, usually freeze dried or fresh frozen, are available. Their greatest use is in the treatment of defects of the long bones produced by massive resections for bone tumors or complex total joint revisions (see Chapter 59).

TABLE 1-6

Local and Systemic Factors Influencing Graft Incorporation

POSITIVE FACTORS	NEGATIVE FACTORS
LOCAL	**LOCAL**
Electrical stimulation	Denervation
Good vascular supply at the graft site	Infection
Growth factors	Local bone disease
Large surface area	Radiation
Mechanical loading	Tumor mechanical instability
Mechanical stability	
SYSTEMIC	**SYSTEMIC**
Growth hormone	Chemotherapy
Insulin	Corticosteroids
Parathyroid hormone	Diabetes
Somatomedins	Malnutrition
Thyroid hormone	Metabolic bone disease
Vitamins A and D	Nonsteroidal antiinflammatory drugs
	Sepsis
	Smoking

CONDITIONS FAVORABLE FOR BONE GRAFTING

For a bone grafting procedure to be successful, patient factors, such as patient overall condition and recipient site preparation, must be optimal, as outlined in Table 1-6.

PREPARATION OF BONE GRAFTS

REMOVAL OF A TIBIAL GRAFT

TECHNIQUE 1-6

- To avoid excessive loss of blood, use a tourniquet (preferably pneumatic) when the tibial graft is removed. After removal of the graft, the tourniquet may be released without disturbing the sterile drapes.

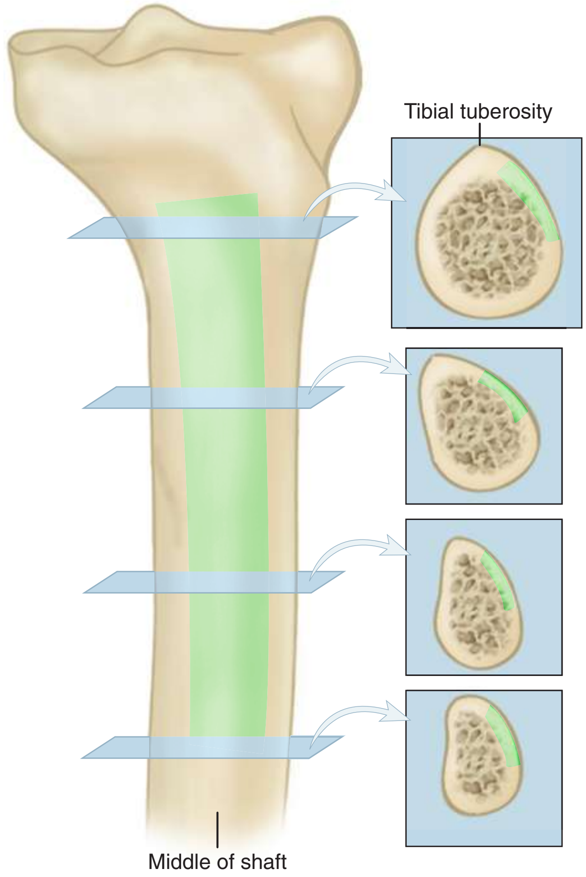


FIGURE 1-19 Method of removing tibial graft. Graft is wider proximally than distally. A hole is drilled at each corner before cutting to decrease stress riser effect of sharp corner after removal of graft. Cortex is cut through at an oblique angle. **SEE TECHNIQUE 1-6.**

- Make a slightly curved longitudinal incision over the anteromedial surface of the tibia, placing it so as to prevent a painful scar over the crest.
- Without reflecting the skin, incise the periosteum to the bone.
- With a periosteal elevator, reflect the periosteum, medially and laterally, exposing the entire surface of the tibia between the crest and the medial border. For better exposure at each end of the longitudinal incision, incise the periosteum transversely; the incision through the periosteum is I shaped.
- Because of the shape of the tibia, the graft usually is wider at the proximal end than at the distal end. This equalizes the strength of the graft because the cortex is thinner proximally than distally. Before cutting the graft, drill a hole at each corner of the anticipated area (Fig. 1-19).
- With a single-blade saw, remove the graft by cutting through the cortex at an oblique angle, preserving the anterior and medial borders of the tibia. Do not cut beyond the holes, especially when cutting across at the ends; overcutting here weakens the donor bone and may serve as the starting point of a future fracture. This is particularly true at the distal end of the graft.
- As the graft is pried from its bed, have an assistant grasp it firmly to prevent it from dropping to the floor.
- Before closing the wound, remove additional cancellous bone from the proximal end of the tibia with a curette. Take care to avoid the articular surface of the tibia or, in a child, the physis.
- The periosteum over the tibia is relatively thick in children and usually can be sutured as a separate layer. In adults, it is often thin, and closure may be unsatisfactory; suturing the periosteum and the deep portion of the subcutaneous tissues as a single layer usually is wise.
- If the graft has been properly cut, little shaping is necessary. Our practice is to remove the endosteal side of the graft because (1) the thin endosteal portion provides a graft to be placed across from the cortical graft; and (2) the endosteal surface, being rough and irregular, should be removed to ensure good contact of the graft with the host bone.

REMOVAL OF FIBULAR GRAFTS

Three points should be considered in the removal of a fibular graft: (1) the peroneal nerve must not be damaged; (2) the distal fourth of the bone must be left to maintain a stable ankle; and (3) the peroneal muscles should not be cut.

TECHNIQUE 1-7

Figures 1-20 and 1-21

- For most grafting procedures, resect the middle third or middle half of the fibula through a Henry approach.
- Dissect along the anterior surface of the septum between the peroneus longus and soleus muscles.
- Reflect the peroneal muscles anteriorly after subperiosteal dissection.
- Begin the stripping distally and progress proximally so that the oblique origin of the muscle fibers from the bone tends to press the periosteal elevator toward the fibula.
- Drill small holes through the fibula at the proximal and distal ends of the graft.
- Connect the holes by multiple small bites with the bone-biting forceps to osteotomize the bone; otherwise, the bone may be crushed. A Gigli saw, an oscillating power saw, or a thin, air-powered cutting drill can be used. An osteotome may split or fracture the graft. *The nutrient artery enters the bone near the middle of the posterior surface and occasionally may require ligation.*
- If the transplant is to substitute for the distal end of the radius or for the distal end of the fibula, resect the proximal third of the fibula through the proximal end of the Henry approach and take care to avoid damaging the peroneal nerve.
- Expose the nerve first at the posteromedial aspect of the distal end of the biceps femoris tendon and trace it distally to where it winds around the neck of the fibula. In this location, the nerve is covered by the origin of the

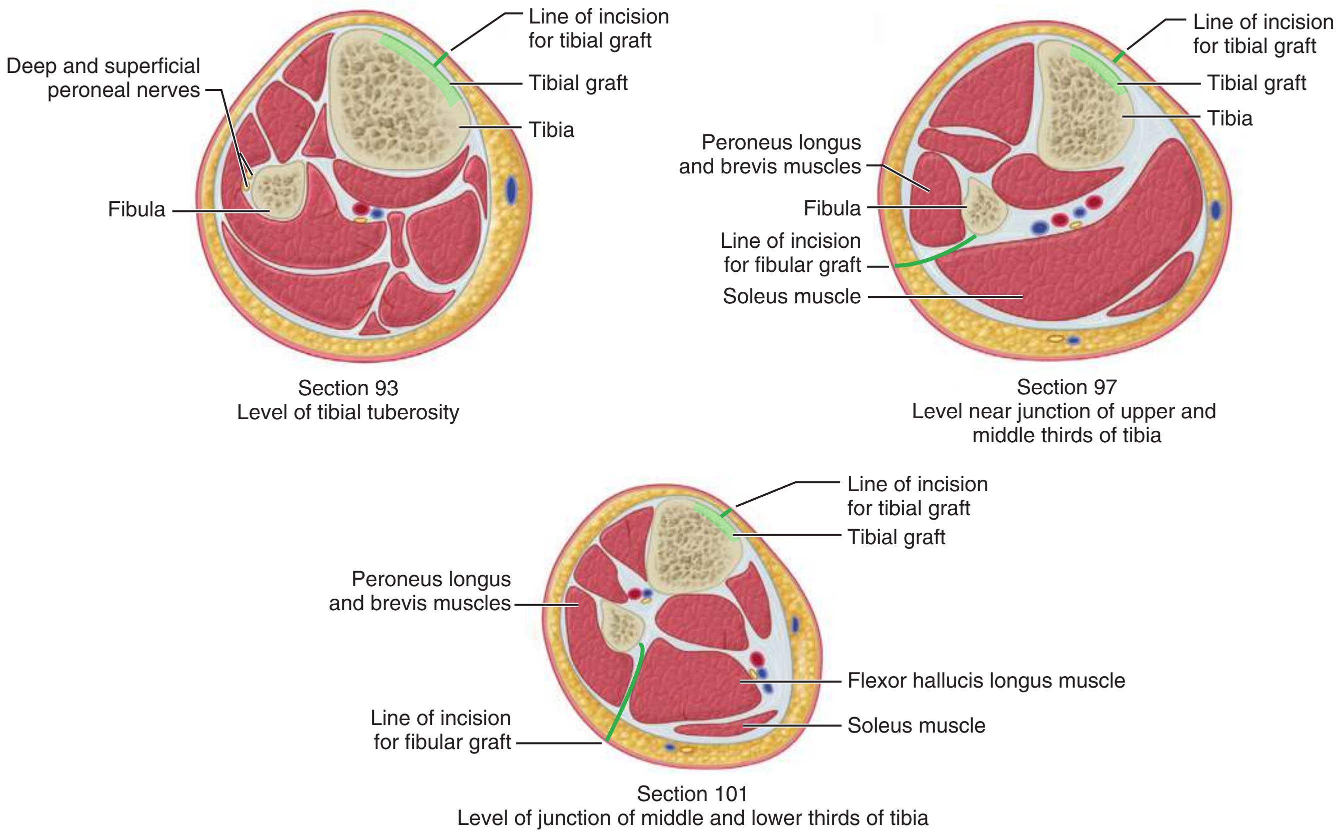


FIGURE 1-20 Cross-sections of leg showing line of approach for removal of whole fibular transplants or tibial grafts. *Colored* segment shows portion of tibia to be removed. Thick, strong angles of tibia are not violated. **SEE TECHNIQUE 1-7.**

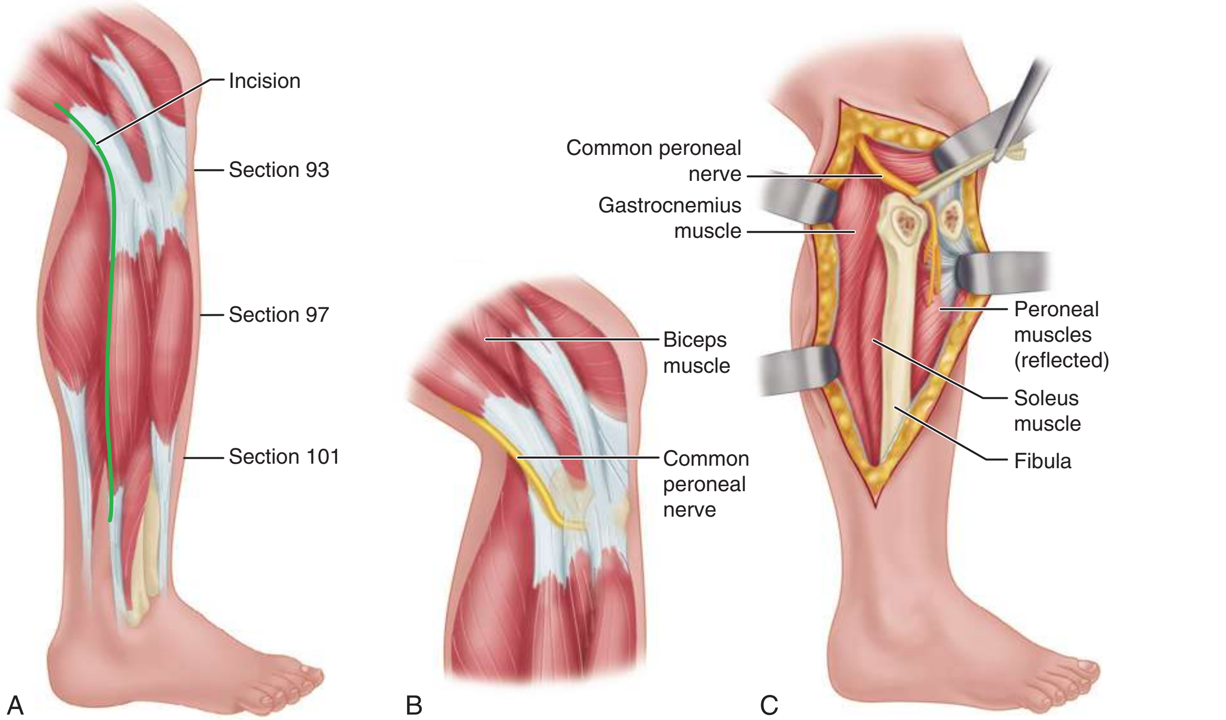


FIGURE 1-21 Resection of fibula for transplant. **A,** Line of skin incision; levels of cross-sections shown in Figure 1-20 are indicated. **B,** Relation of common peroneal nerve to fibular head and neck. **C,** Henry method of displacing peroneal nerve to expose fibular head and neck. **SEE TECHNIQUE 1-7.**

peroneus longus muscle. With the back of the knife blade toward the nerve, divide the thin slip of peroneus longus muscle bridging it. Displace the nerve from its normal bed into an anterior position.

- As the dissection continues, protect the anterior tibial vessels that pass between the neck of the fibula and the tibia by subperiosteal dissection.
- After the resection is complete, suture the biceps tendon and the fibular collateral ligament to the adjacent soft tissues.

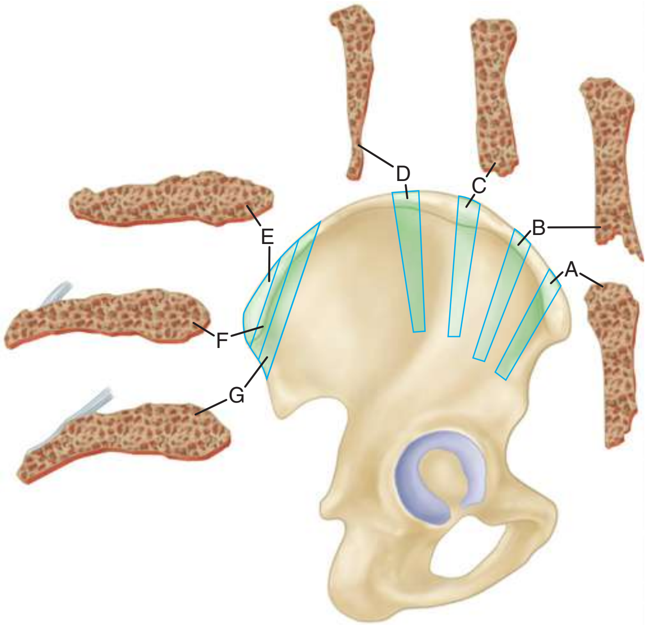


FIGURE 1-22 Coronal sections **(A-D)** from anterior portion of ilium. Accompanying cross-sections show width of bone and its cancellous structure. Iliac grafts for fusion of spine are ordinarily removed from posterior third of crest **(E-G)**.

CANCELLOUS ILIAC CREST BONE GRAFTS

Unless considerable strength is required, the cancellous graft fulfills almost any requirement. Regardless of whether the cells in the graft remain viable, clinical results indicate that cancellous grafts incorporate with the host bone more rapidly than do cortical grafts.

Large cancellous and corticocancellous grafts may be obtained from the anterior superior iliac crest and the posterior iliac crest. Small cancellous grafts may be obtained from the greater trochanter of the femur, femoral condyle, proximal tibial metaphysis, medial malleolus of the tibia, olecranon, and distal radius. At least 2 cm of subchondral bone must remain to avoid collapse of the articular surface.

If form and rigidity are unnecessary, multiple sliver or chip grafts may be removed. When preservation of the iliac crest is desirable, the outer cortex of the ilium may be removed along with considerable cancellous bone. If a more rigid piece of bone is desirable, the posterior or anterior one third of the crest of the ilium is a satisfactory donor site. For wedge grafts, the cuts are made at a right angle to the crest. Jones et al. found that full-thickness iliac grafts harvested with a power saw are stronger than grafts harvested with an osteotome, presumably because of less microfracturing of bone with the saw.

If the patient is prone, the posterior third of the ilium is used; if the patient is supine, the anterior third is available (Fig. 1-22). In children, the physis of the iliac crest is ordinarily preserved together with the attached muscles. To accomplish this, a cut is made parallel to and below the apophysis, and this segment is fractured in greenstick fashion at the posterior end. Ordinarily, only one cortex and the cancellous bone are removed for grafts, and the fractured crest, along with the apophysis, is replaced in contact with the remnant of the ilium and is held in place with heavy nonabsorbable sutures. When full-thickness grafts are removed from the ilium in adults, a similar procedure may be used, preserving the crest of the ilium and its external contour. The patient cannot readily detect the absence of the bone, and the cosmetic result is superior. This method also is less likely to result in a "landslide" hernia. Wolfe and Kawamoto reported a method of taking full-thickness bone from the anterior ilium; the iliac crest is split off obliquely medially and laterally so that the edges of the crest may be reapproximated after the bone has been excised (Fig. 1-23). They also used this method in older children without any evidence of growth disturbance of the iliac crestal physis.

REMOVAL OF AN ILIAC BONE GRAFT

Harvesting autograft bone from the ilium is not without complications. Hernias have been reported to develop in patients from whom massive full-thickness iliac grafts were taken. Muscle-pedicle grafts for arthrodesis of the hip (see Chapter 5 for hip arthrodesis techniques) also have resulted in a hernia when both cortices were removed. With this graft, the abductor muscles and the layer of periosteum laterally are removed with the graft. Careful repair of the supporting structures remaining after removal of an iliac graft is important and probably the best method of preventing these hernias. Full-thickness windows made below the iliac crest are less likely to lead to hernia formation. In addition to hernia formation, nerve injury, arterial injury, or cosmetic deformity can be a problem after harvesting of iliac bone. The lateral femoral cutaneous and ilioinguinal nerves are at risk during harvest of bone from the anterior ilium. The superior cluneal nerves are at risk if dissection is carried farther than 8 cm lateral to the posterior superior iliac spine (Fig. 1-24). The superior gluteal vessels can be damaged by retraction against the roof of the sciatic notch. Removal of large full-thickness grafts from the anterior ilium can alter the contour of the anterior crest, producing significant cosmetic deformity (see Fig. 1-26). Arteriovenous fistula, pseudoaneurysm, ureteral injury, anterior superior iliac spine avulsion, and pelvic instability have been reported as major complications of iliac crest graft procurement.

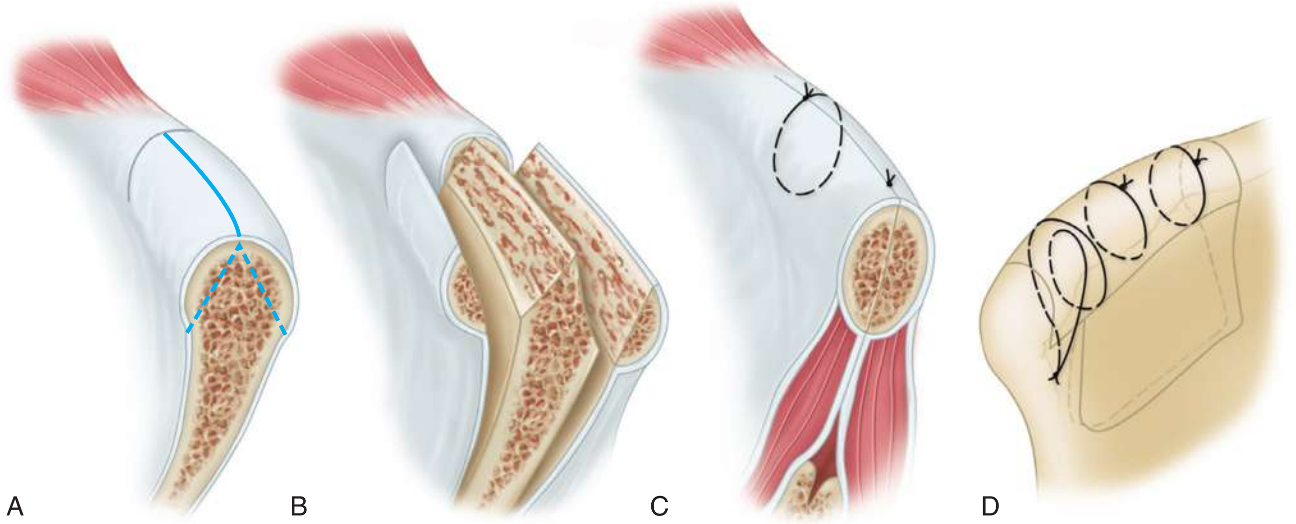


FIGURE 1-23 Wolfe-Kawamoto technique of taking iliac bone graft. **A** and **B,** Outer ridges of iliac crest are split off obliquely with retention of muscular and periosteal attachments. **C** and **D,** Closure of donor site. Note offset anteriorly for reattachment of crest to anterior superior iliac spine **(D)**. (Redrawn from Wolfe SA, Kawamoto HK: Taking the iliac-bone graft: a new technique, J Bone Joint Surg 60A:411, 1978.)

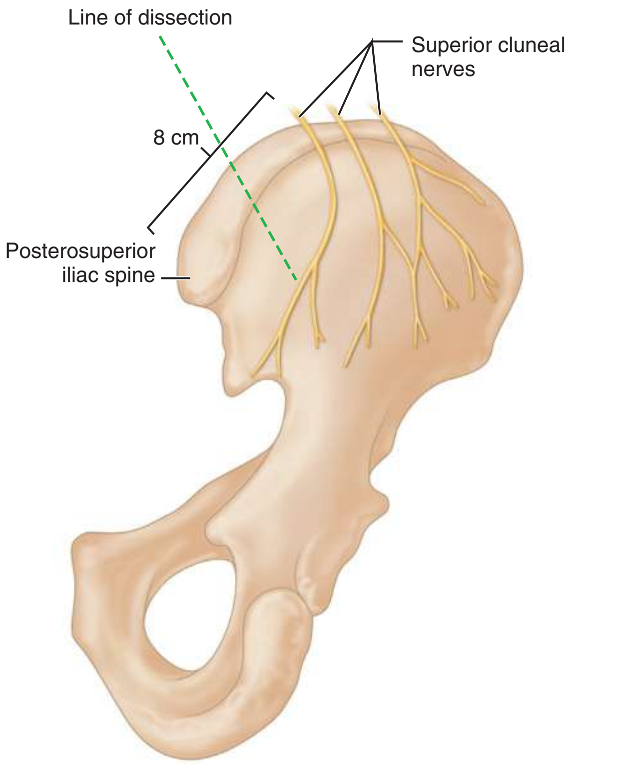


FIGURE 1-24 Posteroanterior view of pelvis showing superior cluneal nerves crossing over posterior iliac crest beginning 8 cm lateral to posterior superior iliac spine. **SEE TECHNIQUE 1-8.**

TECHNIQUE 1-8

- Make an incision along the subcutaneous border of the iliac crest at the point of contact of the periosteum with the origins of the gluteal and trunk muscles; carry the incision down to the bone.
- When the crest of the ilium is not required as part of the graft, split off the lateral side or both sides of the crest in continuity with the periosteum and the attached muscles. To avoid hemorrhage, dissect subperiosteally.
- If a cancellous graft with one cortex is desired, elevate only the muscles from either the inner or the outer table of the ilium. The inner cortical table with underlying cancellous bone may be preferable, owing to body habitus.
- For full-thickness grafts, also strip the iliacus muscle from the inner table of the ilium (Fig. 1-25).
- When chip or sliver grafts are required, remove them with an osteotome or gouge from the outer surface of the wing of the ilium, taking only one cortex.
- After removal of the crest, considerable cancellous bone may be obtained by inserting a curette into the cancellous space between the two intact cortices.
- When removing a cortical graft from the outer table, first outline the area with an osteotome or power saw. Then peel the graft up with slight prying motions with a broad osteotome. Wedge grafts or full-thickness grafts may be removed more easily with a power saw; this technique also is less traumatic than when an osteotome and mallet are used. For this purpose, an oscillating saw or an air-powered cutting drill is satisfactory. Avoid excessive heat by irrigating with saline at room temperature. Avoid removing too much of the crest anteriorly and leaving an unsightly deformity posteriorly (Fig. 1-26).

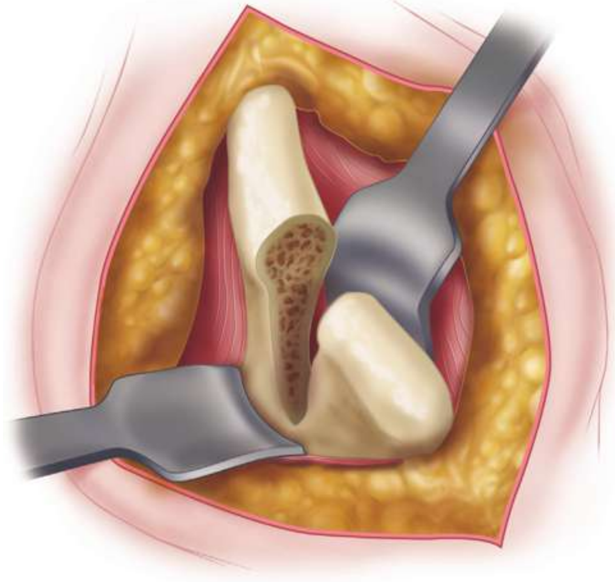


FIGURE 1-25 **Method of removing full-thickness coronal segment of ilium.** (Redrawn from Abbott LC: The use of iliac bone in the treatment of ununited fractures, *AAOS Instr Course Lect* 2:13, 1944.) **SEE TECHNIQUE 1-8.**

FIGURE 1-26 Defect in ilium after large graft was removed. Anterior border of ilium that included the anterior superior iliac spine was preserved, but because the defect was so large, deformity was visible even under clothing. Unsightly contour was improved by removing more bone from the crest posteriorly. **SEE TECHNIQUE 1-8.**

- After removal of the grafts, accurately appose and suture the periosteum and muscular origins with strong interrupted sutures.
- Bleeding from the ilium is sometimes profuse; avoid using Gelfoam and bone wax and depend on wound packing and local pressure. Gelfoam and bone wax are foreign materials. Bone wax is said to retard bone healing, and Gelfoam in large amounts has been associated with sterile serous drainage from wounds. Microcrystalline collagen has been reported to be more efficient in reducing blood loss from cancellous bone than either thrombin powder or thrombin-soaked gelatin foam. Gentle wound suction for 24 to 48 hours combined with meticulous obliteration of dead space is satisfactory for the management of these wounds.
- When harvesting bone from the posterior ilium, Colterjohn and Bednar recommended making the incision parallel to the superior cluneal nerves and perpendicular to the posterior iliac crest (see Fig. 1-24).

SURGICAL APPROACHES

A surgical approach should provide easy access to all structures sought. The incision should be long enough not to hinder any part of the operation. When practical, it should parallel or at least consider the natural creases of the skin to avoid undesirable scars. A longitudinal incision on the flexor or extensor surface of a joint may cause a large, unsightly scar or even a keloid that may permanently restrict motion. A longitudinal midlateral incision, especially on a finger or thumb or on the ulnar border of the hand, produces little scarring because it is located where movements of the skin are relatively slight. The approach also should do as little damage as possible to the deeper structures. It should follow lines of cleavage and planes of fascia and when possible should pass between muscles rather than through them. Important nerves and vessels must be spared by locating and protecting them or by avoiding them completely; when an important structure is in immediate danger, it should be exposed. In addition to learning approaches described by others, the surgeon should know the anatomy so well that an approach can be modified when necessary.

Not all approaches are described in this chapter, but rather only those found suitable for most of the orthopaedic operations now in use. Additional approaches are described in other sections of this book. There has been recent interest in less invasive total joint arthroplasties. These approaches are outlined in Chapters 3, 7, 10, and 12.

Unnecessary scarring and disfigurement should be avoided. Making a long incision parallel to the scar of a previous long incision is unjustified. An incision through an old scar heals as well as a new incision; and even though the scar may not be ideally located, the deeper structures may be reached by retracting the skin and subcutaneous tissues. A second incision made parallel to and near an old scar may impair the circulation in the strip of skin between the two, leading to skin slough.

The position of the patient for surgery also is important. It should be properly established before the operation is begun, and provisions should be made to prevent undesirable changes in position during the operation. The surgeon should be able to reach all parts of the surgical field easily.

A tourniquet, unless specifically contraindicated, should always be used in surgery on the extremities; the dry field it provides makes the dissection easier, the surgical technique less traumatic, and the time required for the operation shorter. Also, in a dry field, the cutaneous nerves are identified and protected more easily, and they often may be used as guides to deeper structures. The identification, dissection, and ligation of vessels also are made easier. Although the extremity is temporarily ischemic, an electrocautery unit should be used to cauterize small vessels that cross the incision. An electrocautery unit is even more useful in surgical sites where a tourniquet cannot be employed, such as the shoulder, hip, spine, or pelvis.

TOES

APPROACH TO THE INTERPHALANGEAL JOINTS

TECHNIQUE 1-9

- For procedures on the interphalangeal joint of the great toe, make an incision 2.5 cm long on the medial aspect of the toe.
- For the interphalangeal joints of the fifth toe, make a lateral incision.
- Approach the interphalangeal joints of the second, third, and fourth toes through an incision just lateral to the corresponding extensor tendon.
- Carry the dissection through the subcutaneous tissue and fascia to the capsule of the joint.
- Reflect the edges of the incision with care to avoid damaging the dorsal or plantar digital vessels and nerves; retract the dorsal nerves and vessels dorsally and the plantar nerves and vessels plantarward.
- To expose the articular surfaces, open the capsule transversely or longitudinally.

APPROACHES TO THE METATARSOPHALANGEAL JOINT OF THE GREAT TOE

The metatarsophalangeal joint of the great toe may be exposed in one of several ways. Two ways are described.

MEDIAL APPROACH TO THE GREAT TOE METATARSOPHALANGEAL JOINT

TECHNIQUE 1-10

- Make a curved incision 5 cm long on the medial aspect of the joint (Fig. 1-27A). Begin it just proximal to the interphalangeal joint, curve it over the dorsum of the metatarsophalangeal joint medial to the extensor hallucis longus tendon, and end it on the medial aspect of the first metatarsal 2.5 cm proximal to the joint.
- As the deep fascia is incised, laterally retract the medial branch of the first dorsal metatarsal artery and the medial branch of the dorsomedial nerve (a branch of the superficial peroneal nerve), which supplies the medial side of the great toe.
- Dissect the fascia from the dorsum down to the bursa over the medial aspect of the metatarsal head.
- Make a curved incision through the bursa and capsule of the joint (Fig. 1-27B); begin the incision over the dorsomedial aspect of the joint, continue it proximally dorsal to the metatarsal head and plantarward and distally

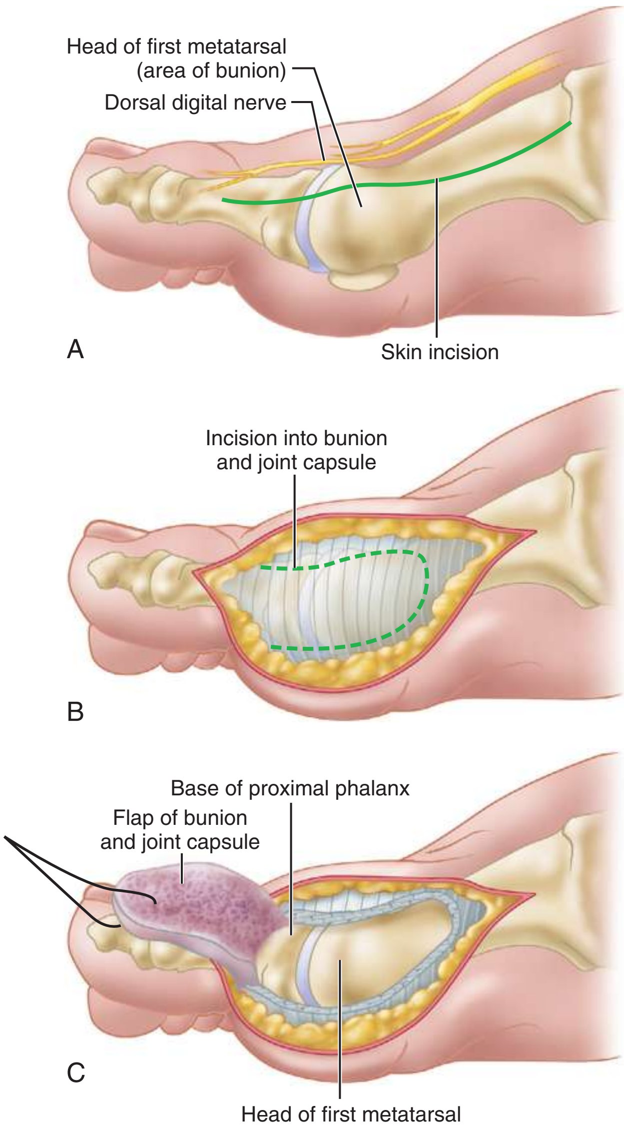


FIGURE 1-27 A-C, Medial approach to metatarsophalangeal joint of great toe (see text). (Modified from Hoppenfeld S, deBoer P: Surgical exposures in orthopaedics: the anatomic approach, Philadelphia, Lippincott Williams & Wilkins, 2003.) **SEE TECHNIQUE 1-10.**

around the joint, and end it distally on the medioplantar aspect of the metatarsophalangeal joint. This incision forms an elliptical, racquet-shaped flap attached at the base of the proximal phalanx (Fig. 1-27C). Although distal reflection of this flap amply exposes the first metatarsophalangeal joint, the use of a dorsomedial approach is preferable because healing of the skin flap may be delayed.

DORSOMEDIAL APPROACH TO GREAT TOE METATARSOPHALANGEAL JOINT

TECHNIQUE 1-11

- Begin the incision just proximal to the interphalangeal joint and continue it proximally for 5 cm parallel with and medial to the extensor hallucis longus tendon.
- To expose the capsule, divide the fascia and retract the tendon.
- The capsule can be incised by forming a flap with its attachment at the base of the first phalanx, as in the preceding approach, or by continuing the dissection in the plane of the skin incision.

APPROACH TO THE LESSER TOE METATARSOPHALANGEAL JOINTS

TECHNIQUE 1-12

- The second, third, and fourth metatarsophalangeal joints are reached by a dorsolateral incision parallel to the corresponding extensor tendon (Fig. 1-28).
- The fifth metatarsophalangeal joint is best exposed by a straight or curved dorsal or dorsolateral incision.
- The joint capsules may be opened transversely or longitudinally, as necessary.

CALCANEUS

Approaches to the calcaneus are carried out most easily with the patient prone. The medial approach, however, can be made with the patient supine, the knee flexed, and the foot crossed over the opposite leg. The lateral approach also can be made with the patient supine by placing a sandbag under the ipsilateral buttock, internally rotating the hip, and everting the foot.

MEDIAL APPROACH TO THE CALCANEUS

TECHNIQUE 1-13

Figure 1-29

- Begin the incision 2.5 cm anterior to and 4 cm inferior to the medial malleolus, carrying it posteriorly along the medial surface of the foot to the Achilles tendon.
- Divide the fat and fascia and define the inferior margin of the abductor hallucis.
- Mobilize the muscle belly and retract it dorsally to expose the medial and inferomedial aspects of the body of the calcaneus.
- Continue the dissection distally by dividing the plantar aponeurosis and the muscles attaching to the calcaneus or by stripping these from the bone with an osteotome. Carefully avoid the medial calcaneal nerve and the nerve to the abductor digiti minimi.

  The inferior surface of the body of the calcaneus can be exposed subperiosteally.

LATERAL APPROACH TO THE CALCANEUS

TECHNIQUE 1-14

- Begin the incision on the lateral margin of the Achilles tendon near its insertion and pass it distally to a point 4 cm inferior to and 2.5 cm anterior to the lateral malleolus (Fig. 1-30).
- Divide the superficial and deep fasciae, isolate the peroneal tendons and incise and elevate the periosteum below the tendons to expose the bone.
- If necessary, and if no infection is present, divide the tendons by Z-plasty and repair them later.

EXTENDED LATERAL APPROACH TO THE CALCANEUS

The extended lateral approach was developed for open fixation of calcaneal fractures. The condition of the skin is most important. Swelling and bruised skin are factors leading to superficial and deep infections. The initial trauma impairs the microvasculature of the skin and subcutaneous tissues. A single-layer interrupted absorbable subcuticular suture is recommended for closure. This is less traumatic to the skin and subcutaneous tissues than a two-layer closure. An inverse relationship between surgeon experience and wound complications has been demonstrated, and patient age and use of nicotine in any form also are important factors.

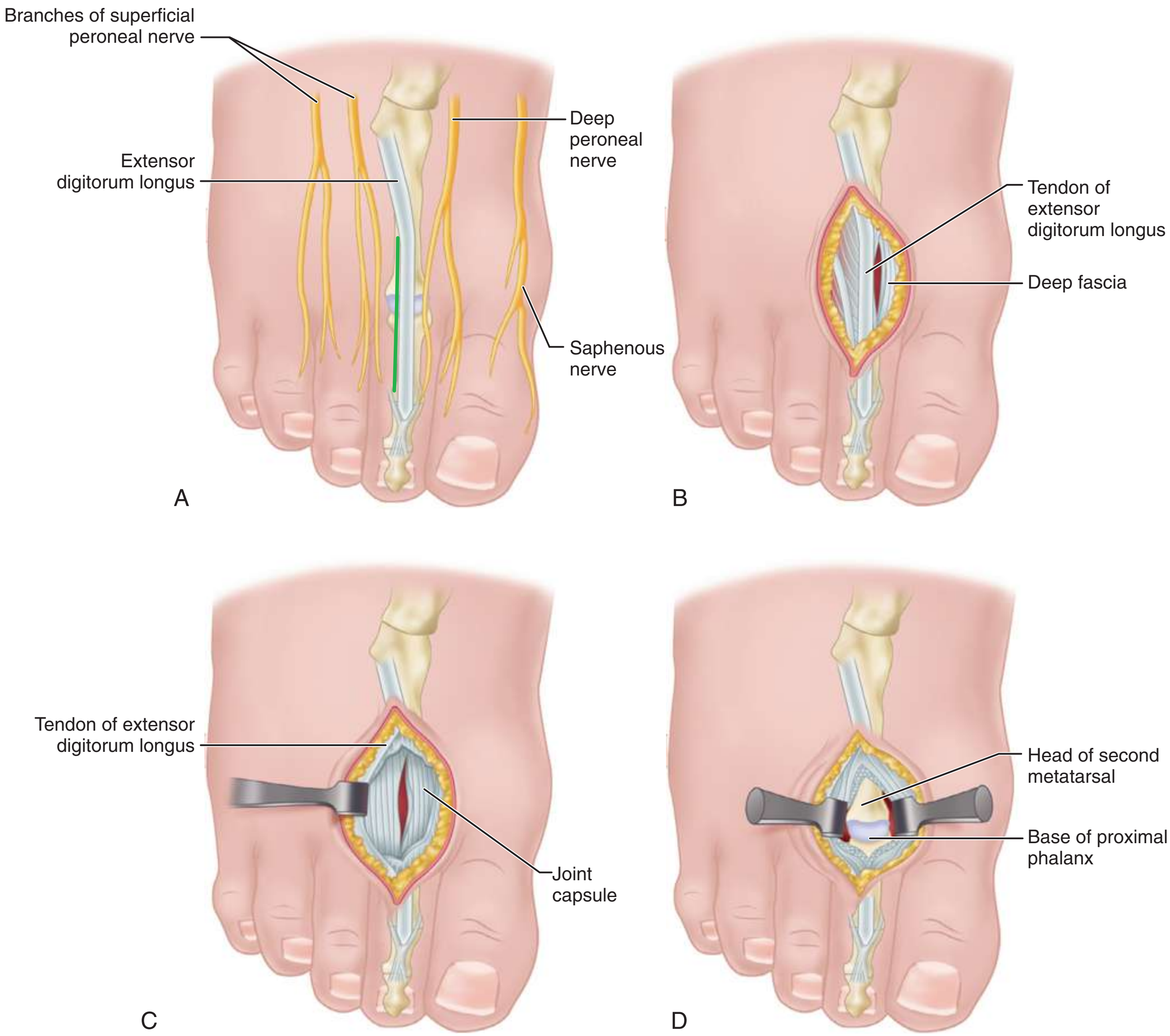


FIGURE 1-28 Approaches to metatarsophalangeal joints of second, third, fourth, and fifth toes. **A,** Skin incision. **B,** Incision through deep fascia medial to tendons. **C,** Longitudinal incision in joint capsule. **D,** Joint is exposed. (Modified from Hoppenfeld S, deBoer P: *Surgical exposures in orthopaedics: the anatomic approach,* Philadelphia, 2003, Lippincott Williams & Wilkins.) **SEE TECHNIQUE 1-12.**

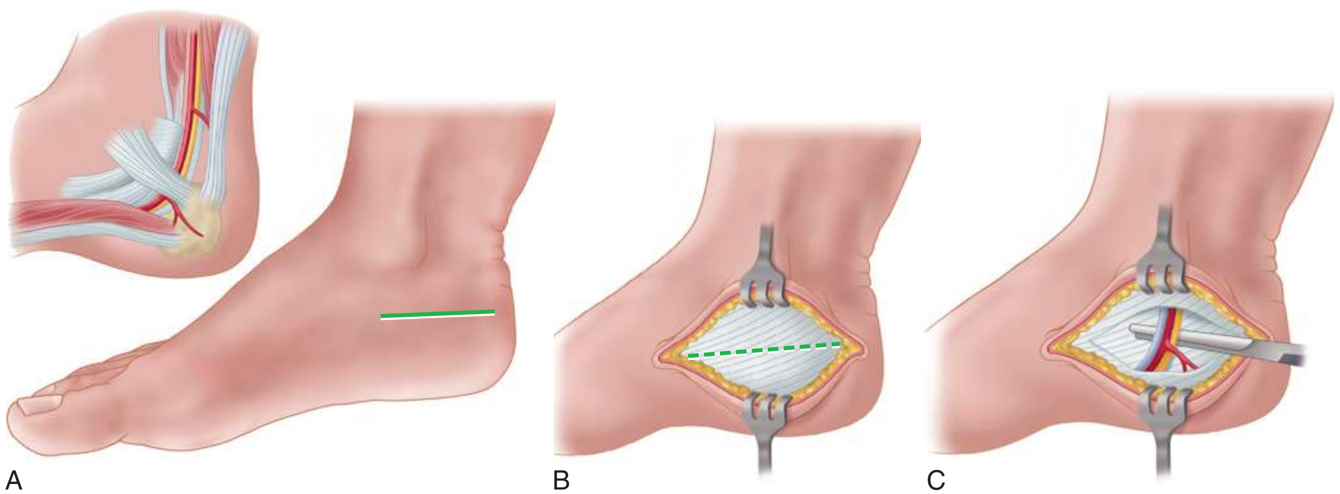


FIGURE 1-29 Medial approach to calcaneus. **A,** Skin incision. **B,** Fascial incision. **C,** Isolation of neurovascular bundle. (Modified from Burdeaux BD: Reduction of calcaneal fractures by the McReynolds medial approach technique and its experimental basis, Clin Orthop Relat Res 177:93, 1983.) **SEE TECHNIQUE 1-13.**

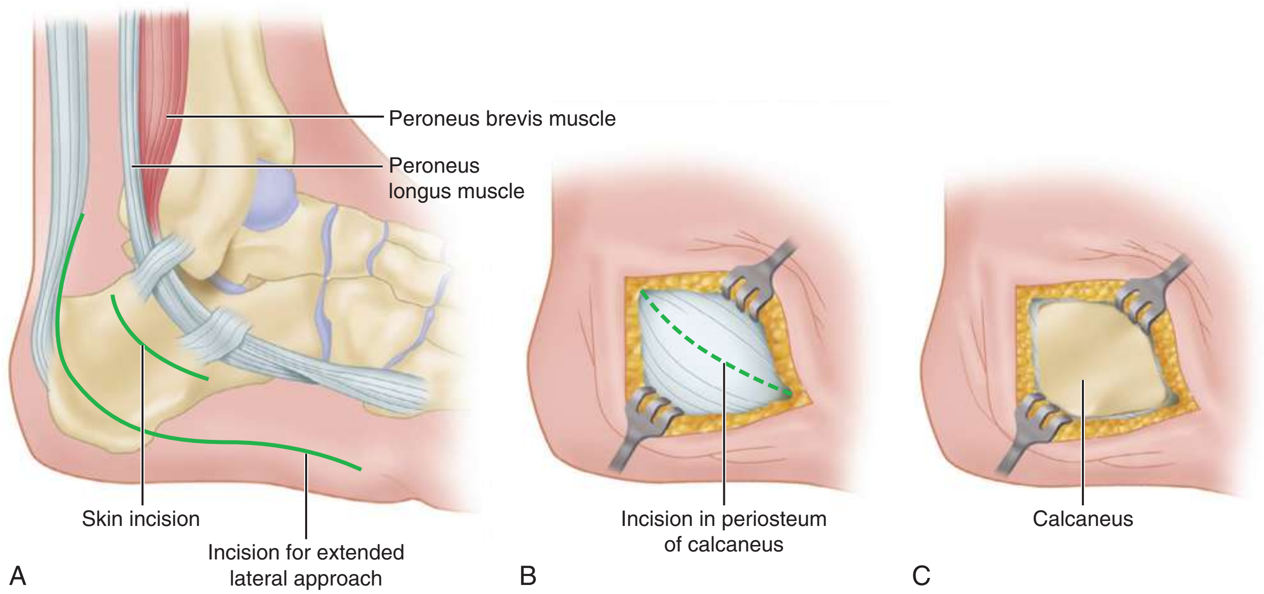


FIGURE 1-30 Lateral approach to calcaneus. **A,** Skin incision. **B,** Incision in periosteum of calcaneus. **C,** Calcaneus is exposed. **SEE TECHNIQUES 1-14 AND 1-15.**

EXTENDED LATERAL APPROACH TO THE CALCANEUS

TECHNIQUE 1-15

- Beginning several centimeters proximal to the posterior tuberosity and the lateral edge of the Achilles tendon, begin the incision and carry it to the smooth skin just above the heel pad. Curve the incision anteriorly following the contour of the heel and carry it to below the tip of the fifth metatarsal base (Fig. 1-30A).
- Develop a full-thickness flap containing the peroneal tendons and sural nerve.
- Reflect it anteriorly and hold it in place with one or two Kirschner wires drilled into the lateral talus.
- At closure, use a single layer of interrupted 2-0 absorbable sutures.
- Use a single tube vacuum drain and apply a sterile Jones-type compression dressing.

U-SHAPED APPROACH TO THE CALCANEUS

TECHNIQUE 1-16

- With the patient prone, support the leg on a large sandbag.
- For access to the entire plantar surface of the calcaneus, make a large U-shaped incision around the posterior four fifths of the bone (Fig. 1-31).
- After the dissections described, retract a flap consisting of skin, the fatty heel pad, and the plantar fascia.

KOCHER APPROACH (CURVED L) TO THE CALCANEUS

TECHNIQUE 1-17

- The Kocher approach is suitable for complete excision of the calcaneus in cases of tumor or infection.
- Incise the skin over the medial border of the Achilles tendon from 7.5 cm proximal to the tuberosity of the calcaneus to the inferoposterior aspect of the tuberosity, continuing it transversely around the posterior aspect of the calcaneus and distally along the lateral surface of the foot to the tuberosity of the fifth metatarsal (see Fig. 1-34B).
- Divide the Achilles tendon at its insertion and carry the dissection down to the bone.
- To reach the superior surface, free all tissues beneath the severed Achilles tendon.
- The calcaneus may be enucleated with or without its periosteal attachments.

  The central third of the incision is ideal for fixation of posterior tuberosity avulsion fractures.

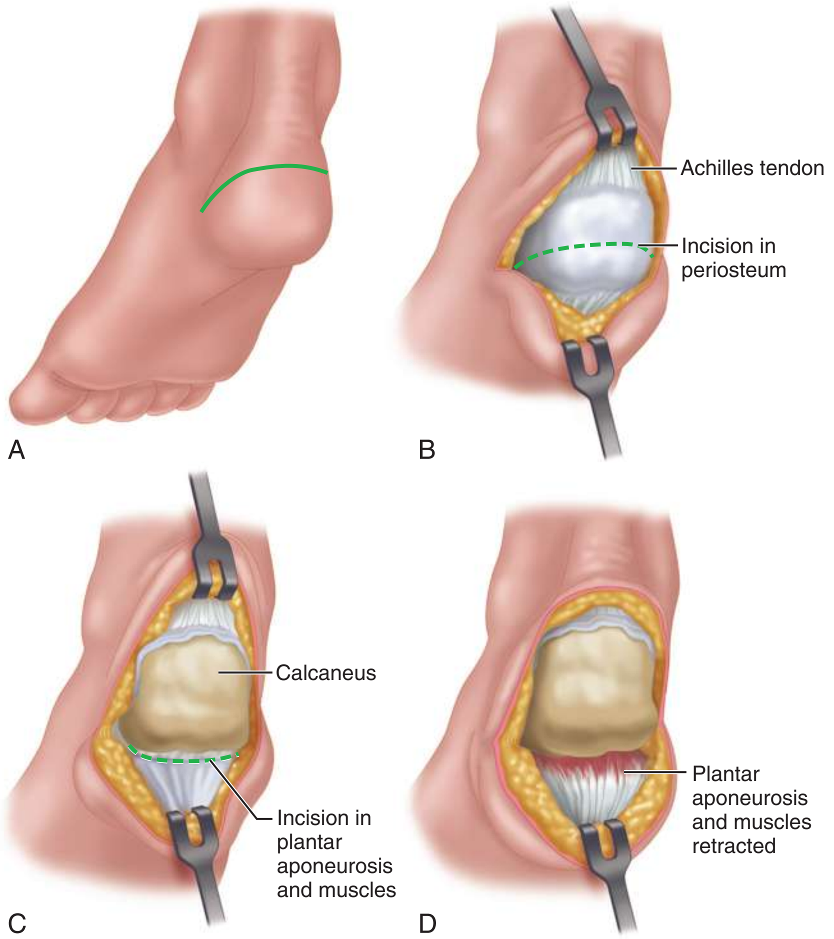


FIGURE 1-31 U-shaped approach to calcaneus. **A,** Skin incision. **B,** Periosteal incision. **C,** Incision in plantar aponeurosis and muscles. **D,** Plantar aponeurosis and muscles are retracted. **SEE TECHNIQUE 1-16.**

TARSUS AND ANKLE

ANTERIOR APPROACHES

ANTEROLATERAL APPROACH TO CHOPART'S JOINT

The anterolateral approach gives excellent access to the ankle joint, the talus, and most other tarsal bones and the anterior tuberosity of the calcaneal joints, and it avoids all important vessels and nerves. Because so many reconstructive operations and other procedures involve the structures exposed, it may well be called the "universal incision" for the foot and ankle. It permits excision of the entire talus, and the only tarsal joints that it cannot reach are those between the navicular and the second and first cuneiforms. This approach is good for a single-incision "triple" arthrodesis and a pantalar arthrodesis, as the tibiotalar, talonavicular, subtalar, and calcaneocuboid joints are exposed.

TECHNIQUE 1-18

- Begin the incision over the anterolateral aspect of the leg medial to the fibula and 5 cm proximal to the ankle joint, carrying it distally over the joint, the anterolateral aspect of the body of the talus, and the calcaneocuboid joint, and end it at the base of the fourth metatarsal (Fig. 1-32A). The incision may begin more proximally or end more distally, or any part may be used, as needed.
- Incise the fascia and the superior and inferior extensor retinacula down to the periosteum of the tibia and the capsule of the ankle joint. This dissection usually divides the anterolateral malleolar and lateral tarsal arteries.
- While retracting the edges of the wound, identify and protect the intermediate dorsal cutaneous branches of the superficial peroneal nerve.
- Divide the extensor digitorum brevis muscle in the direction of its fibers or detach it from its origin and reflect it distally.
- Retract the extensor tendons, the dorsalis pedis artery, and the deep peroneal nerve medially and incise the capsule.
- Expose the talonavicular joint by dissecting deep to the tendons and incise its capsule transversely.
- Continue the dissection laterally through the capsule of the calcaneocuboid joint, which lies on the same plane as the talonavicular joint.
- Incise the mass of fat lateral to and inferior to the neck of the talus to bring the subtalar joint into view.

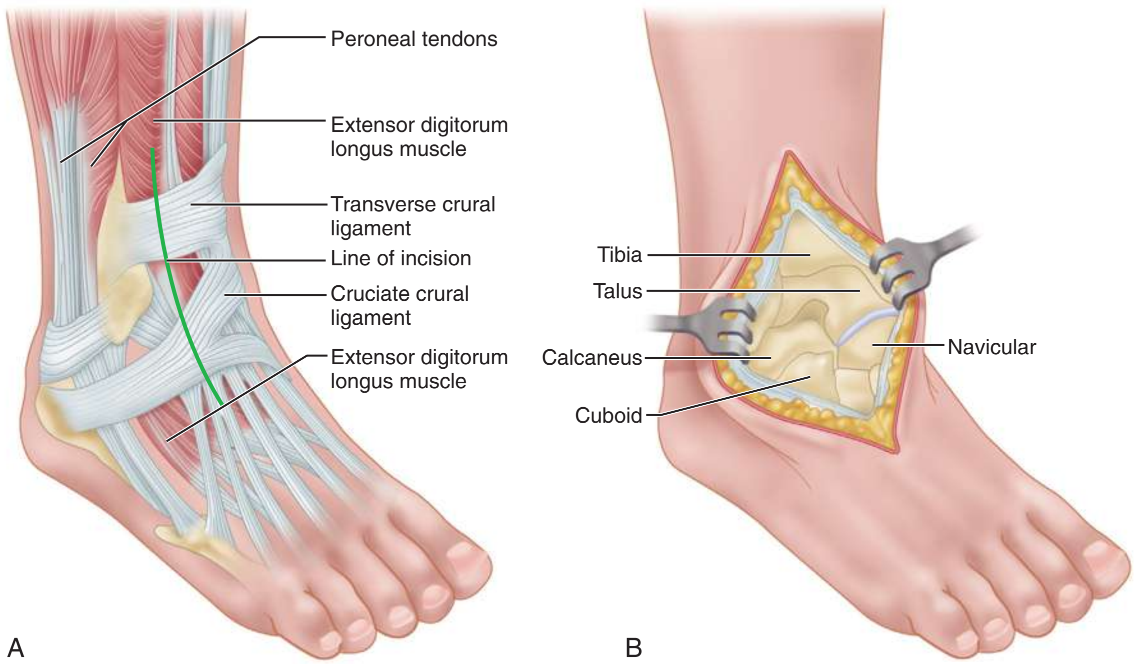


FIGURE 1-32 **A** and **B,** Anterolateral approach to ankle joint and tarsus. **SEE TECHNIQUE 1-18.**

- Extend the dissection distally to provide access to the articulation between the cuboid and the fourth and fifth metatarsals and between the navicular and the third cuneiform (Fig. 1-32B).

ANTERIOR APPROACH TO EXPOSE THE ANKLE JOINT AND BOTH MALLEOLI

Gaining access to the part of the ankle joint between the medial malleolus and the medial articular facet of the body of the talus often is difficult when fusing the ankle through the anterolateral approach. Through the anterior approach, however, both malleoli may be exposed easily. Usually the approach is developed between the extensor hallucis longus and extensor digitorum longus tendons (Fig. 1-33), but it also can be developed between the anterior tibial and extensor hallucis longus tendons. In this case, the neurovascular bundle is retracted laterally with the long extensor tendons of the toes, and the anterior tibial tendon is retracted medially.

TECHNIQUE 1-19

- Begin the incision on the anterior aspect of the leg 7.5 to 10 cm proximal to the ankle and extend it distally to about 5 cm distal to the joint. Its length varies with the surgical indication.
- Divide the deep fascia in line with the skin incision.

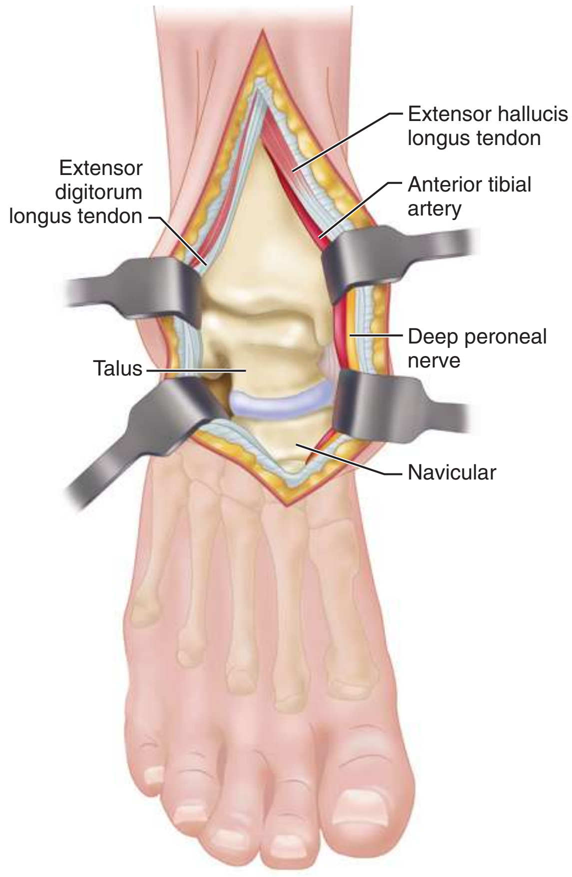


FIGURE 1-33 Anterior approach to ankle joint. Extensor hallucis longus and anterior tibial tendons, along with neurovascular bundle, are retracted medially. Tendons of extensor digitorum longus muscle are retracted laterally. **SEE TECHNIQUE 1-19.**

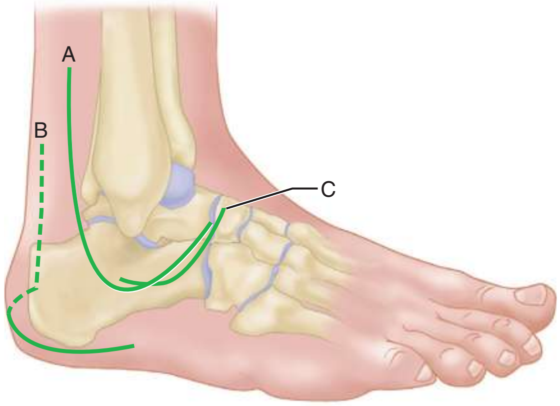


FIGURE 1-34 *A,* Kocher approach to ankle. *B,* Kocher approach to calcaneus. *C,* Ollier approach to midtarsal and subtalar joints. **SEE TECHNIQUES 1-17, 1-19, 1-20, AND 1-21.**

- Isolate, ligate, and divide the anterolateral malleolar and lateral tarsal arteries, and carefully expose the neurovascular bundle and retract it medially.
- Incise the periosteum, capsule, and synovium in line with the skin incision, and expose the full width of the ankle joint anteriorly by subcapsular and subperiosteal dissection (Fig. 1-34A).

LATERAL APPROACHES TO THE TARSUS AND ANKLE

KOCHER LATERAL APPROACH TO THE TARSUS AND ANKLE

The Kocher approach gives excellent exposure of the midtarsal, subtalar, and ankle joints (Fig. 1-34A). The disadvantage of this procedure is that the skin may slough around the margins of the incision, especially if dislocation of the ankle has been necessary, as in a talectomy. The peroneal tendons usually must be divided. In most instances, the anterolateral incision is more satisfactory.

TECHNIQUE 1-20

- From a point just lateral and distal to the head of the talus, curve the incision 2.5 cm inferior to the tip of the lateral malleolus, then posteriorly and proximally, and end it 2.5 cm posterior to the fibula and 5 cm proximal to the tip of the lateral malleolus or, if desired, 5 or 7 cm further proximally, parallel with and posterior to the fibula (Fig. 1-34A).
- Incise the fascia down to the peroneal tendons and retract them posteriorly, protecting the lesser saphenous vein and sural nerve lying immediately posterior to the incision.
- If a larger operative field is necessary, divide the tendons by Z-plasty and retract them.
- Deepen the dissection distally, divide the calcaneofibular ligament, and expose the subtalar joint. The calcaneocuboid and talonavicular joints may be reached through the distal part of this incision.
- After dividing the talofibular ligaments, dislocate the ankle by medial traction if access to its entire articular surface is desired.

OLLIER APPROACH TO THE TARSUS

The Ollier approach is excellent for a triple arthrodesis: the three joints are exposed through a small opening without much retraction, and the wound usually heals well because the proximal flap is dissected full thickness and the skin edges are protected during retraction (see Chapter 84).

TECHNIQUE 1-21

- Begin the skin incision over the dorsolateral aspect of the talonavicular joint, extend it obliquely inferoposteriorly, and end it about 2.5 cm inferior to the lateral malleolus (Fig. 1-34C).
- Divide the inferior extensor retinaculum in the line of the skin incision.
- In the superior part of the incision, expose the long extensor tendons to the toes and retract them medially, preferably without opening their sheaths.
- In the inferior part of the incision, expose the peroneal tendons and retract them inferiorly.
- Divide the origin of the extensor digitorum brevis muscle, retract the muscle distally, and bring into view the sinus tarsi.
- Extend the dissection to expose the subtalar, calcaneocuboid, and talonavicular joints.

POSTEROLATERAL APPROACH TO THE ANKLE

The Gatellier and Chastang posterolateral approach permits open reduction and internal fixation of fractures of the ankle in which the fragment of the posterior tibial lip (posterior malleolus) is large and laterally situated. It makes use of the fact that the fibula usually is fractured in such injuries; should it be intact, it is osteotomized about 10 cm proximal to the tip of the lateral malleolus. The approach also is used for osteochondritis dissecans involving the lateral part of the dome of the talus and for osteochondromatosis of the ankle.

TECHNIQUE 1-22

(GATELLIER AND CHASTANG)

- Begin the incision about 12 cm proximal to the tip of the lateral malleolus and extend it distally along the posterior

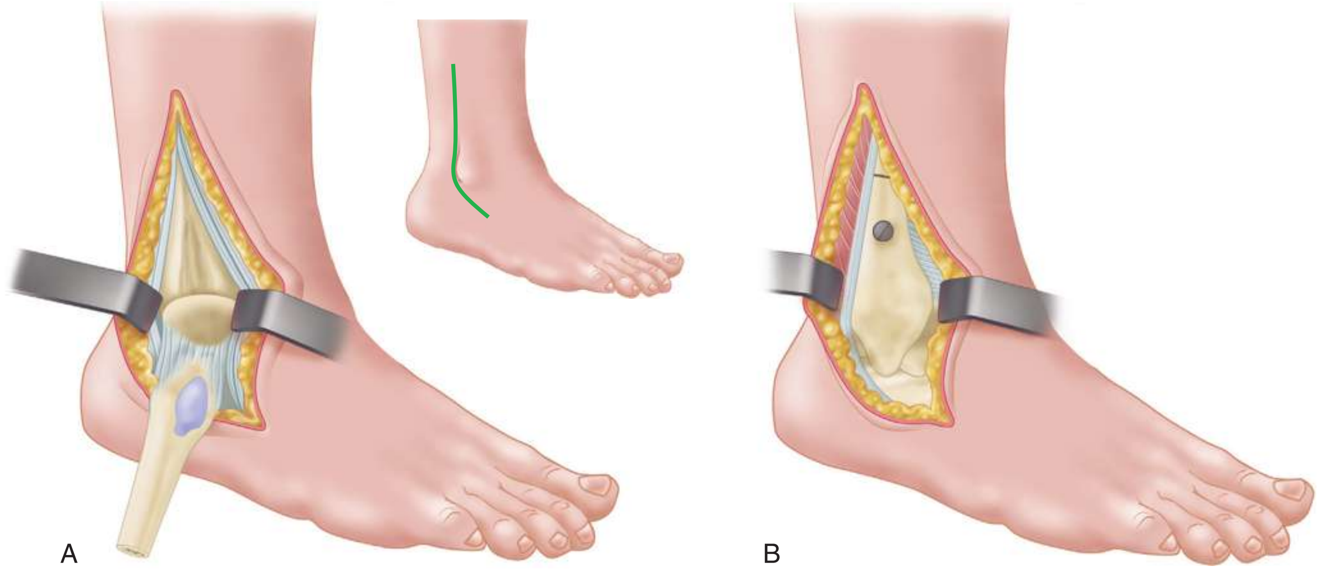


FIGURE 1-35 Posterolateral approach of Gatellier and Chastang. **A,** Peroneal tendons have been displaced anteriorly, and fibula has been divided; distal fragment has been turned laterally after interosseous membrane and anterior and posterior tibiofibular ligaments have been divided. **B,** Distal fibula has been replaced and fixed to tibia with syndesmosis screw. **SEE TECHNIQUE 1-22.**

margin of the fibula to the tip of the malleolus. Curve the incision anteriorly for 2.5 to 4 cm in the line of the peroneal tendons (Fig. 1-35).

- Expose the fibula, including the lateral malleolus subperiosteally, and incise the sheaths of the peroneal retinacula and tendons, permitting the tendons to be displaced anteriorly.
- If the fibula is not fractured, divide it 10 cm proximal to the tip of the lateral malleolus and free the distal fragment by dividing the interosseous membrane and the anterior and posterior tibiofibular ligaments.
- Carefully preserve the calcaneofibular and talofibular ligaments to serve as a hinge and to maintain the integrity of the ankle after operation. Turn the fibula laterally on this hinge and expose the lateral and posterior aspects of the distal tibia and the lateral aspect of the ankle joint. Great care should be used in children to avoid creating a fracture through the distal fibular physis when reflecting the fibula.
- When closing the incision, replace the fibula and secure it with a screw extending transversely from the proximal part of the lateral malleolus through the tibiofibular syndesmosis into the tibia just proximal and parallel to the ankle joint.
- Overdrill the hole made in the fibula to allow for compression across the syndesmosis. Dorsiflex the ankle joint as the screw is tightened because the talar dome is wider at its anterior half than its posterior half. Failure to overdrill the fibula can result in widening of the syndesmosis and ankle mortise, with resulting arthritic degeneration of the tibiotalar joint. Add additional fixation with a small plate and screws if desired.
- Replace the tendons, repair the tendon sheaths and retinacula, and close the incision.
- After the osteotomy or fracture has healed, remove the screw to prevent its becoming loose or breaking.

ANTEROLATERAL APPROACH TO THE LATERAL DOME OF THE TALUS

As an alternative to lateral malleolar osteotomy, Tochigi et al. described an anterolateral approach to the lateral dome of the talus for extensive lateral osteochondral lesions. All but the posterior one fourth of the lateral talus can be exposed. An osteotomy of the anterolateral tibia is required.

TECHNIQUE 1-23

(TOCHIGI, AMENDOLA, MUIR, AND SALTZMAN)

- Make a vertical 10-cm incision along the anterolateral corner of the ankle, avoiding the lateral branch of the superficial peroneal nerve.
- Outline the osteotomy of the anterolateral tibia to include the anterior tibiofibular ligament. The cortical surface of the fragment should be at least 1 cm^2 (Fig. 1-36). Predrill the fragment to accept a 4-mm cancellous screw.
- Use a micro-oscillating saw to begin the osteotomy in two planes. Complete the osteotomy with a small, narrow osteotome by gently levering it in an externally rotated direction. The cartilaginous surface of the tibia is "cracked" as the fragment is rotated.
- At wound closure, rotate the fragment back into position and secure it with a 4-mm cancellous screw and washer.

POSTERIOR APPROACH TO THE ANKLE

If only the anterolateral distal tibia needs to be exposed, the anterolateral tibial osteotomy is omitted and the superficial peroneal nerve is protected until its position becomes more posterior entering deep fascia.

TECHNIQUE 1-24

- With the patient prone, make a 12-cm incision along the posterolateral border of the Achilles tendon down to the insertion of the tendon on the calcaneus (Fig. 1-37A).
- Divide the superficial and deep fasciae, divide the Achilles tendon by Z-plasty or retract it, and incise the fat and areolar tissue to the posterior surface of the tibia in the space between the flexor hallucis longus and the peroneal tendons (Fig. 1-37B).
- Retract the flexor hallucis longus tendon medially to expose 2.5 cm of the distal end of the tibia, the posterior aspect of the ankle joint, the posterior end of the talus, the subtalar joint, and the posterior part of the superior surface of the calcaneus (Fig. 1-37C).
- If the dissection is kept lateral to the flexor hallucis longus tendon, the posterior tibial vessels and the tibial nerve will not be at risk because this tendon protects them.
- Alternatively, the Achilles tendon can be split from just above the ankle joint distally to its insertion on the os calcis. Hammit et al. found a lower wound complication rate without sacrificing exposure using this technique rather than standard posteromedial and posterolateral approaches.

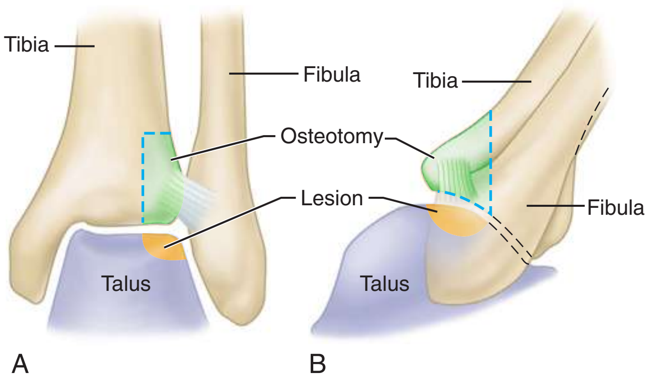


FIGURE 1-36 Tochigi, Amendola, Muir, and Saltzman anterolateral approach to talus. **A,** Anterior view of osteotomy. **B,** Lateral view of osteotomy. (From Tochigi Y, Amendola A, Muir D, et al: Surgical approach for centrolateral talar osteochondral lesions with an anterolateral osteotomy, *Foot Ankle Int* 23:1038, 2002.) **SEE TECHNIQUE 1-23.**

MEDIAL APPROACHES TO THE ANKLE

MEDIAL APPROACH TO THE ANKLE

Koenig and Schaefer approached the ankle from the medial side by a method similar in principle to the Gatellier and Chastang exposure of the posterolateral side. It is not a popular method because, despite utmost care, it is possible to injure the tibial vessels and nerve. Nevertheless, it may be useful for fracture-dislocations of the talus, other traumatic lesions of the ankle joint, and osteochondritis dissecans of the talus.

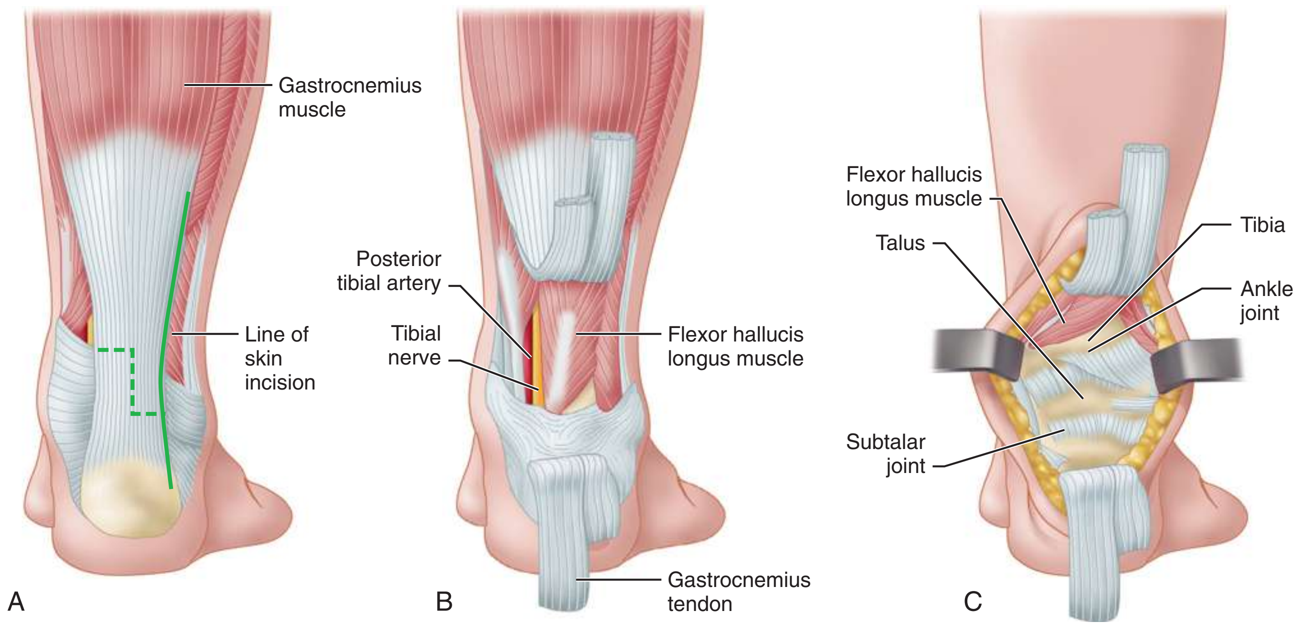


FIGURE 1-37 Posterior approach to ankle. **A,** Skin incision. **B,** Z-plasty division and reflection of Achilles tendon. **C,** Exposure of ankle and subtalar joints after retraction of flexor hallucis longus tendon and posterior capsulotomy. **SEE TECHNIQUE 1-24.**

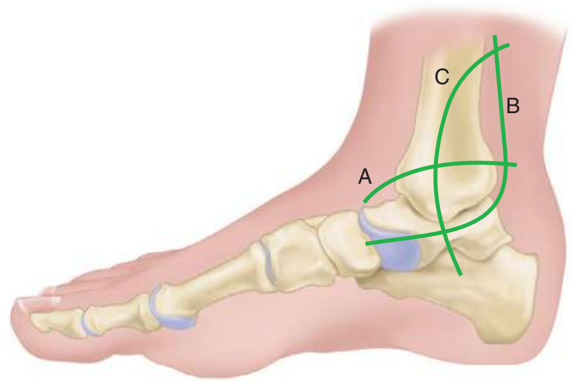


FIGURE 1-38 Incisions for medial approaches to ankle joint: Koenig and Schaefer *(A),* Broomhead *(B),* and Colonna and Ralston *(C).* **SEE TECHNIQUES 1-25 AND 1-26.**

TECHNIQUE 1-25

(KOENIG AND SCHAEFER)

- Curve the incision just proximal to the medial malleolus (Fig. 1-38A) and divide the malleolus with an osteotome or small power saw; preserve the attachment of the deltoid ligament.
- Subluxate the talus and malleolus laterally to reach the joint surfaces.
- Later replace the malleolus and fix it with one or two cancellous screws. To make replacement easier, drill the holes for the screws before the osteotomy, insert the screw, and then remove it. At the end of the operation, reinsert the screws and close the wound.
- The surfaces of the osteotomized bone are smooth, and the malleolus can rotate on a single screw. Two screws are used to prevent rotation of the osteotomized medial malleolus (Fig. 1-39). Interfragmentary technique (see Chapter 53) should be used for screw fixation of the medial malleolus to provide compression across the osteotomy site.

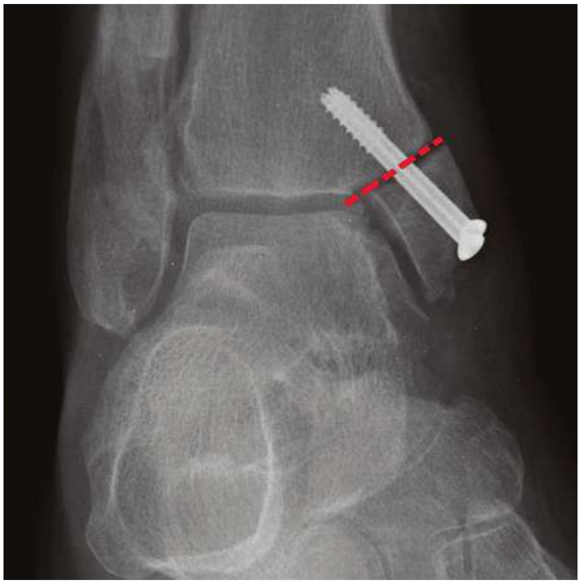


FIGURE 1-39 Osteotomy of medial malleolus for access to medial dome of talus. Note line of osteotomy. **SEE TECHNIQUE 1-25.**

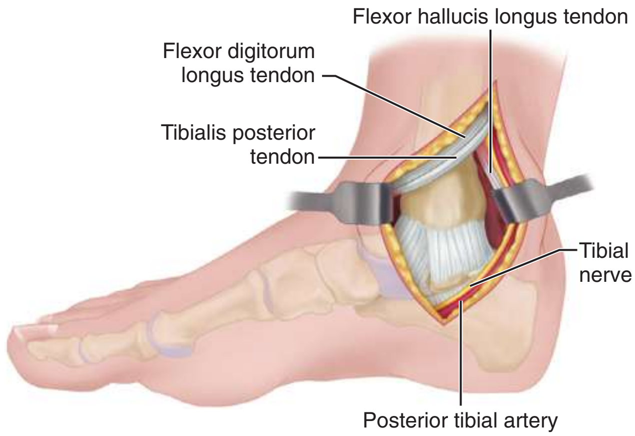


FIGURE 1-40 Colonna and Ralston posteromedial approach to distal tibia. Posterior tibial and flexor digitorum longus tendons have been retracted anteriorly, and flexor hallucis longus tendon, posterior tibial vessels, and tibial nerve have been retracted posteriorly and laterally. **SEE TECHNIQUE 1-26.**

MEDIAL APPROACH TO THE POSTERIOR LIP OF THE TIBIA

Broomhead advised a curved medial incision for fractures of the medial part of the posterior lip of the tibia that require open reduction. The line of approach lies midway between the posterior border of the tibia and the medial border of the Achilles tendon, curves inferior to the medial malleolus to the medial border of the foot, and permits exposure of medial and posterior malleoli (Fig. 1-38B). The latter is exposed by reflecting the capsule and periosteum and retracting the tendons of the posterior tibial, flexor digitorum longus, and flexor hallucis longus muscles together with the neurovascular bundle posteriorly and medially.

Colonna and Ralston described the following modification of Broomhead's approach.

TECHNIQUE 1-26

(COLONNA AND RALSTON)

- Begin the incision at a point about 10 cm proximal and 2.5 cm posterior to the medial malleolus and curve it anteriorly and inferiorly across the center of the medial malleolus and inferiorly and posteriorly 4 cm toward the heel (Fig. 1-38C).
- Expose the medial malleolus by reflecting the periosteum, but preserve the deltoid ligament.
- Divide the flexor retinaculum and retract the flexor hallucis longus tendon and the neurovascular bundle posteriorly and laterally.
- Retract the tibial posterior and flexor digitorum longus tendons medially and anteriorly to expose the posterior tibial fracture (Fig. 1-40).

In addition to the approaches described, short medial, lateral, and dorsal approaches may be used to expose small areas of the tarsal and metatarsal joints. In all, the vessels, nerves, and tendons must be protected.

TIBIA

The tibia is a superficial bone that can be easily exposed anteriorly without damaging any important structure except the tendons of the anterior tibial and extensor hallucis longus muscles, which cross the tibia anteriorly in its lower fourth.

ANTERIOR APPROACH TO THE TIBIA

TECHNIQUE 1-27

- Make a longitudinal incision on either side of the anterior border of the bone.
- Reflect the skin and incise and elevate the periosteum over the desired area.
- Strip the periosteum as little as possible because its circulation is a source of nutrition for the bone.

MEDIAL APPROACH TO THE TIBIA

In some delayed unions and nonunions, Phemister inserted a bone graft in a bed prepared on the posterior surface of the tibia.

TECHNIQUE 1-28

(PHEMISTER)

- Make a longitudinal incision along the posteromedial border of the tibia.
- Incise the subcutaneous tissues and deep fascia and reflect the periosteum from the posterior surface for the required distance.

POSTEROLATERAL APPROACH TO THE TIBIAL SHAFT

The posterolateral approach is valuable in the middle two thirds of the tibia when the anterior and anteromedial aspects of the leg are badly scarred. It also is satisfactory for removing a portion of the fibula for transfer.

TECHNIQUE 1-29

(HARMON, MODIFIED)

- Position the patient prone or on the side, with the affected extremity uppermost.
- Make the skin incision the desired length along the lateral border of the gastrocnemius muscle on the posterolateral aspect of the leg (Fig. 1-41A).
- Develop the plane between the gastrocnemius, the soleus, and the flexor hallucis longus muscles posteriorly and the peroneal muscles anteriorly (Fig. 1-41B).
- Find the lateral border of the soleus muscle and retract it and the gastrocnemius muscle medially and posteriorly; arising from the posterior surface of the fibula is the flexor hallucis longus (Fig. 1-41C).
- Detach the distal part of the origin of the soleus muscle from the fibula and retract it posteriorly and medially (Fig. 1-41D).
- Continue the dissection medially across the interosseous membrane, detaching those fibers of the posterior tibial muscle arising from it (Fig. 1-41E). The posterior tibial artery and the tibial nerve are posterior and separated from the dissection by the posterior tibial and flexor hallucis longus muscles (Fig. 1-41F).
- Follow the interosseous membrane to the lateral border of the tibia and detach subperiosteally the muscles that arise from the posterior surface of the tibia (Fig. 1-41G and H).
- The posterior half of the fibula lies in the lateral part of the wound; its entire shaft can be explored. The flat posterior surface of the tibial shaft can be completely exposed except for its proximal fourth, which lies in close relation to the popliteus muscle and to the proximal parts of the posterior tibial vessels and the tibial nerve.
- When the operation is completed, release the tourniquet, secure hemostasis, and let the posterior muscle mass fall back into place.
- Loosely close the deep fascia on the lateral side of the leg with a few interrupted sutures.

TIBIAL PLATEAU APPROACHES

ANTEROLATERAL APPROACH TO THE LATERAL TIBIAL PLATEAU

The anterolateral approach is commonly used because most tibial plateau fractures involve the lateral tibial plateau.

TECHNIQUE 1-30

(KANDEMIR AND MACLEAN)

- Place the patient supine on a radiolucent table.
- Begin the incision 2 to 3 cm proximal to the joint line and extend it 3 cm below the inferior margin of the tibial tubercle crossing Gerdy's tubercle at the midpoint of the incision (Fig. 1-42).
- Detach the iliotibial band and develop the interval between it and the joint capsule.

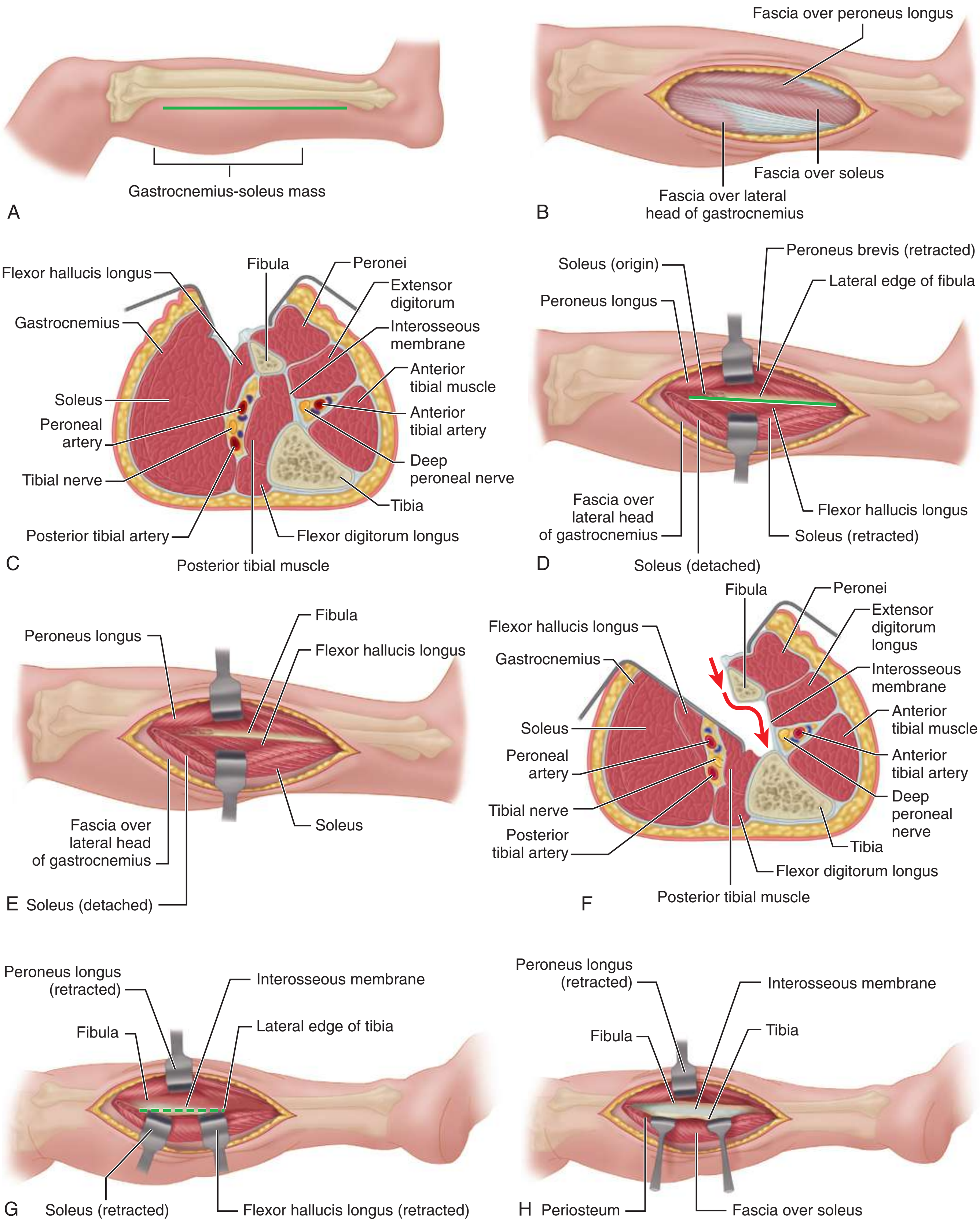


FIGURE 1-41 Posterolateral approach to tibia. **A,** Skin incision. **B,** Plane between gastrocnemius, soleus, and flexor hallucis longus posteriorly and peroneal muscles anteriorly is developed. **C,** Flexor hallucis longus arising from posterior surface of fibula. **D,** Distal part of origin of soleus is detached from fibula and retracted posteriorly and medially. **E,** Dissection medially across interosseous membrane, detaching fibers of posterior tibial muscle. **F,** Posterior tibial artery and tibial nerve are protected by posterior tibial and flexor hallucis longus muscles. **G** and **H,** Muscles are detached subperiosteally from posterior surface of tibia. (Modified from Hoppenfeld S, deBoer P: Surgical exposures in orthopaedics: the anatomic approach, Philadelphia, Lippincott Williams & Wilkins, 2003.) **SEE TECHNIQUE 1-29.**

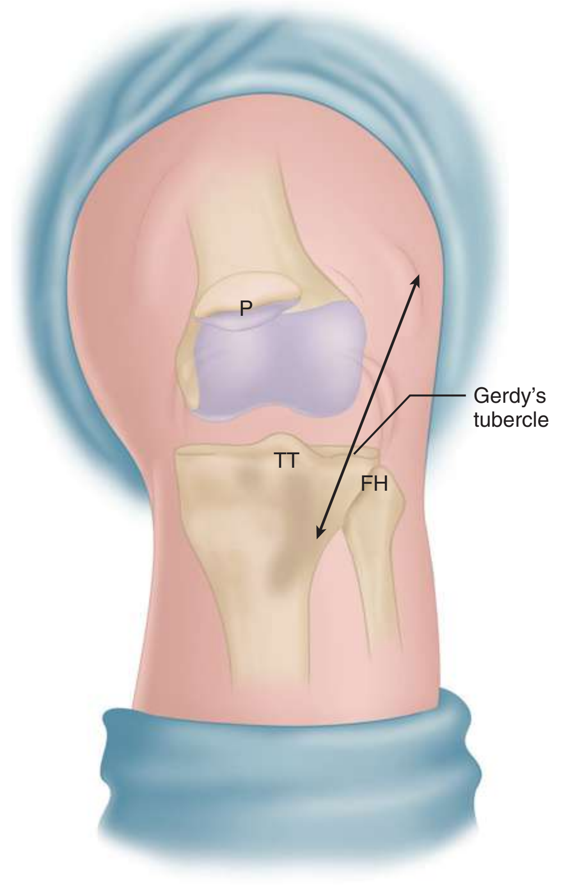


FIGURE 1-42 Anterolateral approach to the tibial plateau. Begin the incision 2-3 cm proximal to the joint line and carry it obliquely across Gerdy's tubercle aiming for a point 1 cm off the lateral aspect of the tibial tubercle. Extend it as far distally as needed. *FH,* Fibular head; *P,* patella; *TT,* tibial tubercle. **SEE TECHNIQUE 1-30.**

- Reflect the origin of the tibialis anterior muscle from the anterolateral tibia and reflect it posteriorly exposing the anterolateral surface of the tibial plateau.
- If direct exposure of the articular surface is necessary, perform a submeniscal arthrotomy incising the menisco-tibial ligaments. Leave the anterior horn of the meniscus intact.
- Place three or four sutures in the periphery of the meniscus to serve as retractors and for later repair. If a repairable vertical meniscal tear is present, pass the necessary number of sutures in a vertical fashion through the inner part of the meniscus for later attachment to the capsule.
- If a submeniscal arthrotomy is not planned, a hockey-stick skin incision can be used for minimally invasive procedures. Make the proximal limb of the incision parallel to the lateral joint line and cross Gerdy's tubercle.

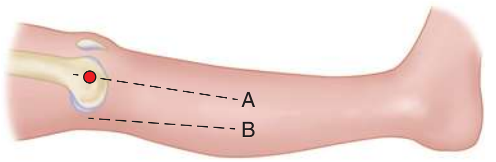


FIGURE 1-43 Medial and posteromedial approaches to the tibial plateau. *A,* Begin the skin incision for the medial approach 2 to 3 cm above the joint line at the medial epicondyle and extend it distally, bisecting the posteromedial border of the tibia and tibial crest. *B,* Begin the skin incision for the posteromedial approach 2 to 3 cm above the joint line and follow the posteromedial border of the tibia. **SEE TECHNIQUES 1-31 AND 1-32.**

MEDIAL APPROACH TO THE MEDIAL TIBIAL PLATEAU

This approach is useful for isolated medial plateau fractures and for medial half of bicondylar plateau fractures.

TECHNIQUE 1-31

- With the patient supine, make an incision 1 to 2 cm proximal to the joint line in line with the medial femoral epicondyle and extend it over the pes anserinus insertion (Fig. 1-43). Avoid the saphenous vein and nerve that usually are posterior.
- Take the pes anserinus tendons down sharply from the tibia, exposing the superficial and deep medial collateral ligaments (MCL).
- Indirectly reduce the fracture and apply a plate over the MCL.

POSTEROMEDIAL APPROACH TO THE MEDIAL TIBIAL PLATEAU

This approach is useful for shear fractures of the medial plateau. It can be performed with the patient supine or prone.

TECHNIQUE 1-32

(SUPINE)
- Externally rotate and slightly flex the knee.
- Make a longitudinal incision along the posteromedial aspect of the tibia, beginning 3 cm above the joint line and extend it as far distally as needed (Fig. 1-43B). Avoid the great saphenous vein and saphenous nerve anterior to the incision.
- Mobilize and retract the pes anserinus tendons proximally and anteriorly or distally and posteriorly.
- Retract the medial gastrocnemius and soleus muscles posteriorly, exposing the junction of popliteal fascia, the semimembranosus insertion, and the MCL.
- Incise the periosteum longitudinally and subperiosteally elevate the popliteus muscle insertion off the posterior tibia (Fig. 1-44).

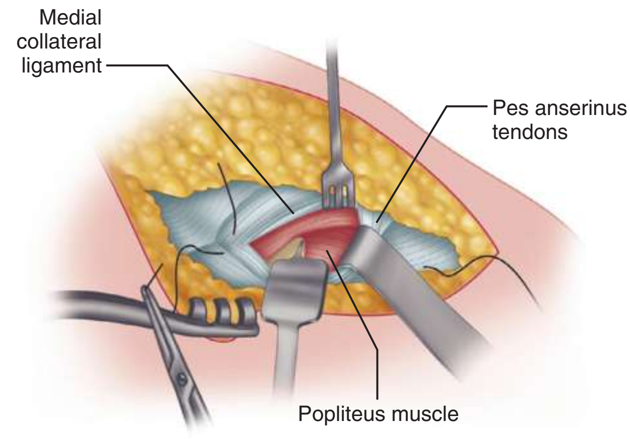


FIGURE 1-44 Posteromedial approach (supine). Retract the tendons of the pes anserinus distal and posterior. Incise the posterior edge of the medial collateral ligament and reflect the popliteus muscle insertion from the posterior border of the tibia. **SEE TECHNIQUE 1-32.**

POSTEROMEDIAL APPROACH (PRONE) TO THE SUPEROMEDIAL TIBIA

The posterior approach to the superomedial region of the tibia is useful for fixation of posteromedial split fractures of the tibial plateau.

TECHNIQUE 1-33

(BANKS AND LAUFMAN)

- With the patient positioned prone, begin the transverse segment of a hockey-stick incision (Fig. 1-45A) at the lateral end of the flexion crease of the knee, and extend it across the popliteal space. Turn the incision distally along the medial side of the calf for 7 to 10 cm.
- Develop the angular flap of skin and subcutaneous tissue and incise the deep fascia in line with the skin incision (Fig. 1-45B). Identify and protect the cutaneous nerves and superficial vessels.
- Define the interval between the tendon of the semitendinosus muscle and the medial head of the gastrocnemius muscle.
- Retract the semitendinosus proximally and medially and the gastrocsoleus component distally and laterally; the

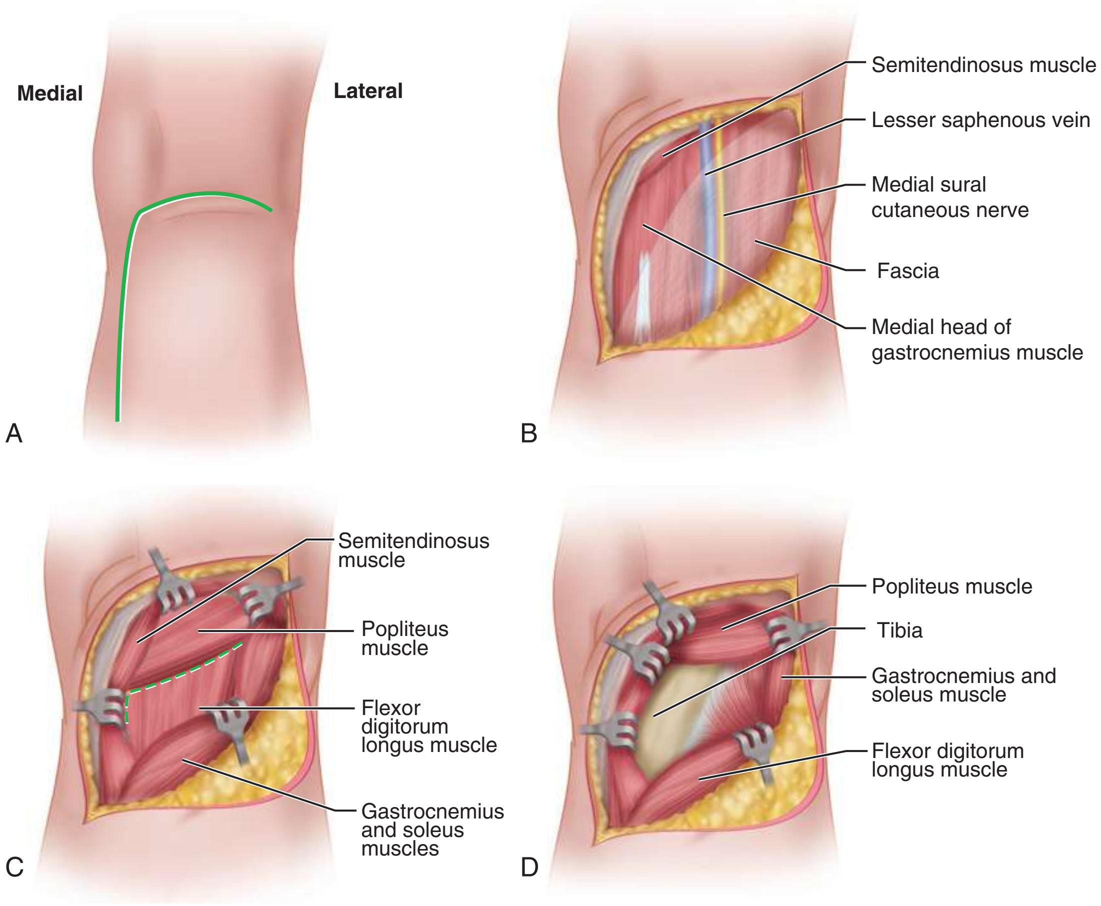


FIGURE 1-45 Banks and Laufman posterior approach to superomedial region of tibia. **A,** Incision extends transversely across popliteal fossa and then turns distally on medial side of calf. **B,** Skin and deep fascia have been incised and reflected. **C,** *Broken line* indicates incision to be made between popliteus and flexor digitorum longus. **D,** Popliteus and flexor digitorum longus have been elevated subperiosteally to expose tibia. **SEE TECHNIQUE 1-33.**

popliteus and flexor digitorum longus muscles lie in the floor of the interval (Fig. 1-45C).

- Elevate subperiosteally the flexor digitorum longus muscle distally and laterally and the popliteus muscle proximally and medially, and expose the posterior surface of the proximal fourth of the tibia (Fig. 1-45D). Further elevation of the popliteus will expose the posterior cruciate ligament fossa.
- If necessary, extend the incision distally along the medial side of the calf by continuing the dissection in the same intermuscular plane. The tibial nerve and posterior tibial artery lie beneath the soleus muscle.

POSTEROLATERAL APPROACH TO THE TIBIAL PLATEAU

This approach is useful for lateral and posterolateral plateau fractures. This approach with a fibular osteotomy is useful for fractures of the posterolateral plateau.

TECHNIQUE 1-34

(SOLOMON ET AL.)

- Position the patient supine with the knee extended. Make a 6-cm longitudinal incision anterior to the biceps femoris tendon contour on the fibular head. The incision can be extended distally as needed.
- Flex the knee to 60 degrees.
- Incise the subcutaneous fat in line with the skin incision, exposing the deep fascia.
- Incise the fascia lata over the biceps tendon and the common peroneal nerve. Identify the common peroneal nerve in the adipose tissue of the popliteal fossa (Fig. 1-46A).
- Knee flexion relaxes the common peroneal nerve. Expose the nerve down to the fibular head. Protect the sural nerve branch from the common peroneal nerve in the popliteal fossa.
- Transect the branch of the common peroneal nerve to the proximal tibiofibular joint.
- Release the common peroneal nerve from the posterior intermuscular septum posterior to the peroneus longus muscle as it enters the lateral compartment.
- Expose the deep peroneal nerve by detaching the peroneus longus and tibialis anterior muscles from the posterior and anterior aspects of the anterior intermuscular septum, respectively.
- Release the deep peroneal nerve as it enters the anterior compartment and goes through the anterior septum.
- Pre-drill the fibular head and neck just lateral to the biceps femoris insertion.

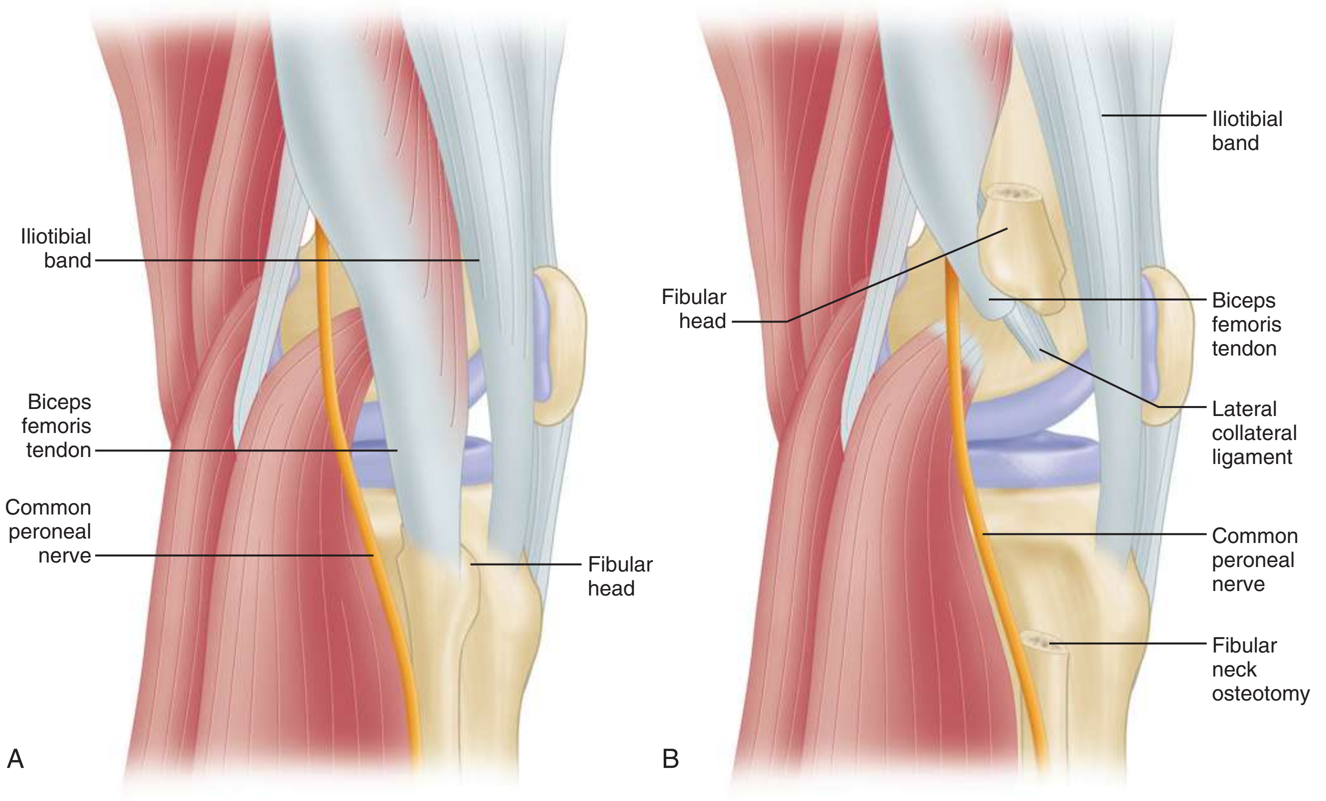


FIGURE 1-46 Posterolateral approach with osteotomy of the fibular neck. **A,** Superficial dissection of posterolateral corner. **B,** Osteotomy and reflection of fibular head proximally with attached biceps femoris tendon and lateral collateral ligament. Flex the knee to relax the common peroneal nerve, lateral head of gastrocnemius muscle, and popliteus muscle. Visualize the joint between to posterior cruciate ligament and posterior border of the iliotibial band. (Redrawn from Solomon LB, Stevenson AW, Baird RPV, Pohl AP. Posterolateral transfibular approach to tibial plateau fracture: technique, results, and rationale, J Orthop Trauma 24:505, 2010.) **SEE TECHNIQUE 1-34.**

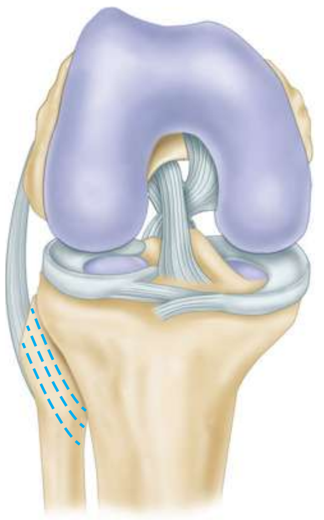


FIGURE 1-47 **Posterolateral approach with osteotomy of fibular head. Make the plane of the osteotomy parallel to fibular articular surface. Remove the entire fibular head if needed but leave the attachments of the fibular collateral ligament and biceps femoris intact.** (Redrawn from Yu B, Han K, Zhan C, et al: Fibular head osteotomy: a new approach for the treatment of lateral or posterolateral tibial plateau fractures. The Knee 17:313, 2010.) **SEE TECHNIQUE 1-34.**

- Osteotomize the fibular neck with an osteotome just above the peroneal nerve (Fig. 1-46B).
- Release the joint capsule from the proximal tibiofibular joint and reflect the fibular head proximally with attached biceps femoris tendon and lateral collateral ligament complex, exposing the postural corner of the knee joint.
- Mobilize the lateral meniscus by detaching the coronary ligament from the posterior cruciate ligament medially to the iliotibial band laterally, and elevate it to expose the tibial articular surfaces.
- At closure, repair the osteotomy with a longitudinal screw.
- Alternatively, the fibular head can be osteotomized in a longitudinal direction as described by Yu et al. One-third of the fibular head or the entire fibular head can be removed, depending on the exposure required (Fig. 1-47). The biceps femoris and lateral collateral ligament insertions are left intact.

POSTEROLATERAL APPROACH TO THE TIBIAL PLATEAU WITHOUT FIBULAR OSTEOTOMY

TECHNIQUE 1-35

(FROSCH ET AL.)

- Place the patient in the lateral decubitus position with the operative side up.
- Support the knee with a thick, rolled pillow.

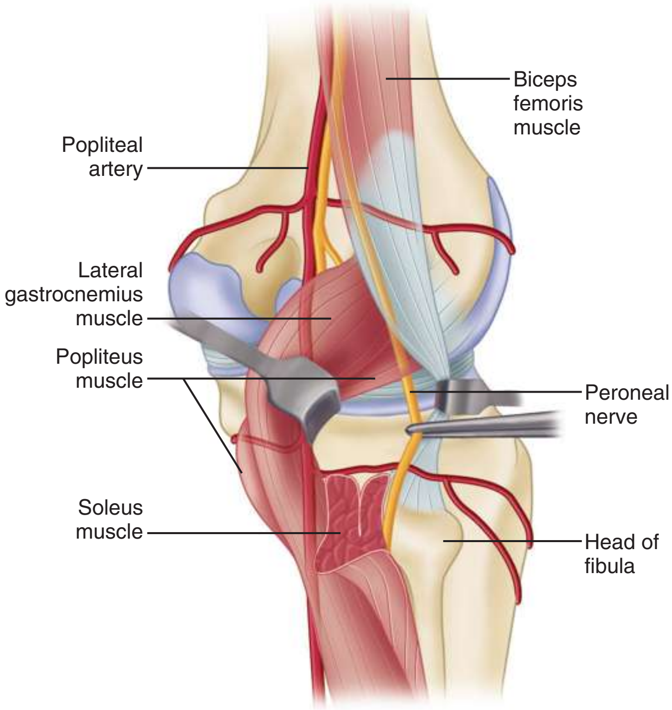


FIGURE 1-48 **Posterolateral corner of tibia. Develop the interval between the popliteus muscle and the biceps femoris muscle. Reflect the soleus muscle origin from the proximal tibia.** (Redrawn from Frosch KH, Balcarek P, Walde T, Stürmer KM: A new posterolateral approach without fibular osteotomy for the treatment of tibial plateau fractures, J Orthop Trauma 24:515, 2010.) **SEE TECHNIQUE 1-35.**

- Make a 15-cm posterolateral incision starting 3 cm above the joint line then following the fibula distally.
- Incise the posterior portion of the iliotibial band from Gerdy's tubercle and perform a lateral arthrotomy.
- Bluntly dissect into the popliteal fossa between the lateral origin of the gastrocnemius muscle and soleus muscle, exposing the popliteus muscle.
- Ligate the inferior geniculate vessels if necessary.
- Develop the interval between the biceps femoris muscle and the popliteus muscle (Fig. 1-48).
- Detach the soleus muscle from the posterior aspect of the fibula exposing the posterolateral plateau.

TSCHERNE-JOHNSON EXTENSILE APPROACH TO THE LATERAL TIBIAL PLATEAU

This approach is useful for depressed lateral plateau fractures.

TECHNIQUE 1-36

(JOHNSON ET AL.)

- Position the patient supine with a bump under the ipsilateral hip.

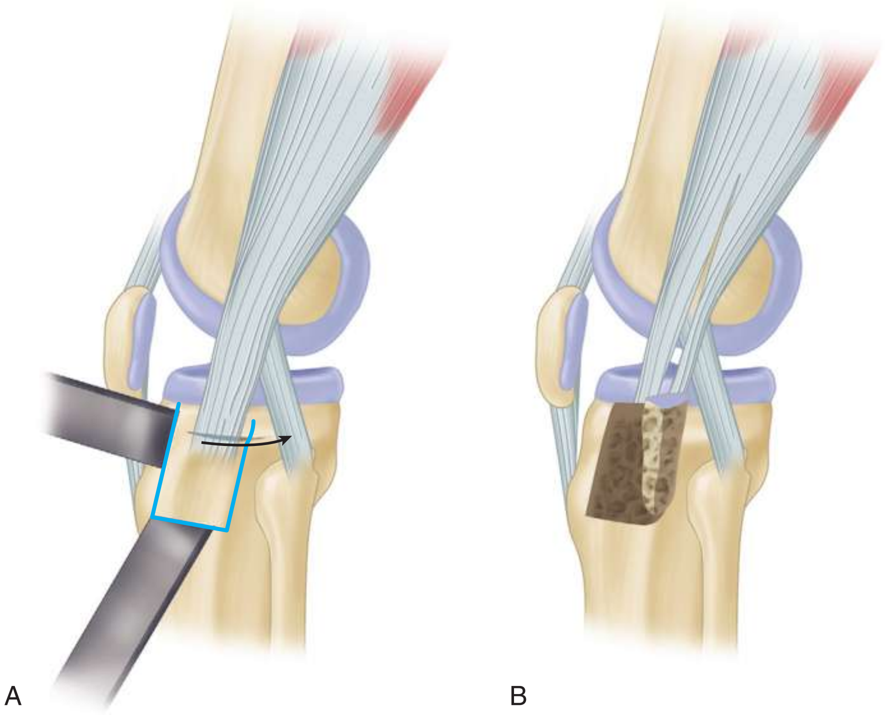


FIGURE 1-49 **Tscherne-Johnson extensile approach to the lateral tibial plateau. A, Elevate Gerdy's tubercle with two osteotomies with bone cuts 90 degrees to each other. Base it on a posterior hinge behind Gerdy's tubercle. B, Externally rotate the fragment leaving the posterior insertion of the iliotibial band attached.** (Redrawn from Johnson EE, Timon S: Tscherne-Johnson extensile approach for tibial plateau fractures. Clin Orthop Relat Res 471:2760, 2013.) **SEE TECHNIQUE 1-36.**

- Flex the knee over a large bump so that the leg will rest just off the edge of the table.
- Perform a lateral parapatellar incision from the supracondylar area of the distal femur to below and lateral to the tibial tubercle.
- Develop a lateral soft-tissue flap from the wound edge to the posterolateral corner of the tibial plateau.
- Identify Gerdy's tubercle and the anterior and posterior edges of the iliotibial band.
- Flex the knee to 40 degrees and incise the central portion of the iliotibial band distally from a point 4 cm above the joint line to the joint line and continue it anteriorly, dividing the anterior half of the band (Fig. 1-49A). Carry the incision anteriorly to the patellar tendon.
- Retract the anterior half of the iliotibial band exposing the lateral joint line.
- Incise the meniscal coronary ligament from posterior to anterior ending at the level of the patellar tendon.
- Place three 2-0 absorbable sutures in the meniscal edge and elevate it. The sutures will be used to later repair the meniscus to the lateral plateau rim.
- Incise the origin of the tibialis anterior muscle along the lateral tibial metaphyseal flair and elevate it distally.
- Perform two osteotomies anterior and distal to Gerdy's tubercle with a narrow osteotome (Fig. 1-49A).
- Rotate the Gerdy's tubercle fragment posteriorly on its posterior soft-tissue hinge to expose the undersurface of the lateral plateau (Fig. 1-49B)
- At closure, repair the osteotomy with an overlying plate and screws with one of the screws directly repairing the osteotomy.

FIBULA

POSTEROLATERAL APPROACH TO THE FIBULA

TECHNIQUE 1-37

(HENRY)

- Beginning 13 cm proximal to the lateral malleolus, incise the skin proximally along the posterior margin of the fibula to the posterior margin of the head of the bone and continue farther proximally for 10 cm along the posterior aspect of the biceps tendon.
- Divide the superficial and deep fasciae. Isolate the common peroneal nerve along the posteromedial aspect of the biceps tendon in the proximal part of the wound, and free it distally to its entrance into the peroneus longus muscle (Fig. 1-50).
- Pointing the knife blade proximally and anteriorly, detach the part of the peroneus longus muscle that arises from

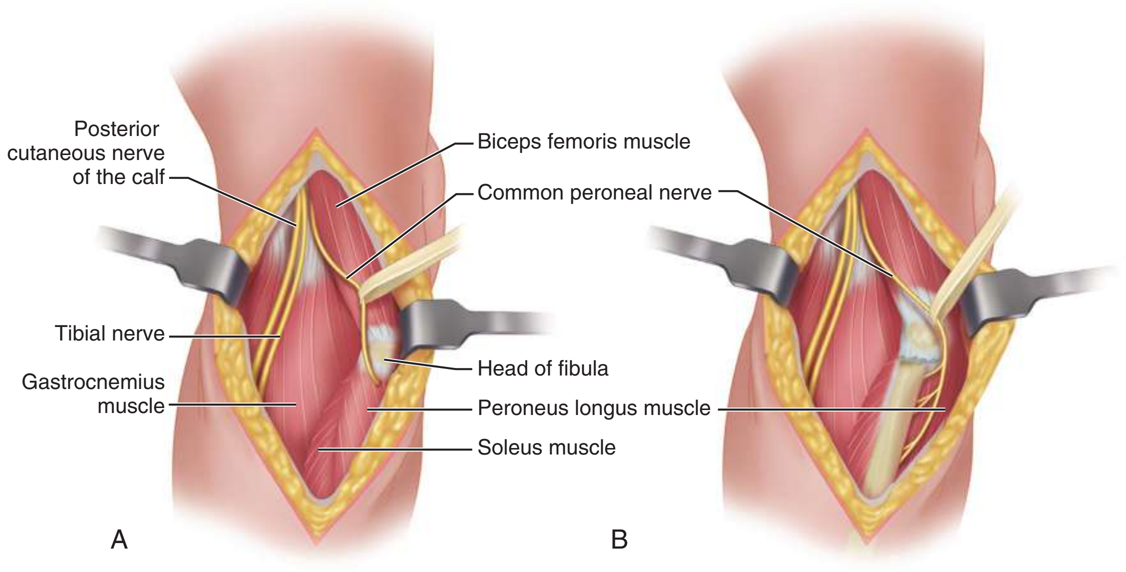


FIGURE 1-50 Method of mobilizing and retracting common peroneal nerve when approaching proximal fibula. **A,** Anatomic relationships. **B,** Part of peroneus longus that arises from lateral surface of fibular head proximal to common peroneal nerve has been detached, allowing nerve to be retracted over fibular head. **SEE TECHNIQUE 1-37.**

the lateral surface of the head of the fibula proximal to the common peroneal nerve. Retract the nerve over the head of the fibula.

- Locate the fascial plane between the soleus muscle posteriorly and the peroneal muscles anteriorly and deepen the dissection along the plane to the fibula.
- Expose the bone by retracting the peroneal muscles anteriorly and incising the periosteum. When retracting these muscles, avoid injuring the branches of the deep peroneal nerve that lie on their deep surfaces and are in close contact with the neck of the fibula and proximal 5 cm of the shaft.
- The distal fourth of the fibula is subcutaneous on its lateral aspect and may be exposed by a longitudinal incision through the skin, fascia, and periosteum.

KNEE

ANTEROMEDIAL AND ANTEROLATERAL APPROACHES

ANTEROMEDIAL PARAPATELLAR APPROACH

When any anteromedial approach is made, including one for meniscectomy, the infrapatellar branch of the saphenous nerve should be protected (Fig. 1-51). The saphenous nerve courses posterior to the sartorius muscle and then pierces the fascia lata between the tendons of the sartorius and gracilis muscles and becomes subcutaneous on the medial aspect of the leg; on the medial aspect of the knee it gives off a large infrapatellar branch to supply the skin over the anteromedial aspect of the knee. Several variations exist in the location and distribution of this infrapatellar branch. Consequently, no single incision on the anteromedial aspect of the knee can avoid it for certain. The nerve should be located and protected if possible.

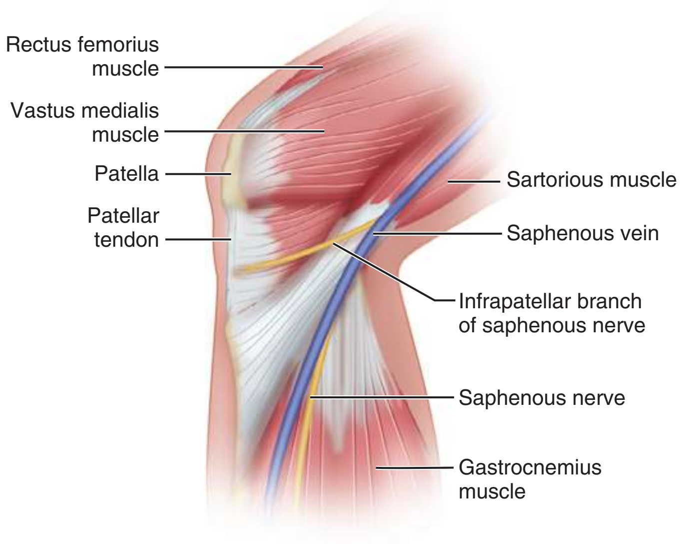


FIGURE 1-51 Anatomic relationships of superficial structures on medial aspect of knee. **SEE TECHNIQUE 1-38.**

TECHNIQUE 1-38 *Figure 1-52*

(VON LANGENBECK)

- Begin the incision at the medial border of the quadriceps tendon 7 to 10 cm proximal to the patella, curve it around the medial border of the patella and back toward the midline, and end it at or distal to the tibial tuberosity. As a more cosmetically pleasing alternative, a longitudinal

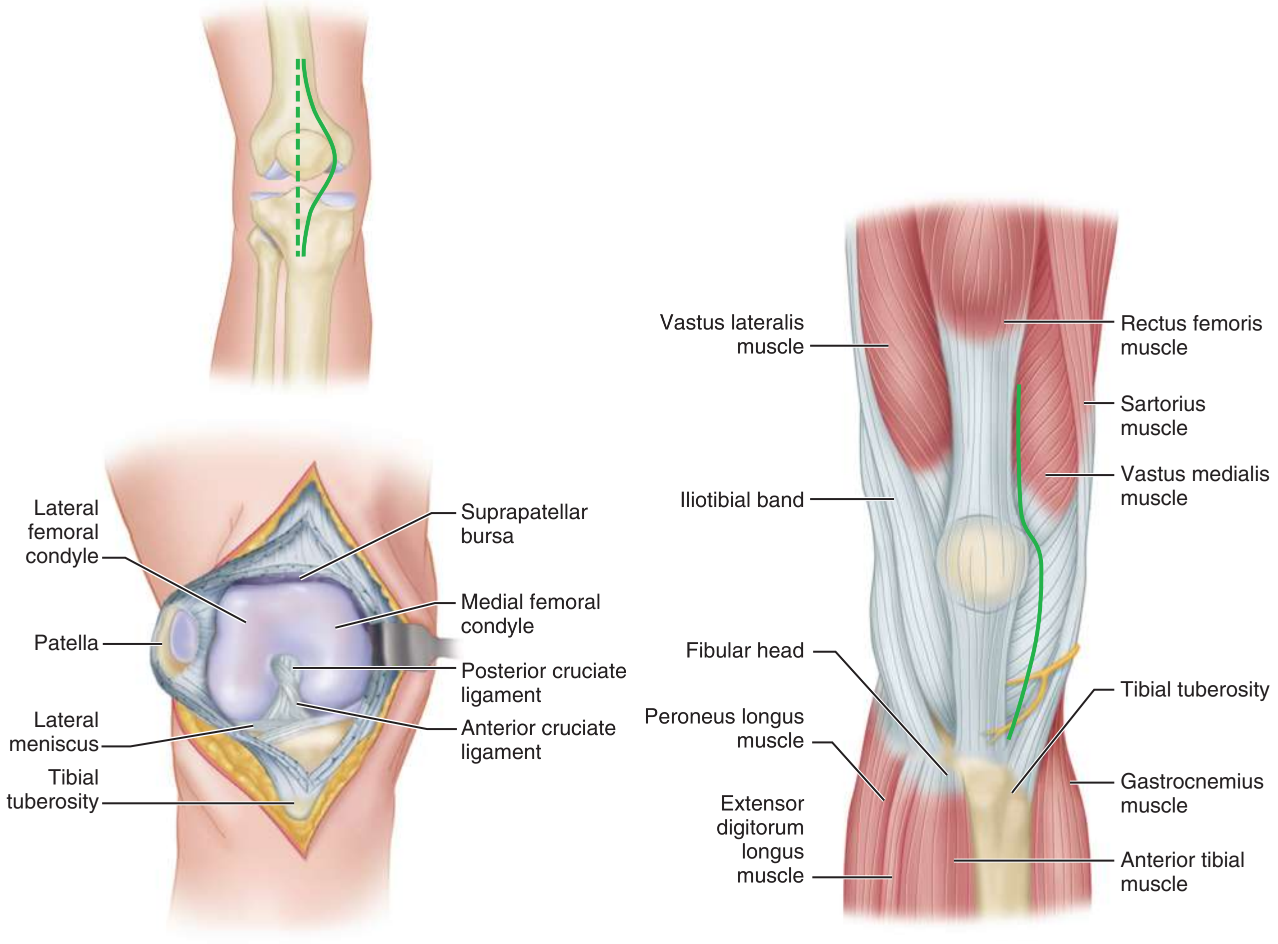


FIGURE 1-52 Anteromedial approach to knee joint. **SEE TECHNIQUE 1-38.**

incision centered over the patella can be made, reflecting the subcutaneous tissue and superficial fascia over the patella medially by blunt dissection to the medial border of the patella.

- Divide and retract the fascia.
- Deepen the dissection between the vastus medialis muscle and the medial border of the quadriceps tendon and incise the capsule and synovium along this medial border and along the medial border of the patella and patellar tendon.
- Retract the patella laterally and flex the knee to gain a good view of the anterior compartment of the joint and the suprapatellar bursa. Divide the ligamentum mucosa if necessary (see Fig. 1-56).
- Attain wider access to the joint in the following ways: (1) extending the incision proximally, (2) extending the proximal part of the incision obliquely medially and separating the fibers of the vastus medialis, (3) dividing the medial alar fold and adjacent fat pad longitudinally, and (4) mobilizing the medial part of the insertion of the patellar tendon subperiosteally.
- If contracture of the quadriceps prevents sufficient exposure, detach the tibial tuberosity and reattach later with a screw. Fernandez described an extensive osteotomy of the tibial tuberosity (see Fig. 1-64) and reattachment of the tuberosity with three lag screws engaging the posterior tibial cortex. This technique achieves rigid fixation and allows early postoperative rehabilitation.

SUBVASTUS (SOUTHERN) ANTEROMEDIAL APPROACH TO THE KNEE

Problems with patellar dislocation, subluxation, and osteonecrosis after total knee arthroplasty performed through an anteromedial parapatellar approach led to the rediscovery of the subvastus, or southern, anteromedial approach first described by Erkes in 1929. According to Hofmann et al., this approach preserves the vascularity of the patella by sparing the intramuscular articular branch of the descending genicular artery and preserves the quadriceps tendon, providing more stability to the patellofemoral joint in total knee arthroplasty. This approach also is useful for lesser anteromedial and medial knee procedures. The relative contraindications to this approach are previous major knee arthroplasty and weight greater than 200 lb, which makes eversion of the patella difficult. In a retrospective study of 143 knees in 96 patients, In et al. found that in patients with a thigh girth of larger than 55 cm the patella could not be everted when using a subvastus approach for total knee arthroplasty.

TECHNIQUE 1-39

(ERKES, AS DESCRIBED BY HOFMANN, PLASTER, AND MURDOCK)

- Exsanguinate the limb and inflate the tourniquet with the knee flexed to at least 90 degrees to prevent tenodesis of the extensor mechanism.
- Make a straight anterior skin incision, beginning 8 cm above the patella, carrying it distally just medial and 2 cm distal to the tibial tubercle.
- Incise the superficial fascia slightly medial to the patella (Fig. 1-53A) and bluntly dissect it off the vastus medialis muscle fascia down to the muscle insertion (Fig. 1-53B).
- Identify the inferior edge of the vastus medialis and bluntly dissect it off the periosteum and intermuscular septum for a distance of 10 cm proximal to the adductor tubercle.
- Identify the tendinous insertion of the muscle on the medial patellar retinaculum (Fig. 1-53C) and lift the vastus medialis muscle anteriorly and perform an L-shaped arthrotomy beginning medially through the vastus insertion on the medial patellar retinaculum and carrying it along the medial edge of the patella.
- Partially release the medial edge of the patellar tendon and evert the patella laterally with the knee extended (Fig. 1-53D).

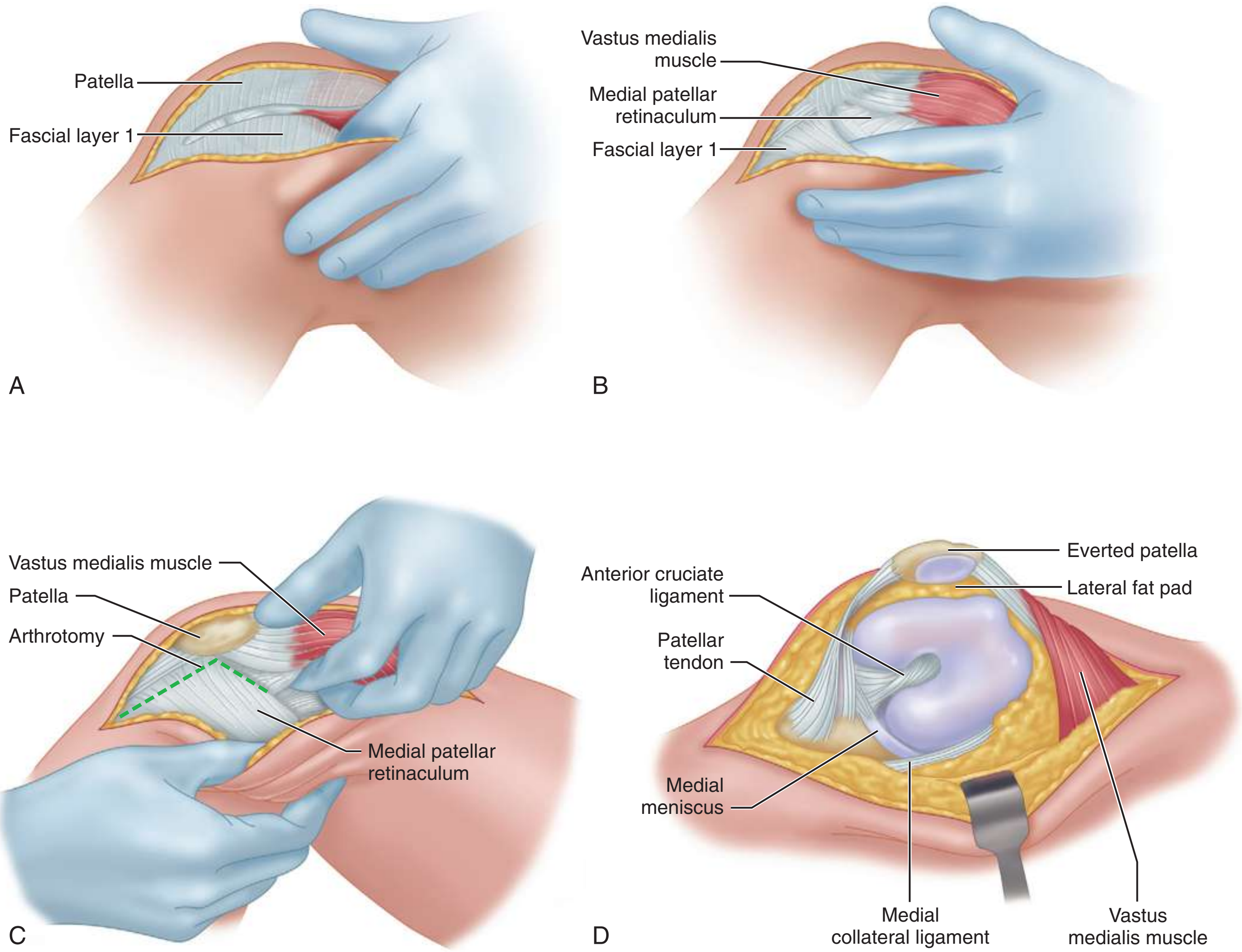


FIGURE 1-53 Subvastus anteromedial approach. **A,** Superficial fascia is incised medial to patella. **B,** Superficial fascia is bluntly elevated from perimuscular fascia of vastus medialis down to its insertion on medial patellar retinaculum. **C,** Tendinous insertion elevated by blunt dissection. *Dashed line* indicates arthrotomy. **D,** Patella is everted, and knee is flexed. **SEE TECHNIQUE 1-39.**

ANTEROLATERAL APPROACH TO THE KNEE

Usually the anterolateral approach is not as satisfactory as the anteromedial one, primarily because it is more difficult to displace the patella medially than laterally. It also requires a longer incision, and often the patellar tendon must be partially freed subperiosteally or subcortically. The iliotibial band can be released or lengthened, and the tight posterolateral corner can be released easily. The fibular head can be resected through the same incision to decompress the peroneal nerve if necessary.

TECHNIQUE 1-40

Figure 1-54

(KOCHER)

- Begin the incision 7.5 cm proximal to the patella at the insertion of the vastus lateralis muscle into the quadriceps tendon; continue it distally along the lateral border of this tendon, the patella, and the patellar tendon; and end it 2.5 cm distal to the tibial tuberosity.
- Deepen the dissection through the joint capsule.
- Retract the patella medially, with the tendons attached to it, and expose the articular surface of the joint.

Satish et al. found the modified Keblish approach useful in total knee arthroplasty in patients with fixed valgus knees. The approach relies on a quadriceps snip and coronal Z-plasty of lateral retinacular capsule complex. The lateral retinacular complex is separated into two layers, deep (capsule and synovium) and superficial. The lateral parapatellar arthrotomy is performed 3 to 7 cm lateral to the patella and the deep and superficial layers are separated with dissection carried medially toward the patella. The superficial layer is kept attached to the patella, and the deep layer remains attached to the iliotibial band. At closure, the layers are approximated in an expanded fashion (Fig. 1-55).

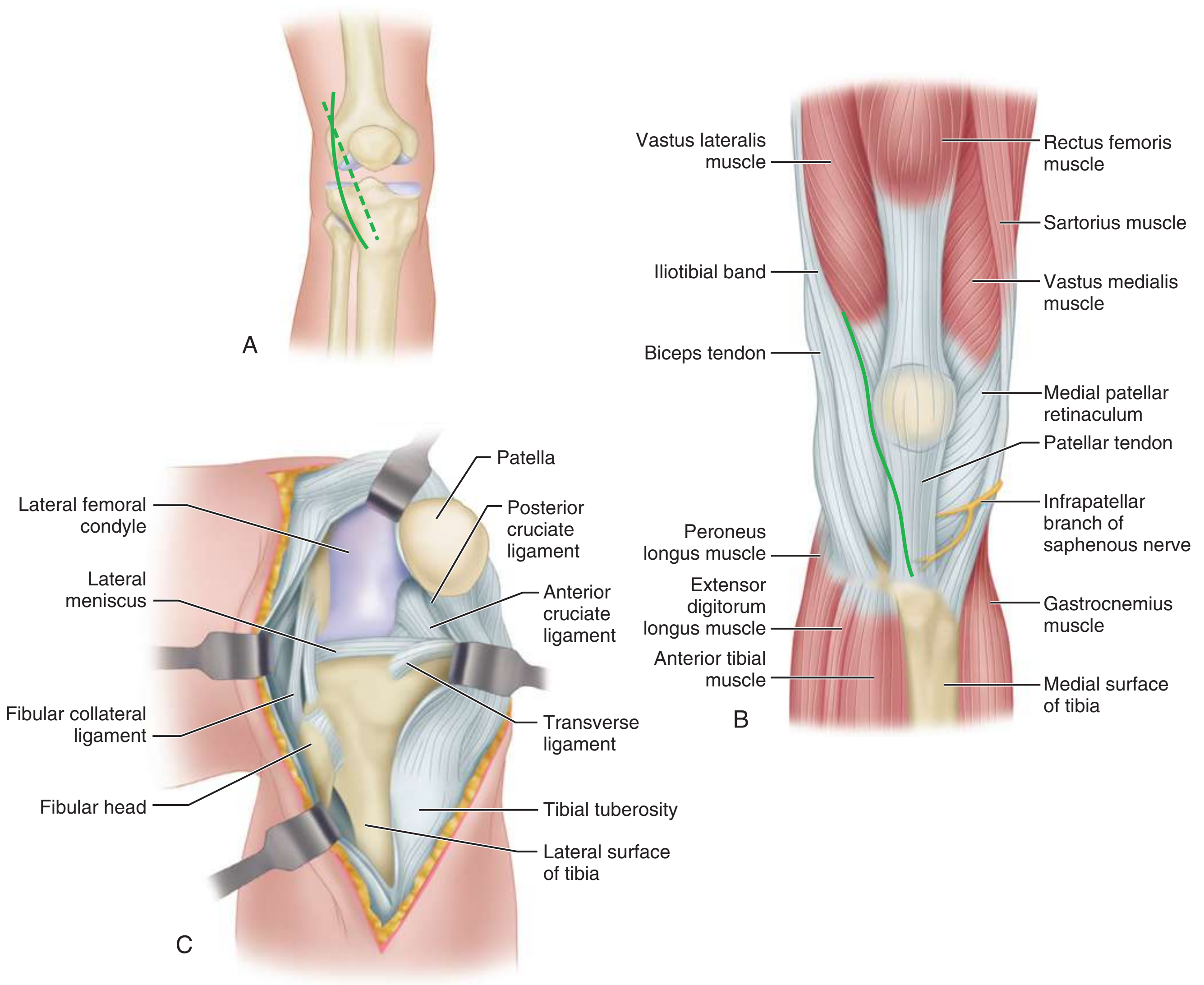


FIGURE 1-54 **A-C,** Kocher anterolateral approach to knee joint. **SEE TECHNIQUE 1-40.**

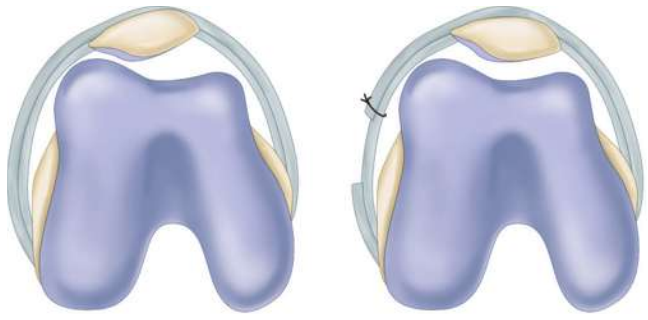


FIGURE 1-55 **Coronal Z-plasty of lateral retinaculum capsule complex.** (Redrawn from Satish BRJ, Ganesan JC, Chandran P, et al: Efficacy and mid-term results of lateral parapatellar approach without tibial tubercle osteotomy for primary total knee arthroplasty in fixed valgus knees, J Arthroplasty 28:1751, 2013.)

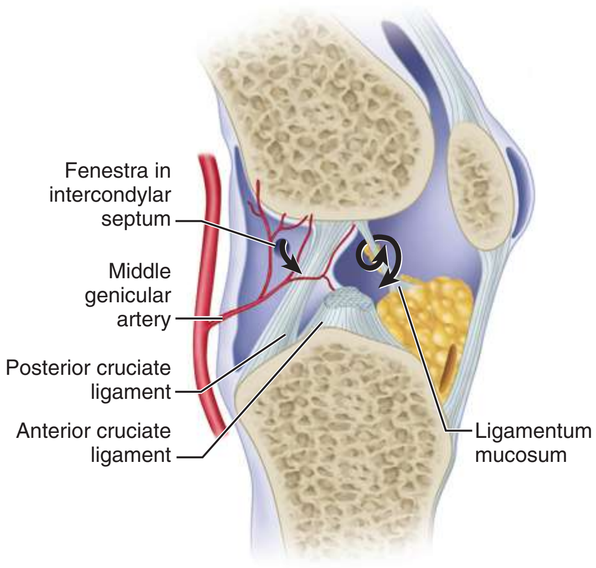


FIGURE 1-56 Median septum separating two posterior compartments of knee. Note fenestra at proximal pole. Synovial septum invests cruciate ligaments and contains branch of middle genicular artery. **SEE TECHNIQUE 1-38.**

POSTEROLATERAL AND POSTEROMEDIAL APPROACHES TO THE KNEE

In some patients, a median septum separates the posterior aspect of the knee into two compartments. The posterior cruciate ligament is extrasynovial and projects anteriorly in the septum; it contributes to the partition between the two posterior compartments. The middle genicular artery courses anteriorly in the septum to nourish the tissues of the intercondylar notch of the femur (Fig. 1-56). The presence of this septum may assume great importance when exploring the posterior aspect of the knee for a loose body or when draining the joint in the rare instances in which pyogenic arthritis of the knee requires posterior drainage. In the latter, both posterior compartments must be opened for drainage, not one alone (see Chapter 22).

POSTEROLATERAL APPROACH TO THE KNEE

TECHNIQUE 1-41 *Figure 1-57*

(HENDERSON)

- With the knee flexed between 60 and 90 degrees, make a curved incision on the lateral side of the knee, just anterior to the biceps femoris tendon and the head of the fibula, and avoid the common peroneal nerve, which passes over the lateral aspect of the neck of the fibula.
- In the proximal part of the incision, trace the anterior surface of the lateral intermuscular septum to the linea aspera 5 cm proximal to the lateral femoral condyle.
- Expose the lateral femoral condyle and the origin of the fibular collateral ligament.
- The tendon of the popliteus muscle lies between the biceps tendon and the fibular collateral ligament; mobilize and retract it posteriorly, and expose the posterolateral aspect of the joint capsule.
- Make a longitudinal incision through the capsule and synovium of the posterior compartment. To see the insertion of the muscle fibers of the short head of the biceps muscle onto the long head of the biceps, develop the interval between the lateral head of the quadriceps muscle and the long head of the biceps tendon. To isolate the common peroneal nerve, dissect directly posterior to the long head of the biceps. These intervals are useful in repair of the posterolateral corner of the knee.

Bowers and Huffman found the Hughston and Jacobson technique for exposure of the posterolateral corner by wafer osteotomy of the lateral collateral ligament insertion on the lateral femoral epicondyle with reflection of the ligament distally useful. Alternatively, if a fracture of the lateral femoral condyle needs to be treated, an osteotomy of Gerdy's tubercle can be performed with reflection of the iliotibial band proximally as described by Liebergall et al.

POSTEROMEDIAL APPROACH TO THE KNEE

TECHNIQUE 1-42 *Figure 1-58*

(HENDERSON)

- With the knee flexed 90 degrees, make a curved incision, slightly convex anteriorly and approximately 7.5 cm long, distally from the adductor tubercle and along the course of the tibial collateral ligament, anterior to the relaxed tendons of the semimembranosus, semitendinosus, sartorius, and gracilis muscles.
- Expose and incise the oblique part of the tibial collateral ligament and incise the capsule longitudinally and enter the posteromedial compartment of the knee posterior to the tibial collateral ligament, retracting the hamstring tendons posteriorly.

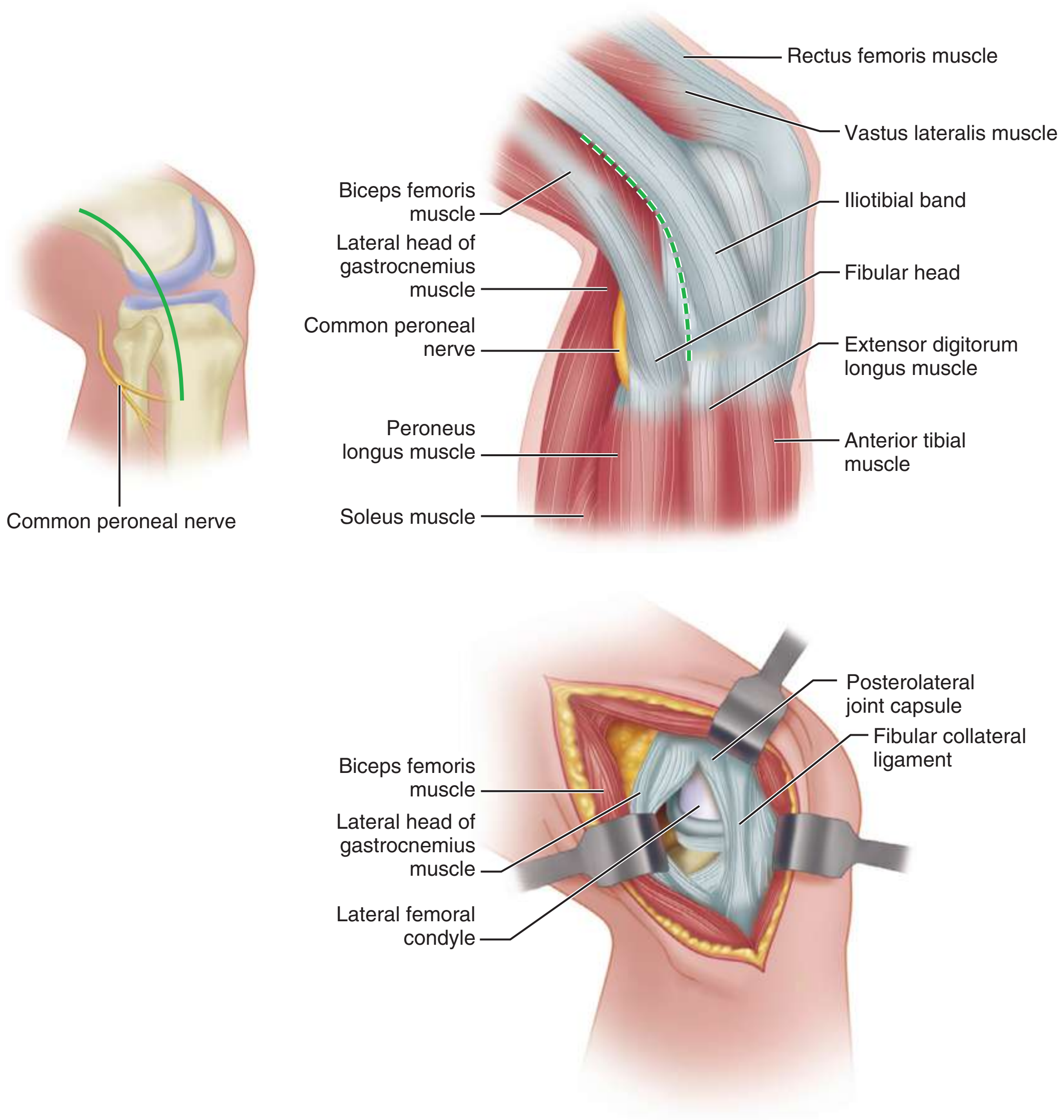


FIGURE 1-57 Henderson posterolateral approach to knee joint. **SEE TECHNIQUE 1-41.**

MEDIAL APPROACHES TO THE KNEE AND SUPPORTING STRUCTURES

Usually the entire medial meniscus can be excised through a medial parapatellar incision about 5 cm long. If the posterior horn of the meniscus cannot be excised through this incision, a separate posteromedial Henderson approach can be made (Fig. 1-58). The anterior and posterior compartments may be entered, however, through an approach in which only one incision is made through the skin but two incisions are used through the deeper structures; this type of approach is rarely indicated.

MEDIAL APPROACH TO THE KNEE

The Cave approach is a curved incision that allows exposure of the anterior and posterior compartments.

TECHNIQUE 1-43

(CAVE)

- With the knee flexed at a right angle, identify the medial femoral epicondyle and begin the incision 1 cm posterior to and on a level with it approximately 1 cm proximal to the joint line. Carry the incision distally and anteriorly to a point 0.5 cm distal to the joint line and anterior to the border of the patellar tendon.
- After reflecting the subcutaneous tissues, expose the anterior compartment through an incision that begins anterior to the tibial collateral ligament, continues distally and anteriorly in a curve similar to that of the skin incision, and ends just distal to the joint line (Fig. 1-59).
- To expose the posterior compartment, make a second deep incision posterior to the tibial collateral ligament,

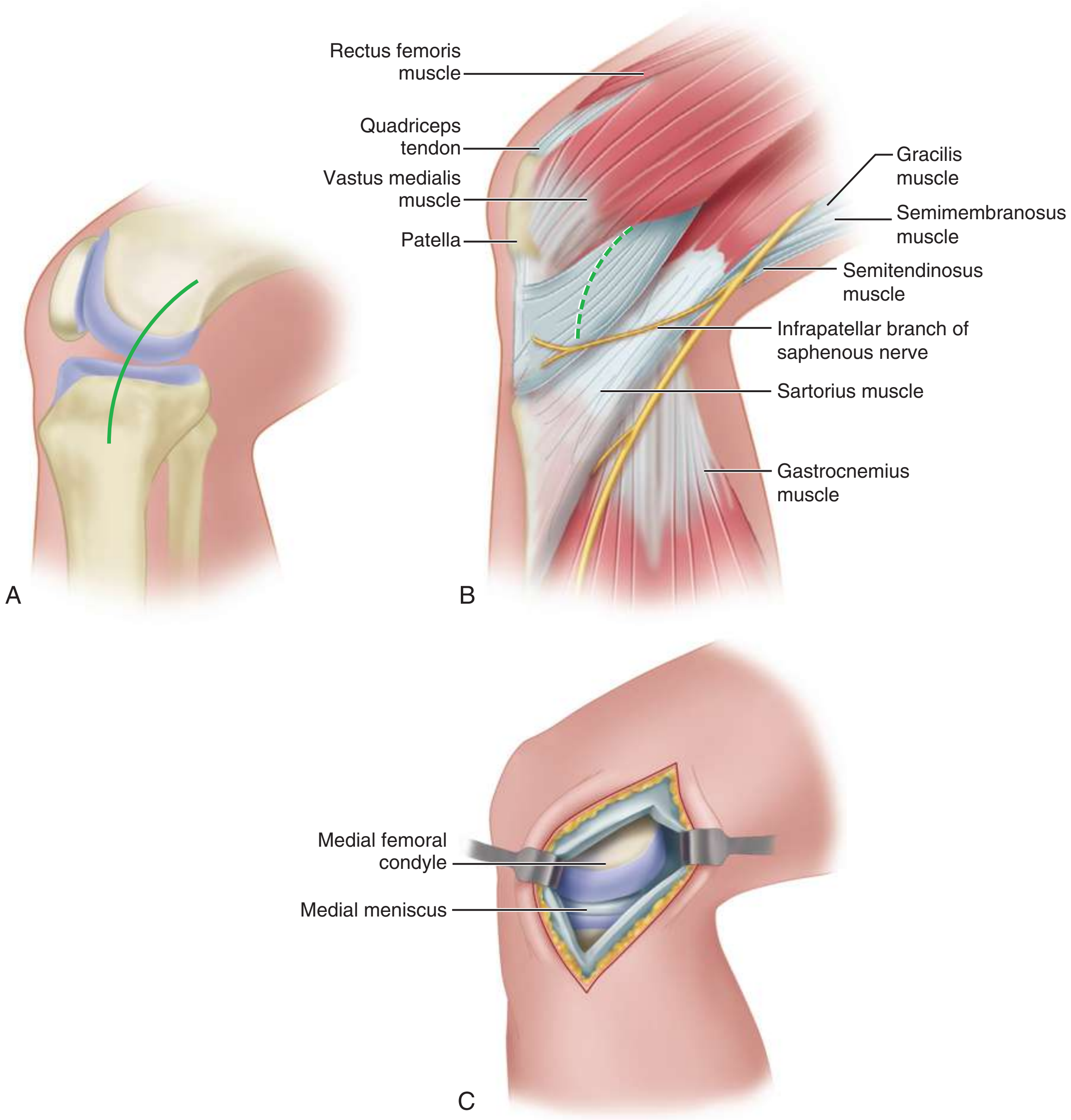


FIGURE 1-58 **A-C,** Henderson posteromedial approach to knee joint. **SEE TECHNIQUE 1-42.**

from the level of the femoral epicondyle straight distally across the joint line.

MEDIAL APPROACH TO THE KNEE

TECHNIQUE 1-44

(HOPPENFELD AND DEBOER)

- With the patient supine and the affected knee flexed about 60 degrees, place the foot on the opposite shin and abduct and externally rotate the hip.
- Begin the incision 2 cm proximal to the adductor tubercle of the femur, curve it anteroinferiorly about 3 cm medial to the medial border of the patella, and end it 6 cm distal to the joint line on the anteromedial aspect of the tibia (Fig. 1-60A).
- Retract the skin flaps to expose the fascia of the knee and extend the exposure from the midline anteriorly to the posteromedial corner of the knee (Fig. 1-60B).
- Cut the infrapatellar branch of the saphenous nerve and bury its end in fat; preserve the saphenous nerve itself and the long saphenous vein.
- Longitudinally incise the fascia along the anterior border of the sartorius, starting at the tibial attachment of the muscle and extending it to 5 cm proximal to the joint line.

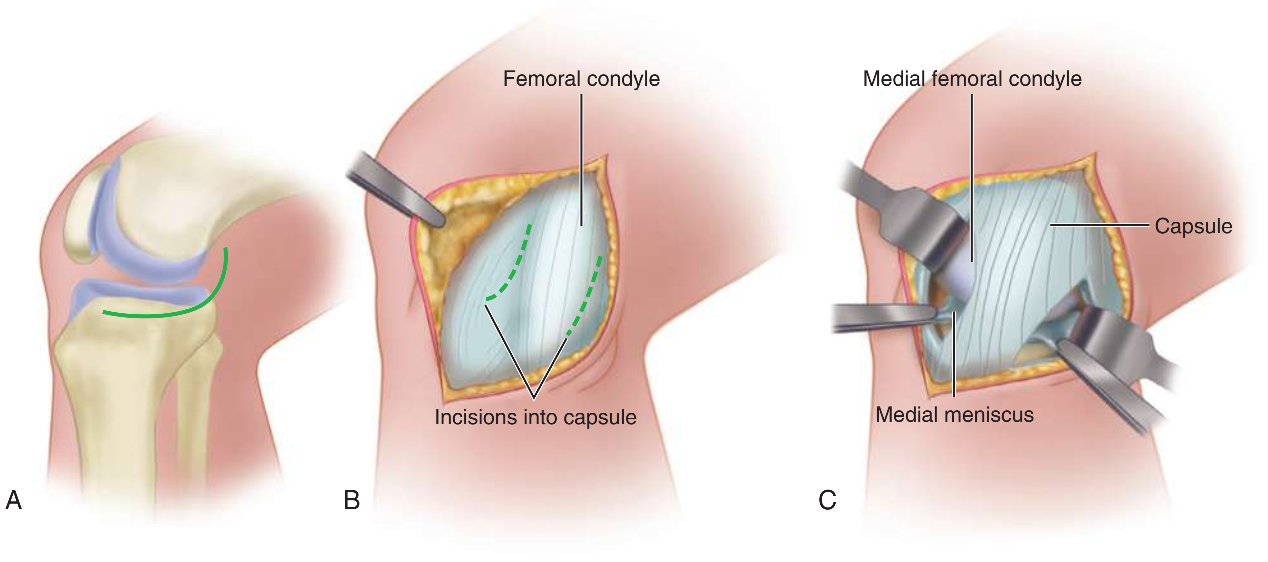


FIGURE 1-59 Exposure of anterior and posterior compartments of knee joint through one skin incision, according to Cave. **A,** Single skin incision. **B,** Two incisions through deep structures. **C,** Removal of meniscus. **SEE TECHNIQUE 1-43.**

- Flex the knee further and allow the sartorius to retract posteriorly, exposing the semitendinosus and gracilis muscles (Fig. 1-60C).
- Retract all three components of the pes anserinus posteriorly and expose the tibial attachment of the tibial collateral ligament, which inserts 6 to 7 cm distal to the joint line (Fig. 1-60D).
- To open the joint anteriorly, make a longitudinal medial parapatellar incision through the retinaculum and synovium (Fig. 1-60E).
- To expose the posterior third of the medial meniscus and the posteromedial corner of the knee, retract the three components of the pes anserinus posteriorly (Fig. 1-60F) and separate the medial head of the gastrocnemius muscle from the posterior capsule of the knee almost to the midline by blunt dissection (Fig. 1-60G).
- To open the joint posteriorly, make an incision through the capsule posterior to the tibial collateral ligament.

TRANSVERSE APPROACH TO THE MENISCUS

Using a transverse approach to the medial meniscus has the advantage that the scar has no contact with the femoral articular surface.

TECHNIQUE 1-45

- Make a transverse incision 5 cm long at the level of the articular surface of the tibia, extending laterally from the medial border of the patellar tendon to the anterior border of the tibial collateral ligament (Fig. 1-61).
- Incise the capsule along the same line and dissect the proximal edge of the divided capsule from the underlying synovium and retract it proximally.
- Open the synovium along the proximal border of the medial meniscus. Charnley advised making a preliminary 1.5-cm opening into the small synovial sac beneath the meniscus, introducing a blunt hook into it, and turning the hook so that its end rests on the proximal surface of the meniscus. By cutting down on the point of the hook, one can make the synovial incision at the most distal level.
- Divide the anterior attachment of the meniscus, retract the tibial collateral ligament, and complete the excision of the meniscus in the usual way (see Chapter 45).
- When closing the incision, place the first suture in the synovium at the medial side near the collateral ligament while the knee is still flexed; if the joint is extended before the first suture is inserted, the posterior part of the synovial incision retracts under the tibial collateral ligament. To complete the suture line, extend the joint.
- The transverse incision is not satisfactory for removing the lateral meniscus because it would require partial division of the iliotibial band. To avoid this, make an oblique incision 7.5 cm long centered over the joint line (Fig. 1-62).
- In the capsule, make a hockey-stick incision that runs transversely along the joint line and curves obliquely proximally along the anterior border of the iliotibial band for a short distance.
- Undermine and retract the capsule and incise the synovial membrane transversely as previously described.

LATERAL APPROACHES TO THE KNEE AND SUPPORTING STRUCTURES

Lateral approaches permit good exposure for complete excision of the lateral meniscus. They do not require division or release of the fibular collateral ligament.

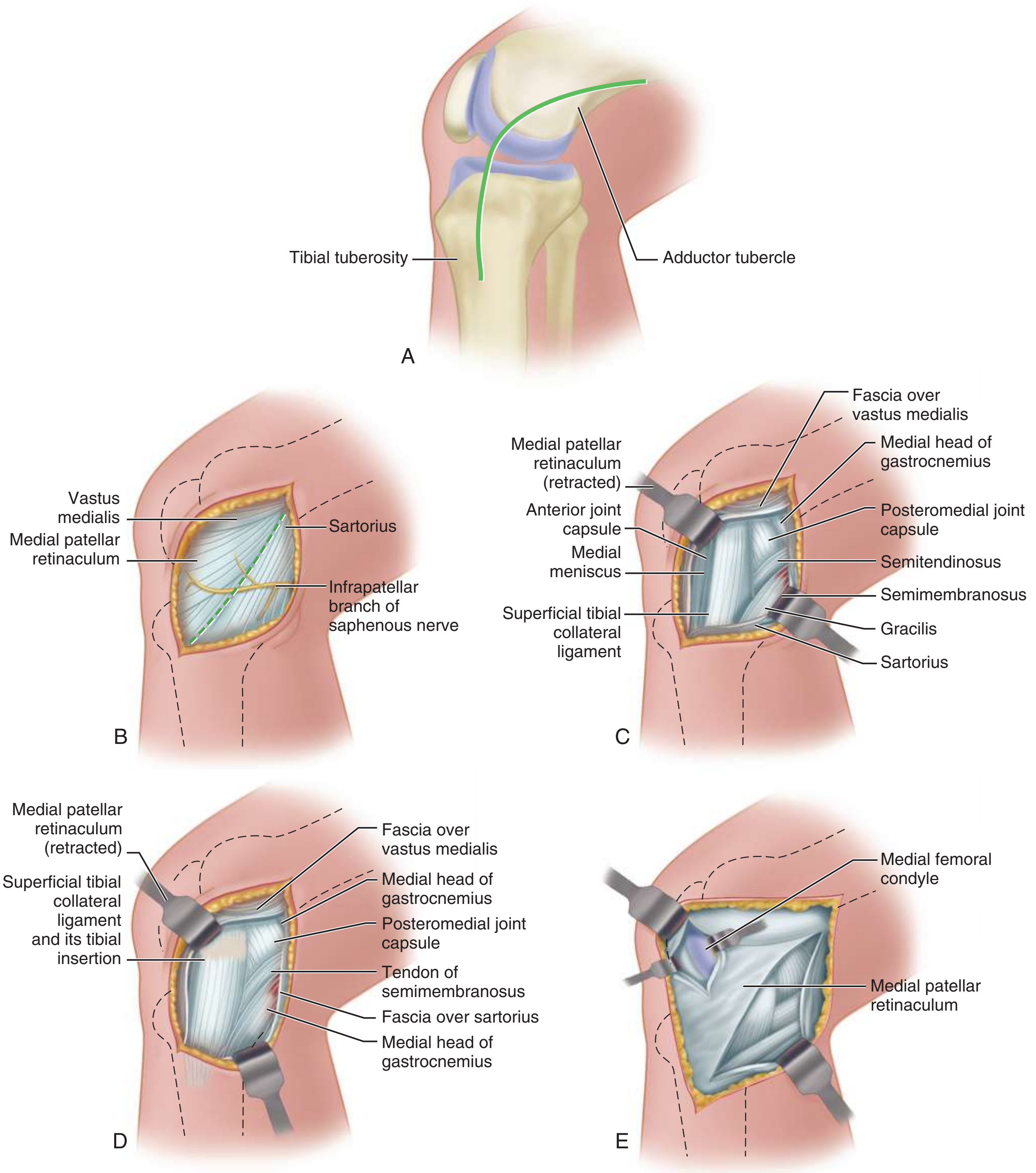


FIGURE 1-60 Medial approach to knee and supporting structures. **A,** Skin incision. **B,** Skin flaps have been retracted. **C,** Sartorius has been retracted posteriorly, exposing semitendinosus and gracilis. **D,** All three components of pes anserinus have been retracted posteriorly to expose tibial attachment of tibial collateral ligament. **E,** Medial parapatellar incision has been made through retinaculum and synovium.

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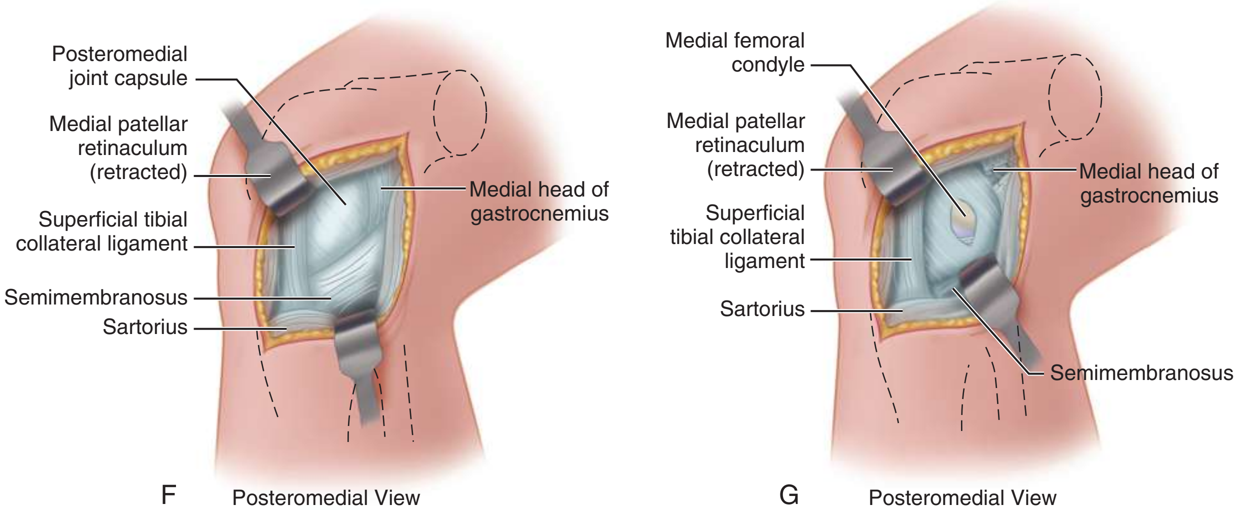

FIGURE 1-60, cont'd F, Three components of pes anserinus have been retracted posteriorly to expose posteromedial corner. G, Medial head of gastrocnemius has been separated from posterior capsule of knee and has been retracted. Capsulotomy is made posterior to tibial collateral ligament. (Modified from Hoppenfeld S, deBoer P: Surgical exposures in orthopaedics: the anatomic approach, Philadelphia, Lippincott Williams & Wilkins, 2003.) **SEE TECHNIQUE 1-44.**

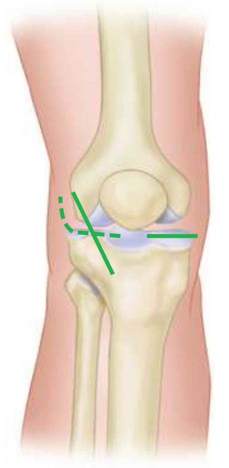

FIGURE 1-61 Transverse approaches to menisci. Medial meniscus is approached through transverse incisions in skin and capsule; lateral meniscus is approached through oblique incision in skin and hockey-stick incision in capsule. **SEE TECHNIQUE 1-45.**

LATERAL APPROACH TO THE KNEE

TECHNIQUE 1-46

(BRUSER)

- Place the patient supine and drape the limb to permit full flexion of the knee. Flex the knee fully so that the foot rests flat on the operating table.
- Begin the incision anteriorly where the patellar tendon crosses the lateral joint line, continue it posteriorly along the joint line, and end it at an imaginary line extending from the proximal end of the fibula to the lateral femoral condyle (Fig. 1-62A).
- Incise the subcutaneous tissue and expose the iliotibial band, whose fibers are parallel with the skin incision when the knee is fully flexed (Fig. 1-62B). Split the band in line with its fibers. Posteriorly, take care to avoid injuring the relaxed fibular collateral ligament; it is protected by areolar tissue, which separates it from the iliotibial band.
- Retract the margins of the iliotibial band; this is possible to achieve without much force because the band is relaxed when the knee and hip are flexed.
- Locate the lateral inferior genicular artery, which lies outside the synovium between the collateral ligament and the posterolateral aspect of the meniscus.
- Incise the synovium. The lateral meniscus lies in the depth of the incision and can be excised completely (Fig. 1-62C).
- With the knee flexed 90 degrees, close the synovium (Fig. 1-62D); and with the knee extended, close the deep fascia.

LATERAL APPROACH TO THE KNEE

Brown et al. have developed an approach for lateral meniscectomy in which the knee is flexed to allow important structures to fall posteriorly as in the Bruser approach. In addition, a varus strain is created to open the lateral joint space.

TECHNIQUE 1-47

(BROWN ET AL.)

- Place the patient supine with the extremity straight and with a small sandbag under the ipsilateral hip.

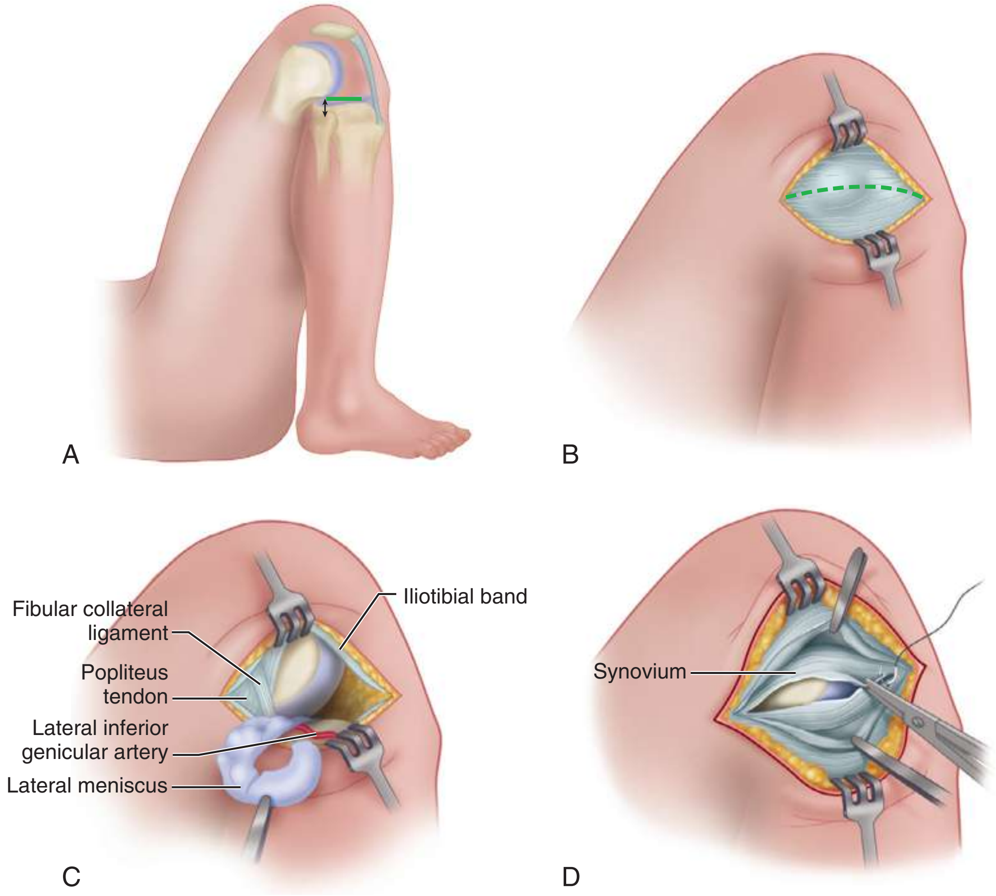

FIGURE 1-62 Bruser lateral approach to knee. **A,** Skin incision (see text). **B,** *Broken line* indicates proposed incision in iliotibial band, whose fibers, when knee is fully flexed, are parallel with skin incision. **C,** Knee has been extended slightly, and lateral meniscus is being excised. **D,** Lateral meniscus has been excised, and synovium is being closed. (Modified from Bruser DM: A direct lateral approach to the lateral compartment of the knee joint, J Bone Joint Surg 42B:348, 1960.) **SEE TECHNIQUES 1-45 AND 1-46.**

- Make a vertical, oblique, or transverse skin incision on the anterolateral aspect of the knee.
- Identify the anterior border of the iliotibial band and make an incision in the fascia 0.5 to 1 cm anterior to the band in line with its fibers.
- Incise the synovium in line with this incision and inspect the joint.
- By sharp dissection, free the anterior horn of the meniscus.
- Flex the knee, cross the foot over the opposite knee, and push firmly toward the opposite hip, applying a varus force to the knee. Ensure the thigh on the involved side is in line with the sagittal plane of the trunk; the hip is flexed about 45 degrees and externally rotated about 40 degrees. Push, as described, until the joint space opens up 3 to 5 mm. If necessary, internally rotate the tibia to bring the lateral tibial plateau into better view; however, this tends to close the joint space.
- With proper retractors, expose the entire meniscus, which can be excised completely by sharp dissection.

LATERAL APPROACH TO THE KNEE

TECHNIQUE 1-48

(HOPPENFELD AND DEBOER)

- Place the patient supine with a sandbag beneath the ipsilateral buttock and flex the knee 90 degrees.
- Begin the incision 3 cm lateral to the middle of the patella, extend it distally over the Gerdy tubercle on the tibia, and end it 4 to 5 cm distal to the joint line. Complete the incision proximally by curving it along the line of the femur (Fig. 1-63A).
- Widely mobilize the skin flaps anteriorly and posteriorly.
- Incise the fascia between the iliotibial band and biceps femoris, carefully avoiding the common peroneal nerve on the posterior aspect of the biceps tendon (Fig. 1-63B).
- Retract the iliotibial band anteriorly and the biceps femoris and common peroneal nerve posteriorly to expose the

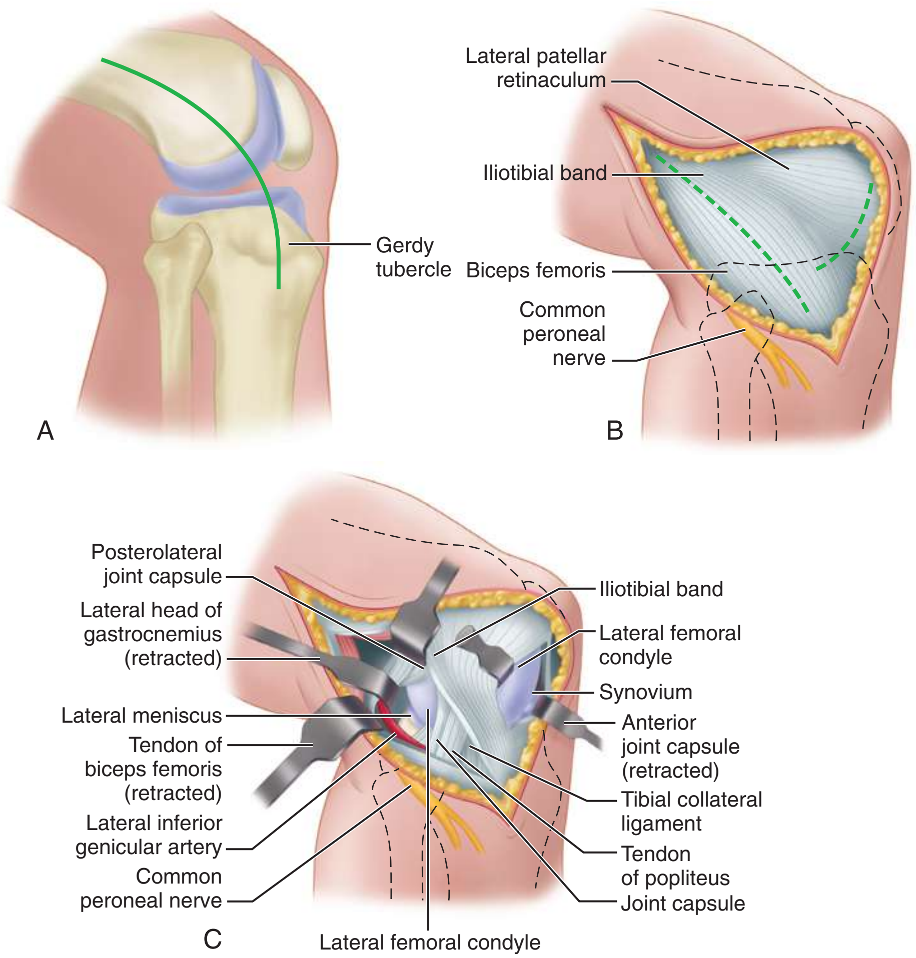

FIGURE 1-63 **Lateral approach to knee and supporting structures. A,** Skin incision. **B,** Incision between biceps femoris and iliotibial band. **C,** Deep dissection (see text). (Modified from Hoppenfeld S, deBoer P: Surgical exposures in orthopaedics: the anatomic approach, Philadelphia, Lippincott Williams & Wilkins, 2003.) **SEE TECHNIQUE 1-48.**

fibular collateral ligament and the posterolateral corner of the knee capsule (Fig. 1-63C).

- To expose the lateral meniscus, make a separate lateral parapatellar incision through the fascia and joint capsule (Fig. 1-63B).
- To avoid cutting the meniscus, begin the arthrotomy 2 cm proximal to the joint line.
- To expose the posterior horn of the lateral meniscus, locate the origin of the lateral head of the gastrocnemius muscle on the posterior surface of the lateral femoral condyle.
- Dissect between it and the posterolateral corner of the joint capsule; ligate or cauterize the lateral superior genicular arterial branches located in this area.
- Make a longitudinal incision in the capsule, beginning well proximal to the joint line to avoid damaging the meniscus or the popliteus tendon. Inspect the posterior half of the lateral compartment posterior to the fibular collateral ligament (see Fig. 1-63C).

EXTENSILE APPROACH TO THE KNEE

Fernandez described an extensile anterior approach to the knee based on an anterolateral approach that allows easy access to the medial and lateral compartments in the following ways: (1) by an extensive osteotomy of the tibial tuberosity that allows proximal reflection of the patella, patellar tendon, and retropatellar fat pad and (2) by transecting the anterior horn and anterior portion of the coronary ligament of the medial meniscus or the lateral meniscus or both as necessary to achieve adequate exposure. This approach may be used for tumor resection, ligament reconstruction, fracture reduction and fixation, and adult reconstructive procedures. Part or all of this approach may be used as necessary to achieve the required exposure. Rigid screw fixation of the tibial tuberosity engaging the posterior cortex of the tibia allows early postoperative knee motion.

Perry et al. first reported transection of the anterior horn of the lateral meniscus to aid exposure of lateral tibial plateau fractures. Alternatively, the articular surface of either tibial plateau can be approached with a submeniscal exposure by releasing the peripheral attachment of the meniscus at the coronary ligament and by elevating the meniscus, as described by Gossling and Peterson.

TECHNIQUE 1-49

(FERNANDEZ)

- Place the patient supine and drape the limb to allow at least 60 degrees of knee flexion.
- Begin a lateral parapatellar incision 10 cm proximal to the lateral joint line; continue it distally along the lateral border of the patella, patellar tendon, and tibial tuberosity; and end it 15 cm distal to the lateral joint line (Fig. 1-64A).
- Develop skin flaps deep in the subcutaneous tissue, extending medially to the anterior edge of the tibial collateral ligament and laterally, exposing the iliotibial band and the proximal origins of the anterior tibial and peroneal muscles (Fig. 1-64B).
- To expose the lateral tibial metaphysis, detach the anterior tibial muscle and retract it distally, and elevate the iliotibial band by dividing it transversely at the joint line or by performing a flat osteotomy of the Gerdy tubercle (Fig. 1-64C). If exposure of the posteromedial portion of the tibial metaphysis is necessary, divide the tibial insertion of the pes anserinus or elevate it as an osteoperiosteal flap.
- Fernandez advocates an extended osteotomy into the tibial crest in the presence of a bicondylar tibial plateau fracture to ensure that the osteotomy fragment is securely fixed into the tibial diaphysis below the level of the fracture. A less extensive osteotomy may be used as appropriate.
- Perform an extended trapezoidal osteotomy of the tibial tuberosity as follows:
  1. Mark with an osteotome a site 5 cm in length, 2 cm in width proximally, and 1.5 cm in width distally.
  2. Drill three holes for later reattachment of the tibial tuberosity.
  3. Complete the osteotomy with a flat osteotome.
- Elevate the tibial tuberosity and patellar tendon and incise the joint capsule transversely, medially, and laterally at the joint line.
- Carry each limb of the capsular incision proximally to the level of the anterior border of the vastus medialis and vastus lateralis (Fig. 1-64C and D).
- If further exposure of the articular surface of the tibial plateaus is needed, detach one or both menisci by transection of the anterior horn, cutting the transverse ligament and dividing the anterior portion of the coronary ligament. The meniscus may be elevated and held with a stay suture (Fig. 1-64E).
- At wound closure, repair the anterior meniscus, coronary ligament, and transverse ligament with 2-0 nonabsorbable sutures. Use square stitches to repair the meniscus and two or three U-shaped stitches to stabilize the periphery of the meniscus.
- Tie the stitches over the joint capsule after closure of the medial and lateral arthrotomies (Fig. 1-64F).
- Reattach the anterior tibial muscle and pes anserinus to bone with interrupted sutures.
- Reattach Gerdy's tubercle with a lag screw.
- Rigidly fix the tibial tuberosity osteotomy with lag screws obtaining good purchase in the posterior cortex of the tibia.
- Close the arthrotomy with interrupted sutures (Fig. 1-64G).

DIRECT POSTERIOR, POSTEROMEDIAL, AND POSTEROLATERAL APPROACHES TO THE KNEE

The posterior midline approach involves structures that, if damaged, can produce a permanent, serious disability. Thorough knowledge of the anatomy of the popliteal space is essential. Figure 1-65 shows the relationship of the flexion crease to the joint line, and Figure 1-66 shows the collateral circulation around the knee posteriorly. The approach provides access to the posterior capsule of the knee joint, the posterior part of the menisci, the posterior compartments of the knee, the posterior aspect of the femoral and tibial condyles, and the origin of the posterior cruciate ligament. All posterior approaches are done with the patient supine.

DIRECT POSTERIOR APPROACH TO THE KNEE

TECHNIQUE 1-50

(BRACKETT AND OSGOOD; PUTTI; ABBOTT AND CARPENTER)

- Make a curvilinear incision 10 to 15 cm long over the popliteal space (Fig. 1-67A), with the proximal limb following the tendon of the semitendinosus muscle distally to the level of the joint. Curve it laterally across the posterior aspect of the joint for about 5 cm and distally over the lateral head of the gastrocnemius muscle.
- Reflect the skin and subcutaneous tissues to expose the popliteal fascia.
- Identify the posterior cutaneous nerve of the calf (the medial sural cutaneous nerve) lying beneath the fascia and between the two heads of the gastrocnemius muscle because it is the clue to the dissection. Lateral to it, the short saphenous vein perforates the popliteal fascia to join the popliteal vein at the middle of the fossa. Trace the posterior cutaneous nerve of the calf (the medial sural cutaneous nerve) proximally to its origin from the tibial nerve because the contents of the fossa can be dissected accurately and safely once this nerve is located. Trace the tibial nerve distally and expose its branches to the heads of the gastrocnemius, the plantaris, and the soleus muscles; these branches are accompanied by arteries and veins. Follow the tibial nerve proximally to the apex of the fossa where it joins the common peroneal nerve (Fig. 1-67B). Dissect the common peroneal nerve distally along the medial border of the biceps muscle and tendon, and protect the lateral cutaneous nerve of the calf and the anastomotic peroneal nerve.

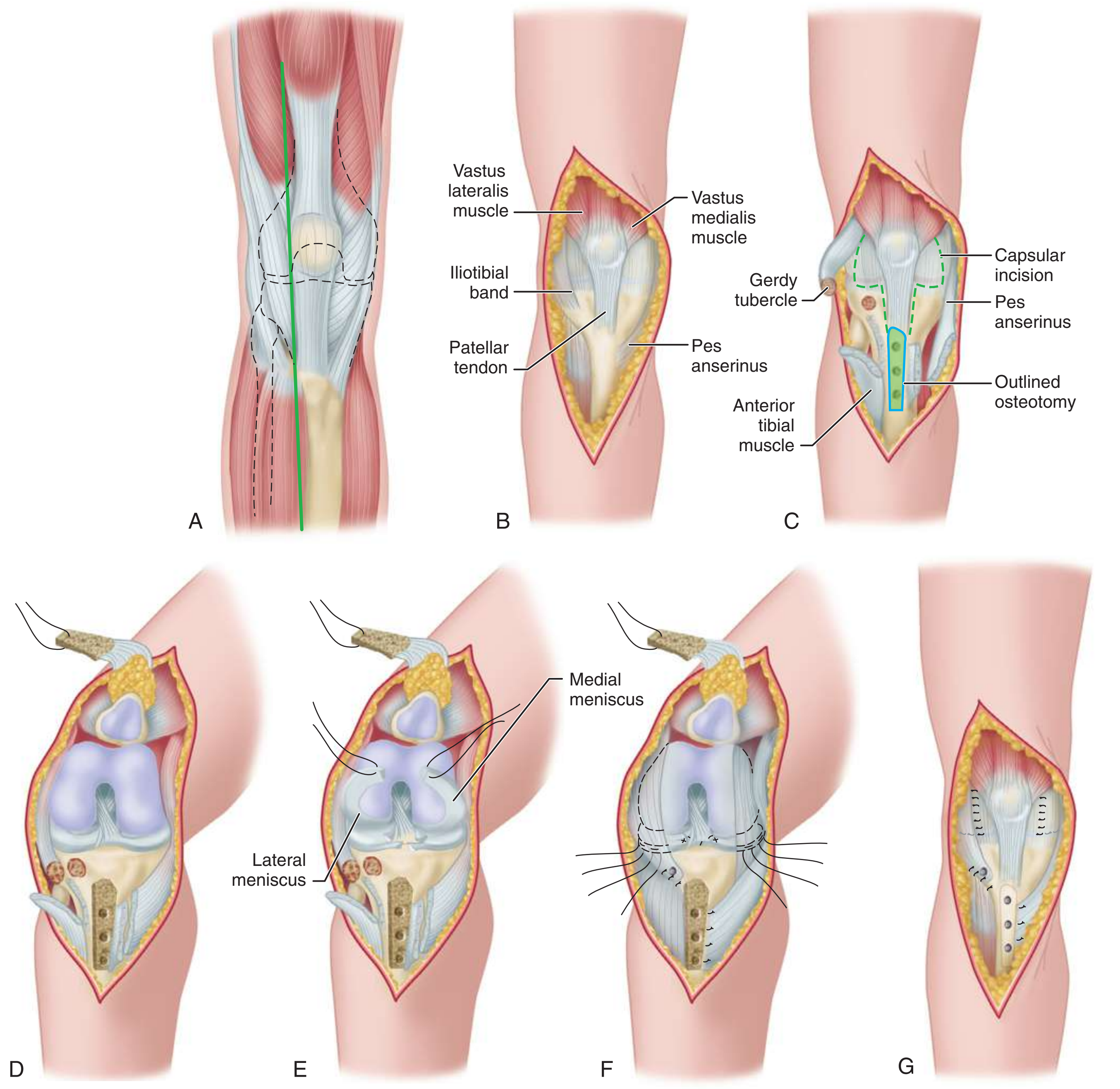

FIGURE 1-64 Fernandez extensile anterior approach. **A,** Anterolateral incision. **B,** Extensor mechanism exposed. **C,** Iliotibial band is reflected with Gerdy tubercle. Anterior compartment and pes anserinus are detached and elevated as necessary. Osteotomy of tibial tuberosity is outlined, and screw holes are predrilled (see text). **D,** Patella, patellar tendon, and tibial tuberosity are elevated. **E,** Medial and lateral menisci are detached anteriorly and peripherally and are elevated. **F,** Meniscal repair is performed with 2-0 nonabsorbable sutures (see text). Gerdy tubercle is reattached with lag screw. Anterior tibial and pes anserinus are reattached. **G,** Tibial tuberosity is secured with lag screws engaging posterior cortex of tibia. Capsule is closed with interrupted sutures. Sutures in periphery of menisci are now tied (see text). (Modified from Fernandez DL: Anterior approach to the knee with osteotomy of the tibial tubercle for bicondylar tibial fractures, J Bone Joint Surg 70A:208, 1988.) **SEE TECHNIQUE 1-49.**

- Expose the popliteal artery and vein, which lie directly anterior and medial to the tibial nerve. Gently retract the artery and vein and locate and trace the superolateral and superomedial genicular vessels passing beneath the hamstring muscles on either side just proximal to the heads of origin of the gastrocnemius (Fig. 1-66).
- Open the posterior compartments of the joint with the knee extended and explore them with the knee slightly flexed. The medial head of the gastrocnemius arises at a more proximal level from the femoral condyle than does the lateral head, and the groove it forms with the semimembranosus forms a safe and comparatively avascular approach to the medial compartment (Fig. 1-67C). Turn the tendinous origin of the medial head of the gastrocnemius laterally to serve as a retractor for the popliteal vessels and nerves (Fig. 1-67D).
- Greater access can be achieved by ligating one or more genicular vessels. If the posterolateral aspect of the joint is to be exposed, elevate the lateral head of the gastrocnemius muscle from the femur and approach the lateral compartment between the tendon of the biceps femoris and the lateral head of the gastrocnemius muscle.
- When closing the wound, place interrupted sutures in the capsule, the deep fascia, and the skin. The popliteal fascia is best closed by placing all sutures before drawing them tight. Tie the sutures one by one.

Nicandri et al. reported that the medial head of the gastrocnemius can be left intact by identifying and ligating the anterior branches of the middle geniculate artery and dissecting free the tibial motor branches to the medial head of the gastrocnemius. This allows enough mobilization of the medial head of the gastrocnemius to expose the posterior cruciate ligament insertion on the posterior tibia.

FIGURE 1-65 Knee with Kirschner wire taped along flexion crease. Note relation of wire to joint line. Flexion crease sags distally in elderly or obese individuals.

DIRECT POSTEROMEDIAL APPROACH TO THE KNEE FOR TIBIAL PLATEAU FRACTURE

Galla and Lobehoffer described a direct posteromedial approach for managing medial tibial plateau fractures. This approach does not involve dissection of the popliteal neurovascular structures and uses the interval between the semimembranosus complex and the medial head of the gastrocnemius muscle.

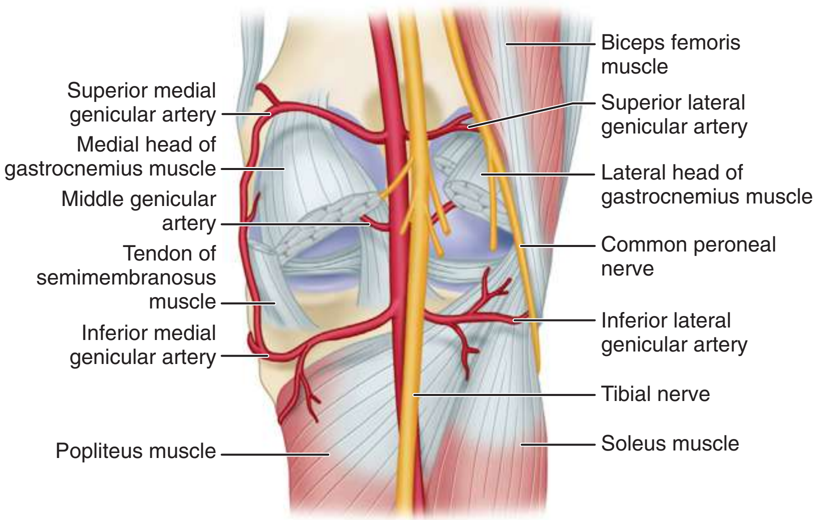

FIGURE 1-66 Collateral circulation around knee posteriorly. **SEE TECHNIQUE 1-50.**

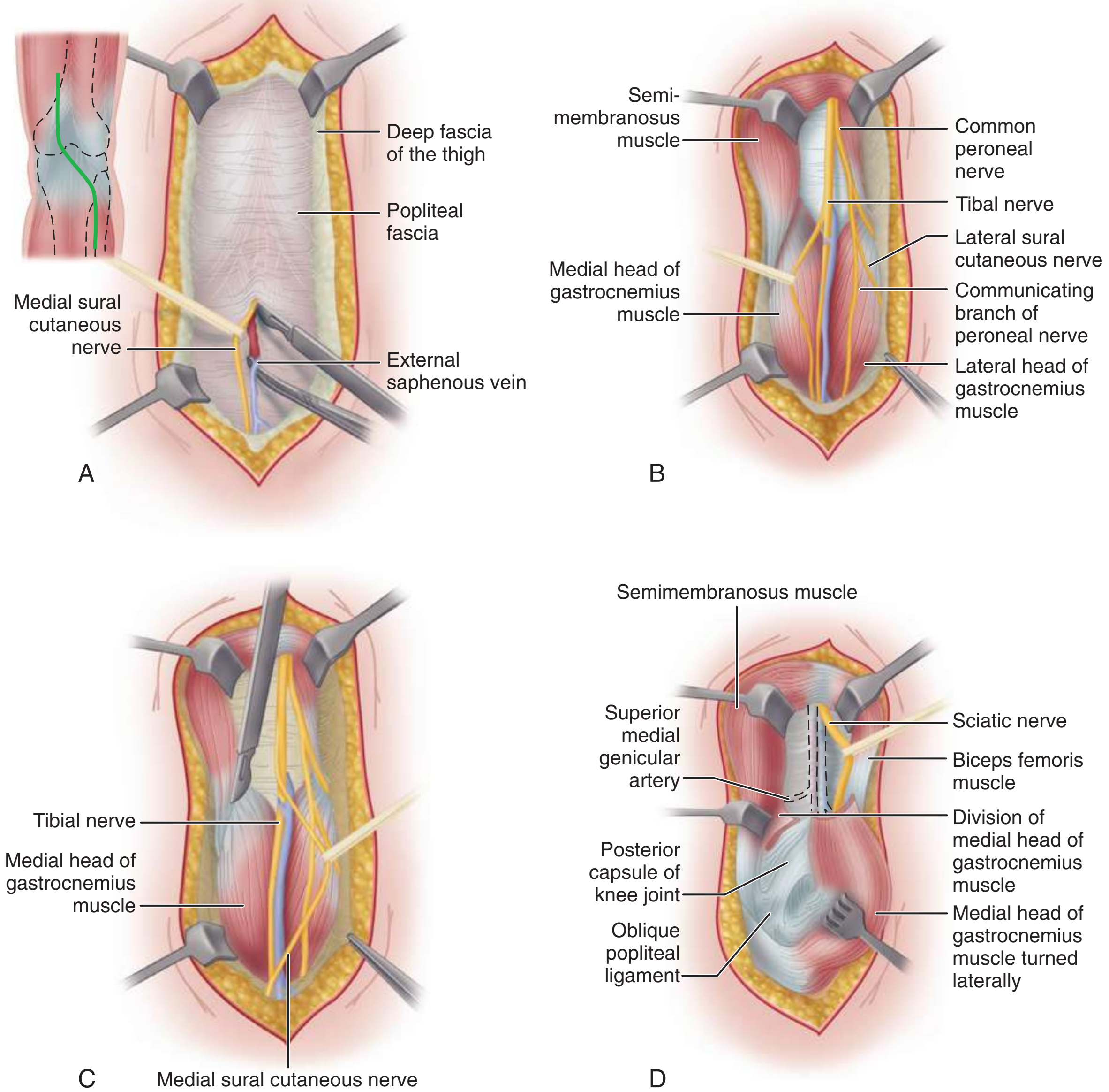

FIGURE 1-67 Posterior approach to knee joint. **A,** Posterior curvilinear incision. Posterior cutaneous nerve of calf exposed and retracted. **B,** Sciatic nerve and its division defined. **C,** Medial head of gastrocnemius muscle exposed. **D,** Tendon of origin of medial head of gastrocnemius muscle divided, exposing capsule of knee joint. If further exposure is necessary, lateral head of gastrocnemius is defined, incised, and retracted in similar fashion. **SEE TECHNIQUE 1-50.**

TECHNIQUE 1-51

(GALLA AND LOBENHOFFER AS DESCRIBED BY FAKLER ET AL.)

- Make a straight 6- to 8-cm-long longitudinal skin incision along the medial border of the medial head of the gastrocnemius muscle, beginning at the level of the joint line.
- Incise the subcutaneous tissue and popliteal fascia sharply.
- Free up the medial head of the gastrocnemius muscle without detaching it and retract it laterally.
- Bluntly dissect the semimembranosus complex and retract it medially (Fig. 1-68).
- Identify the upper edge of the popliteus muscle and detach it subperiosteally, exposing the posteromedial tibial plateau.
- If more exposure is needed, incise the tibial insertion of the semimembranosus muscle in a subperiosteal fashion.

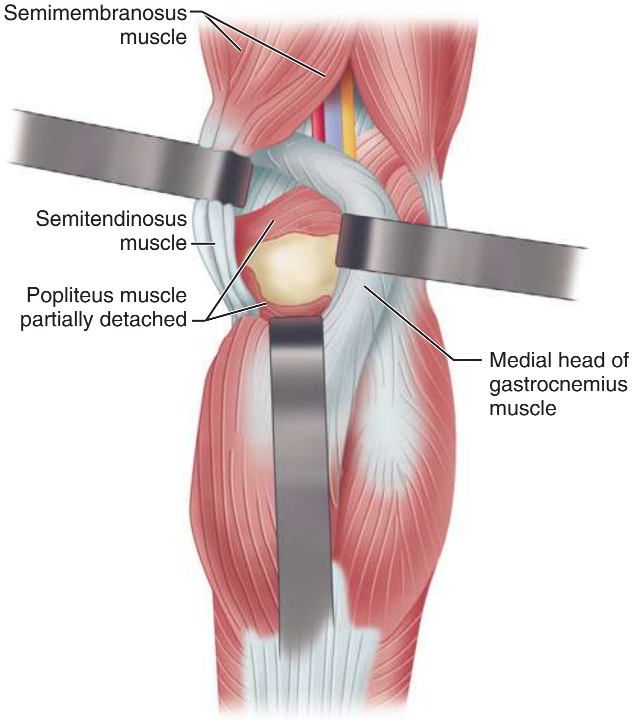

FIGURE 1-68 Galla and Lobenhoffer posteromedial approach. (Modified from Fakler JKM, Ryzewicz M, Hartshorn C, et al: Optimizing the management of Moore type I posteromedial split fracture-dislocations of the tibial head: description of the Lobenhoffer approach, J Orthop Trauma 21:330, 2007.) **SEE TECHNIQUE 1-51.**

DIRECT POSTEROLATERAL APPROACH TO THE KNEE

Minkoff et al. described a limited posterolateral approach to the proximal lateral tibia and knee. It uses the interval between the popliteus and soleus muscles and exposes the uppermost lateral portion of the posterior tibial metaphysis and the proximal tibiofibular joint. Although this approach was developed to excise an osteoid osteoma from the lateral tibial plateau, it can be used for other conditions affecting the posterior aspect of the knee.

TECHNIQUE 1-52

(MINKOFF, JAFFE, AND MENENDEZ)

- Begin the skin incision 1 to 2 cm below the popliteal crease slightly medial to the midline of the knee, carrying it transversely and curving it distally just medial and parallel to the head of the fibula, ending 5 to 6 cm distal to it.
- Reflect the skin and subcutaneous flap inferomedially.
- Isolate the lateral cutaneous nerve of the calf, retract it laterally, and preserve it.
- Identify the short saphenous vein superficial to the fascia and divide and ligate it.
- Open the fascia carefully in line with the incision. The sural nerve lies deep to the fascia just superficial to the heads of the gastrocnemius muscle and must be protected (Fig. 1-69A).
- Identify the common peroneal nerve and retract it laterally.
- Develop the interval between the lateral head of the gastrocnemius and the soleus muscles and retract the lateral head of the gastrocnemius medially.
- Retract the popliteal artery and vein and the tibial nerve along with the lateral head of the gastrocnemius (Fig. 1-69B). Dissect free the fibular origin of the soleus muscle and retract it distally.
- Retract the underlying popliteus muscle medially to expose the posterior aspect of the lateral tibial plateau and proximal tibiofibular joint (Fig. 1-69C).

FEMUR

ANTEROLATERAL APPROACH TO THE FEMUR

The anterolateral approach exposes the middle third of the femur, but postoperative adhesions between the individual muscles of the quadriceps group and between the vastus intermedius and the femur may limit knee flexion. The quadriceps mechanism must be handled gently. Infections of the middle third of the shaft are best approached posterolaterally. When the shaft must be approached from the medial side, this anterolateral approach, rather than an anteromedial one, is indicated.

TECHNIQUE 1-53

(THOMPSON)

- Incise the skin over the middle third of the femur in a line between the anterior superior iliac spine and the lateral margin of the patella (Fig. 1-70).
- Incise the superficial and deep fasciae and separate the rectus femoris and vastus lateralis muscles along their intermuscular septum. The vastus intermedius muscle is brought into view.
- Divide the vastus intermedius muscle in the line of its fibers down to the femur.
- Expose the femur by subperiosteal reflection of the incised vastus intermedius muscle.

Henry exposed the entire femoral shaft by extending this incision proximally and distally. The approach is not recommended for operations on the proximal third of the femur because exposing the bone here is difficult without injuring the lateral femoral circumflex artery and the nerve to the vastus lateralis muscle. Distally, the incision may be extended to within 12 to 15 cm of the knee joint; at this point, however, the insertion of the vastus lateralis muscle into the quadriceps tendon is encountered, as is the more distal suprapatellar bursa.

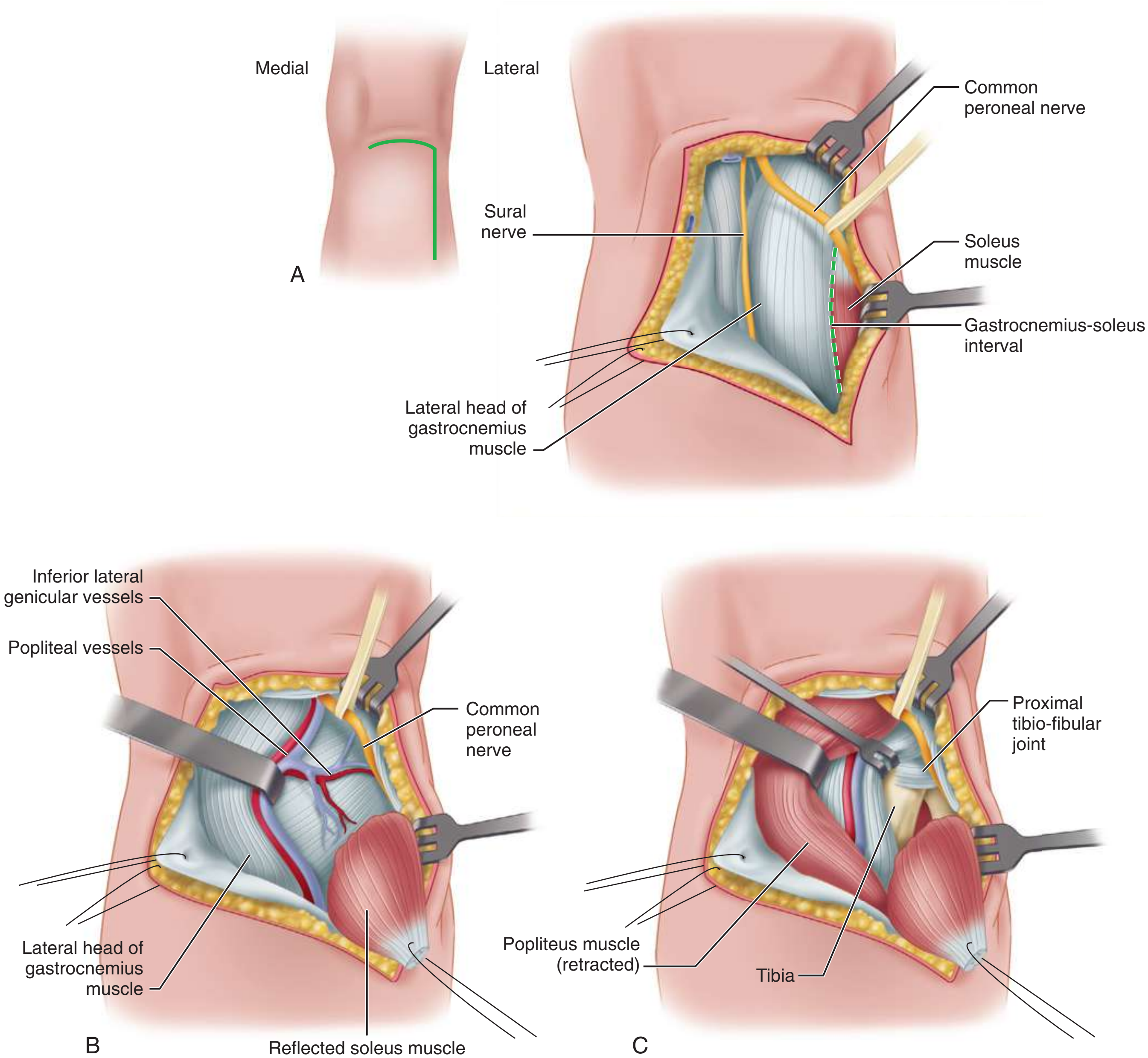

FIGURE 1-69 Minkoff, Jaffe, and Menendez posterolateral approach. **A,** Superficial dissection. **B,** Gastrocnemius and popliteal vessels are retracted medially, and fibular origin of soleus is reflected distally. **C,** Popliteus is retracted medially, exposing the posterior aspect of tibial plateau and proximal tibiofibular joint. (Modified from Minkoff J, Jaffe L, Menendez L: Limited posterolateral surgical approach to the knee for excision of osteoid osteoma, Clin Orthop Relat Res 223:237, 1987.) **SEE TECHNIQUE 1-52.**

LATERAL APPROACH TO THE FEMORAL SHAFT

Anatomically, the entire femoral shaft may be exposed by the lateral approach, but only its less extensive forms are recommended. The posterolateral approach is preferred whenever possible to avoid splitting the vastus lateralis.

TECHNIQUE 1-54

- Make an incision of the desired length over the lateral aspect of the thigh along a line from the greater trochanter to the lateral femoral condyle (Fig. 1-71A).
- Incise the superficial and deep fasciae.
- Divide the vastus lateralis and vastus intermedius muscles in the direction of their fibers and open and reflect the periosteum for the proper distance.

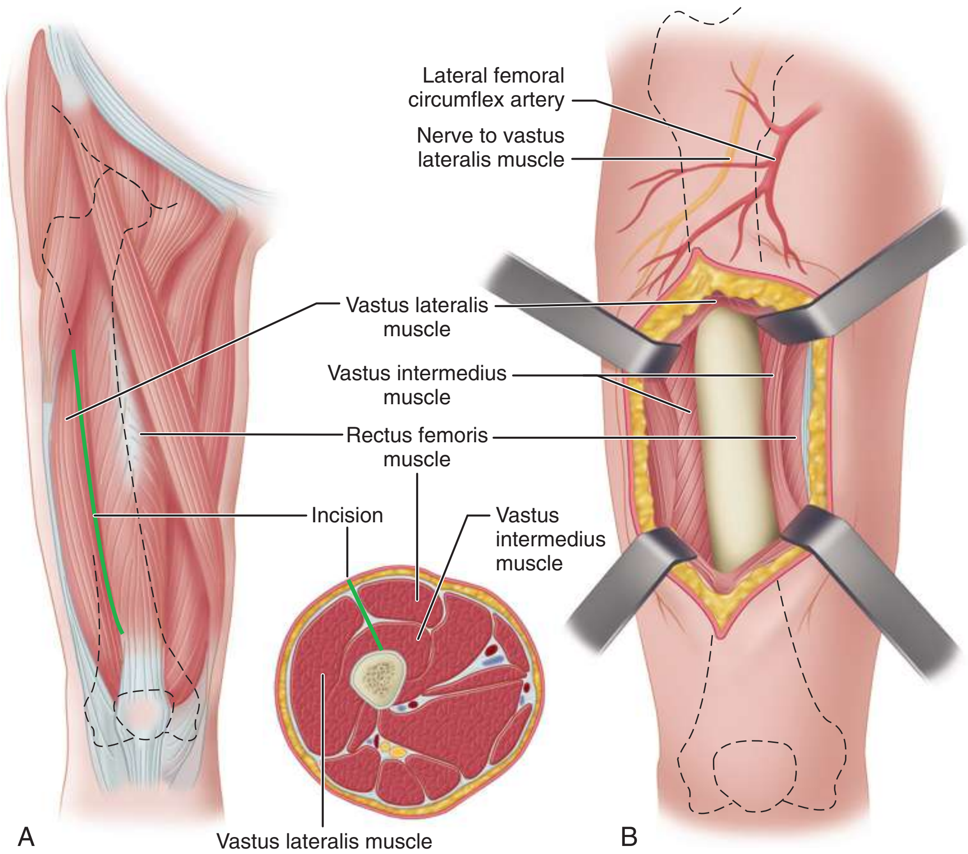

FIGURE 1-70 Anterolateral approach to femur. **A,** Skin incision. **B,** Femur exposed by separation of rectus femoris and vastus lateralis muscles and division of vastus intermedius muscle. **SEE TECHNIQUE 1-53.**

- A branch of the lateral femoral circumflex artery is encountered when exposing the proximal fourth of the femur and the lateral superior genicular artery in the distal fourth; these may be clamped, divided, and ligated without harm.

POSTEROLATERAL APPROACH TO THE FEMORAL SHAFT

TECHNIQUE 1-55

- Turn the patient slightly to elevate the affected side.
- Make the incision from the base of the greater trochanter distally to the lateral condyle (Fig. 1-71B).
- Incise the superficial fascia and fascia lata along the anterior border of the iliotibial band.
- Expose the posterior part of the vastus lateralis muscle and retract it anteriorly (in muscular individuals this retraction may be difficult); continue the dissection down to bone along the anterior surface of the lateral intermuscular septum, which is attached to the linea aspera.
- Retract the deep structures and split the periosteum in the line of the incision.
- With a periosteal elevator, free the attachment of the vastus intermedius muscle as far as necessary.
- In the middle third of the thigh, the second perforating branch of the profunda femoris artery and vein run transversely from the biceps femoris to the vastus lateralis. Ligate and divide these vessels.
- To avoid damaging the sciatic nerve and the profunda femoris artery and vein, do not separate the long and short heads of the biceps femoris muscle.

POSTERIOR APPROACH TO THE FEMUR

TECHNIQUE 1-56

(BOSWORTH)

- With the patient prone, incise the skin and deep fascia longitudinally in the middle of the posterior aspect of the thigh, from just distal to the gluteal fold to the proximal margin of the popliteal space.
- Use the long head of the biceps as a guide. By blunt dissection with the index finger, palpate the posterior surface of the femur at the middle of the thigh. To expose the

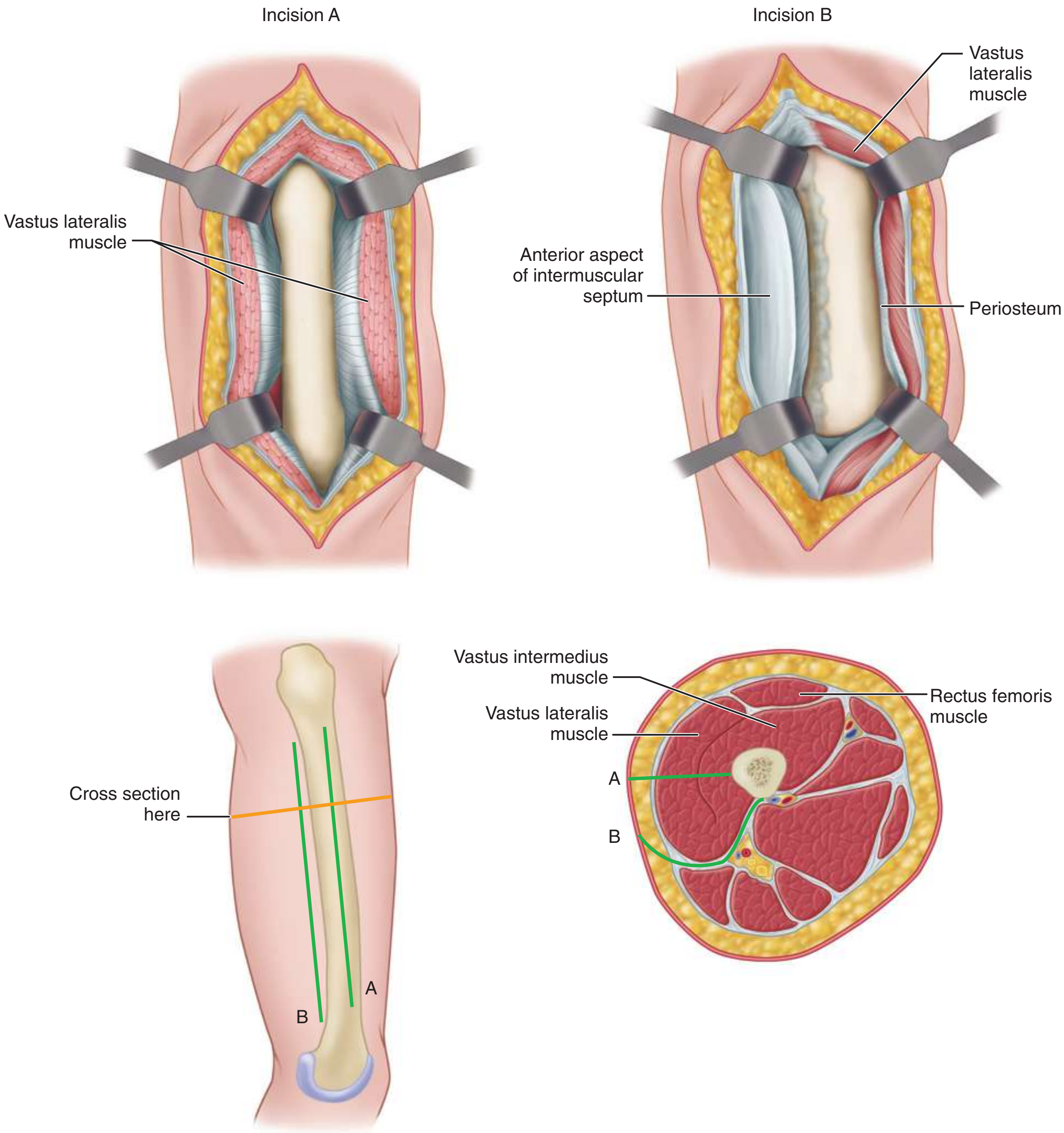

FIGURE 1-71 Posterolateral and lateral approaches to middle third of femur. Lateral approach *(A)*. Vastus lateralis and vastus intermedius have been incised in line with their fibers. Cross-section shows these approaches. Posterolateral approach *(B)* along lateral intermuscular septum. **SEE TECHNIQUES 1-54 AND 1-55.**

middle three fifths of the linea aspera, use the fingers to retract the attachment of the vastus medialis and lateralis muscles.

- To expose the proximal part of the middle three fifths of the femur, continue the blunt dissection along the lateral border of the long head of the biceps, developing the fascial plane between the long head of the biceps and the vastus lateralis muscle, and reflect the long head of the biceps *medially* (Fig. 1-72A).
- To expose the distal part of the middle three fifths of the femur, carry the dissection along the medial surface of the long head of the biceps, developing the fascial plane between the long head of the biceps and the semitendinosus, and retract the long head of the biceps and the sciatic nerve *laterally* (Fig. 1-72B).
- To expose the entire middle three fifths of the femur, carry the blunt dissection to the linea aspera lateral to the long head of the biceps, divide the latter muscle in the distal

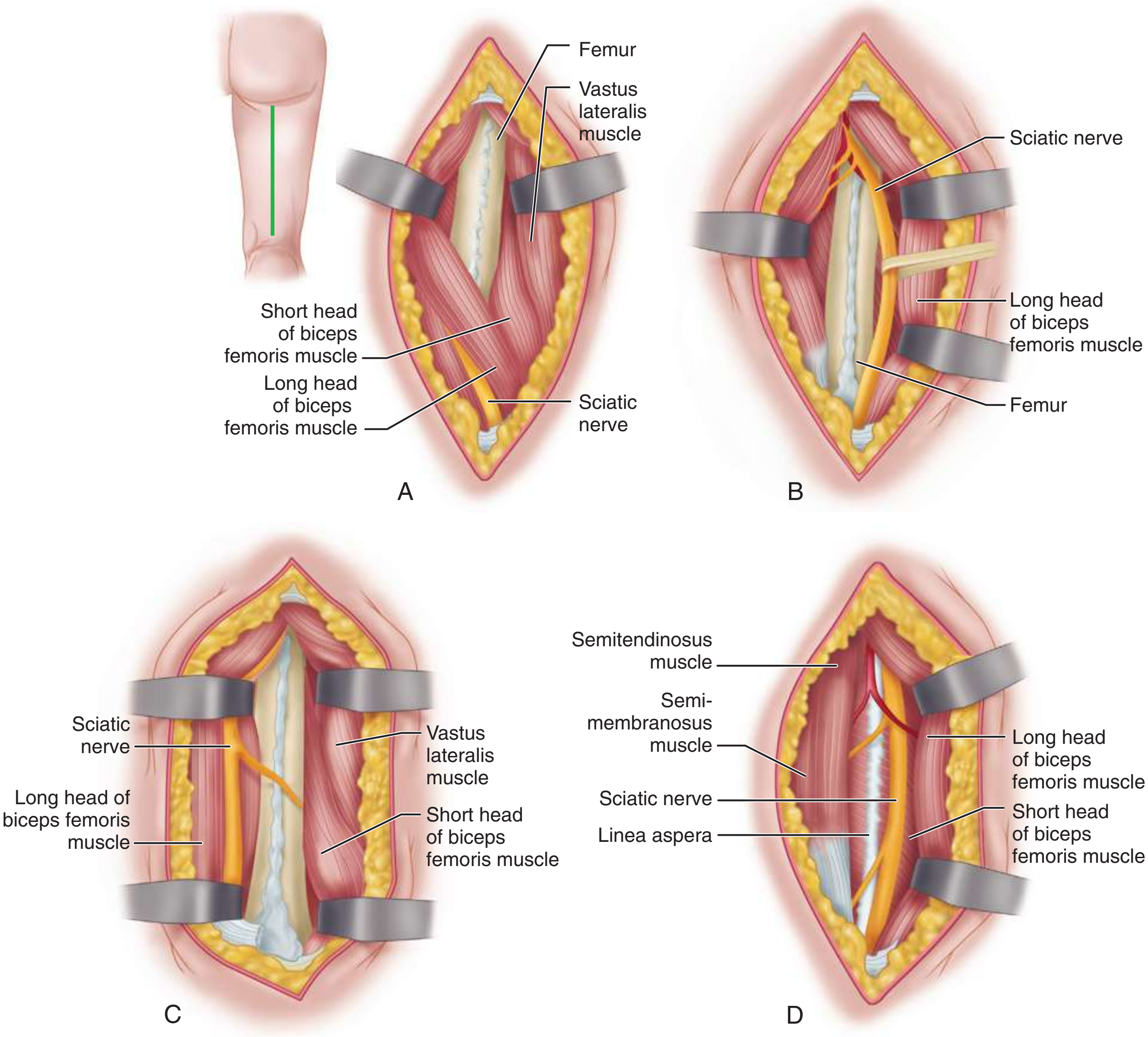

FIGURE 1-72 Bosworth posterior approach to femur. **A,** To expose proximal part of middle three fifths of femur, long head of biceps femoris has been retracted medially. *Inset,* Skin incision. **B,** To expose distal part of middle three fifths of femur, long head of biceps femoris and sciatic nerve have been retracted laterally. **C,** To expose entire middle three fifths of femur, long head of biceps femoris has been divided in distal part of wound, and this muscle and sciatic nerve have been retracted medially. **D,** Sciatic nerve would be subject to injury if entire middle three fifths of femur were exposed by retracting biceps femoris laterally. **SEE TECHNIQUE 1-56.**

part of the wound, and displace it *medially,* together with the sciatic nerve (Fig. 1-72C).

- Part of the nerve supply to the short head of the biceps crosses the exposure near its center; this branch of the sciatic nerve may be saved or divided, depending on the requirements of the incision because it does not make up the entire nerve supply of this part of the biceps.
- After exposing the linea aspera, free the muscle attachments by sharp dissection and expose the femur by subperiosteal dissection.
- Bosworth points out that the entire middle three fifths of the femur should *never* be exposed by retracting the long head of the biceps and sciatic nerve *laterally* because this unnecessarily endangers the sciatic nerve (Fig. 1-72D).
- When the distal end of the long head of the biceps is to be divided, place sutures in the distal segment of the muscle before the division is carried out; this makes suturing the muscle easier when the wound is being closed.
- After suturing the biceps, close the wound by suturing only the skin and subcutaneous tissue because the other structures fall into position.
- When developing this approach, the surgeon must keep in mind the possibility of damaging the sciatic nerve. Rough handling and prolonged or strenuous retraction of the nerve may cause distressing symptoms after surgery or possibly a permanent disability in the leg.

MEDIAL APPROACH TO THE POSTERIOR SURFACE OF THE FEMUR IN THE POPLITEAL SPACE

When possible, the medial approach to the posterior surface of the femur in the popliteal space should be used in preference to an anteromedial approach because in the latter the vastus medialis must be separated from the rectus femoris and the vastus intermedius must be split.

TECHNIQUE 1-57

(HENRY)

- With the knee slightly flexed, begin the incision 15 cm proximal to the adductor tubercle and continue it distally along the adductor tendon, following the angle of the knee to 5 cm distal to the tubercle (Fig. 1-73A).
- In the distal part of the incision, carry the dissection posteriorly to the anterior edge of the sartorius muscle just proximal to the level of the adductor tubercle.
- Free the deep fascia proximally over this muscle, taking care to avoid puncturing the synovial membrane, which is beneath the muscle when the joint is flexed. After this procedure, the sartorius falls posteriorly, exposing the tendon of the adductor magnus muscle. Protect the saphenous nerve, which follows the sartorius on its deep surface; the great saphenous vein is superficial and is not in danger if the incision is made properly.
- Divide the thin fascia posterior to the adductor tendon by blunt dissection to the posterior surface of the femur at the popliteal space.
- Retract the large vessels and nerves posteriorly; branches from the muscles to the bone may be isolated, clamped, and divided.
- Retract the adductor magnus tendon and a part of the vastus medialis muscle anteriorly and expose the bone. The tibial and common peroneal nerves are not encountered because they lie lateral and posterior to the line of incision.

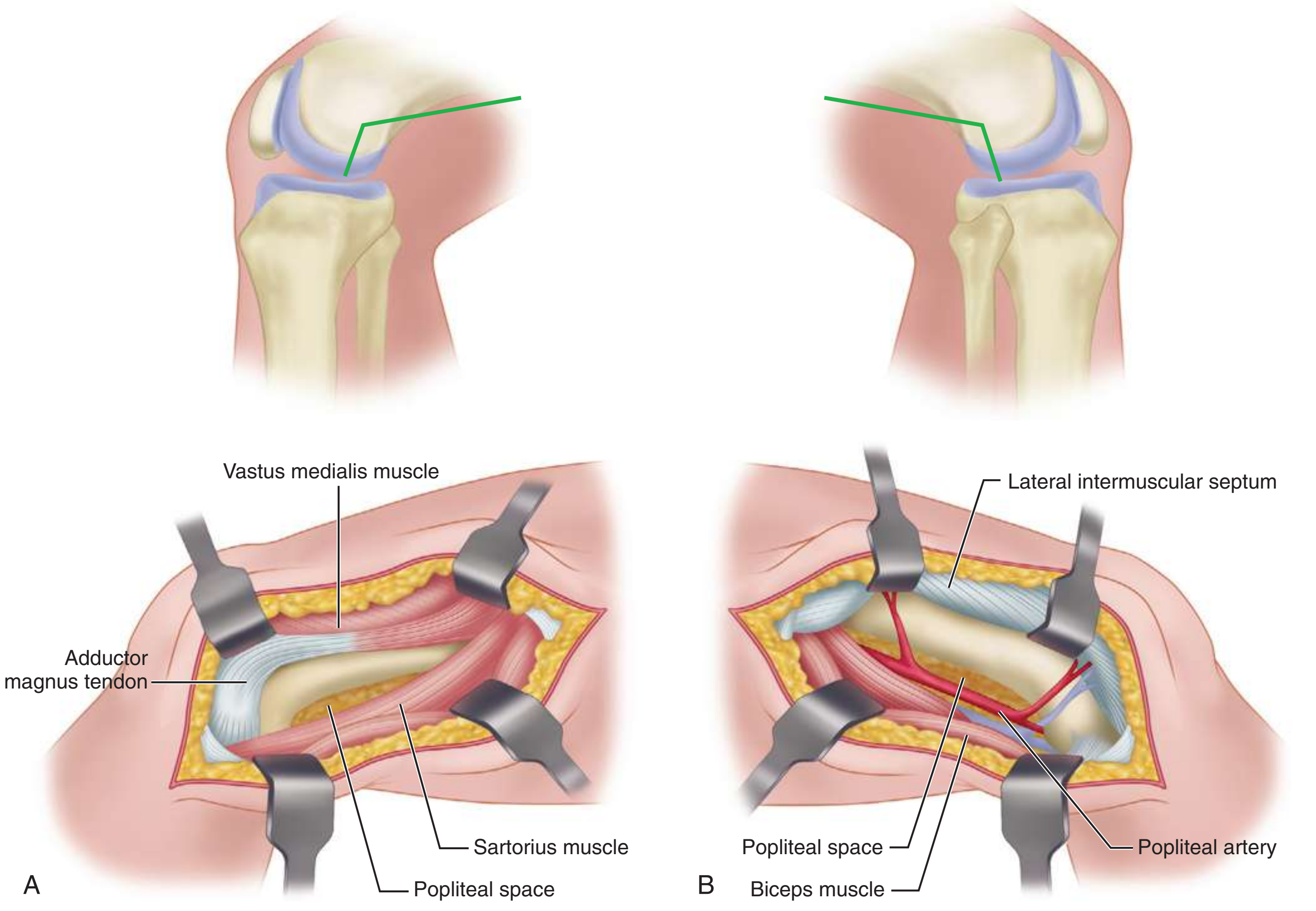

FIGURE 1-73 Henry medial and lateral approaches to posterior surface of femur in popliteal space. **A,** Medial approach. **B,** Lateral approach. **SEE TECHNIQUES 1-57 AND 1-58.**

LATERAL APPROACH TO THE POSTERIOR SURFACE OF THE FEMUR IN THE POPLITEAL SPACE

TECHNIQUE 1-58

(HENRY)

- With the knee slightly flexed, incise the skin and superficial fascia for 15 cm along the posterior edge of the iliotibial band and follow the angle of the knee to the head of the fibula (Fig. 1-73A).
- Divide the deep fascia immediately posterior to the iliotibial band.
- Just proximal to the condyle, separate the attachment of the short head of the biceps from the posterior surface of the lateral intermuscular septum; reach the popliteal space by blunt dissection between these structures.
- Ligate and divide the branches of the perforating vessels and retract the popliteal vessels posteriorly in the posterior wall of the wound. The tibial nerve lies posterior to the popliteal vessels, and the common peroneal nerve follows the medial edge of the biceps.
- Expose the surface of the femur by incising and elevating the periosteum.

LATERAL APPROACH TO THE PROXIMAL SHAFT AND THE TROCHANTERIC REGION

The lateral approach is excellent for reduction and internal fixation of trochanteric fractures or for subtrochanteric osteotomies under direct vision.

TECHNIQUE 1-59

- Begin the incision about 5 cm proximal and anterior to the greater trochanter, curving it distally and posteriorly over the posterolateral aspect of the trochanter and distally along the lateral surface of the thigh, parallel with the femur, for 10 cm or more, depending on the desired exposure (Fig. 1-74A).
- Deepen the dissection in the line of the incision down to the fascia lata.
- In the distal part of the wound, incise the fascia lata with a scalpel and split it proximally with scissors. In the proximal part of the wound, divide the fascia just posterior to the tensor fasciae latae muscle to avoid splitting this muscle.
- By retraction, bring into view the vastus lateralis muscle and its origin from the inferior border of the greater trochanter. Divide the origin of the muscle transversely along this border down to the posterolateral surface of the femur.
- Divide the vastus lateralis and its fascia longitudinally with scissors, beginning on its posterolateral surface, 0.5 cm from its attachment to the linea aspera.
- Alternatively, first split the muscle fascia alone laterally instead of posterolaterally, dissect the muscle from its deep surface posteriorly, and divide the muscle near the linea aspera (closing the fascia lata then is easier). The muscle is divided where it is thin rather than thick, as is necessary in a direct lateral muscle-splitting approach (Fig. 1-74A and B). Section no more than 0.5 cm of the muscle at one time. Keep the body of the vastus retracted anteriorly; by this means, if one of the perforating arteries is divided, it may be clamped and tied before it retracts beyond the linea aspera.
- After dividing the muscle along the femur for the required distance, elevate it with a periosteal elevator and expose the lateral and anterolateral surfaces of the femoral shaft (Fig. 1-74C).
- By further subperiosteal elevation of the proximal part of the vastus lateralis and intermedius muscles, expose the intertrochanteric line and the anterior surface of the femur just below this line.
- The base of the femoral neck may be exposed by dividing the capsule of the joint at its attachment to the intertrochanteric line.
- If a wider exposure is desired, elevate the distal part of the gluteus minimus from its insertion on the trochanter.
- In closure, the vastus lateralis muscle falls over the lateral surface of the femur. Suture the fascia lata and close the remainder of the wound routinely.

HIP

Numerous new approaches to the hip have been described since the 1990s; most are based on older approaches and are modified for a specific surgical procedure. In this section, the general approaches we have found most useful are described. The specific approaches used in revision total hip arthroplasty are described in Chapter 3. Approaches used for minimally invasive hip arthroplasty procedures are described in Chapters 3 and 4.

The approach selected should be based on access needed, the potential for complications, the procedure to be performed, and the experience of the surgeon. The need for maintaining the primary blood supply to the femoral head (medial femoral circumflex artery and its ascending branches) must be considered before the procedure (Fig. 1-75). In total hip arthroplasty, disruption of the ascending branches of the medial circumflex femoral artery is of no consequence. If hip resurfacing, femoral neck fracture repair, or osteotomy is to be performed, lateral anterolateral, anterior, or medial approaches are more desirous to prevent osteonecrosis of the femoral head. Lateral approaches requiring osteotomy of the greater trochanter have a significant nonunion rate of that osteotomy, which should also be considered.

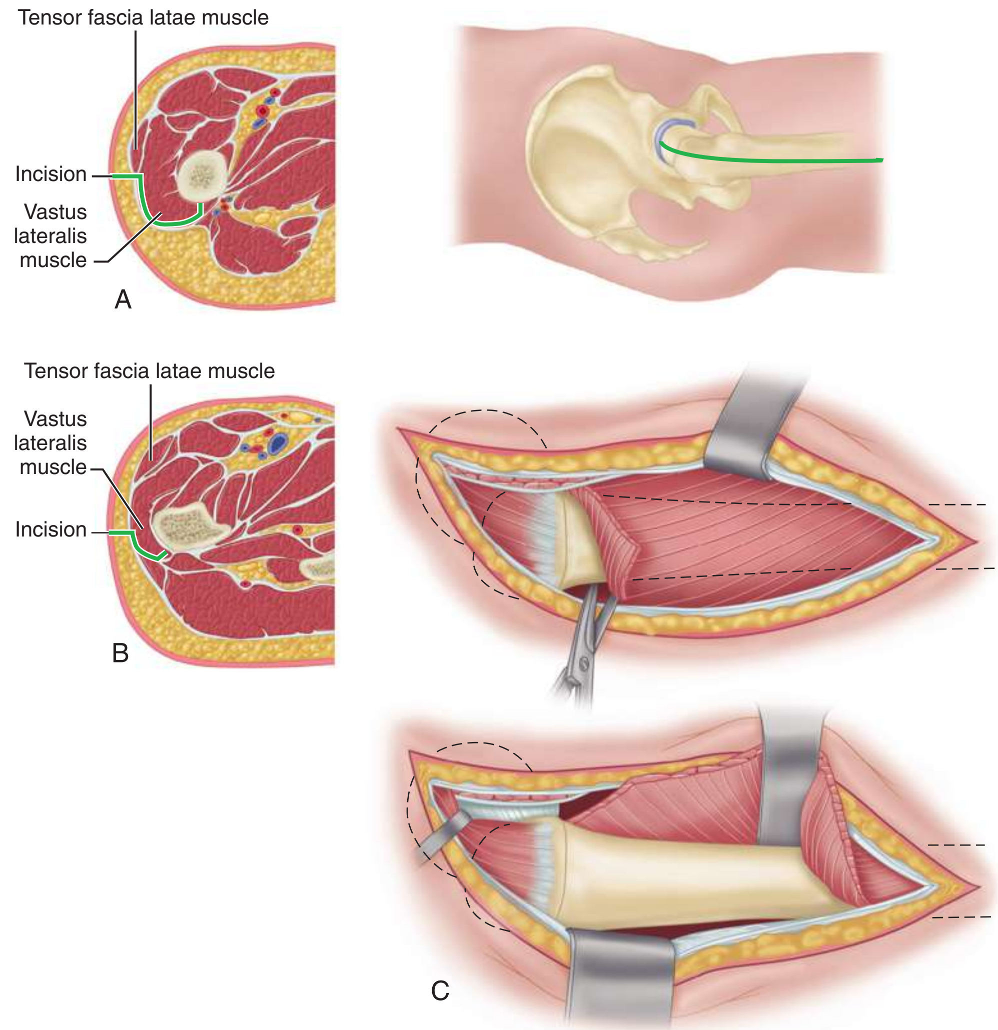

FIGURE 1-74 Lateral approach to proximal shaft and trochanteric region of femur. **A,** Cross-section shows level of approach at lesser trochanter. Fascia lata has been incised in line with skin incision. Vastus lateralis has been incised transversely just distal to greater trochanter and is being incised longitudinally 0.5 cm from linea aspera. *Inset,* Skin incision. **B,** Cross-section shows approach at level of distal end of skin incision. **C,** Approach has been completed by dissecting vastus lateralis subperiosteally from femur. Hip joint may be exposed by continuing approach proximally as in Watson-Jones approach. **SEE TECHNIQUE 1-59.**

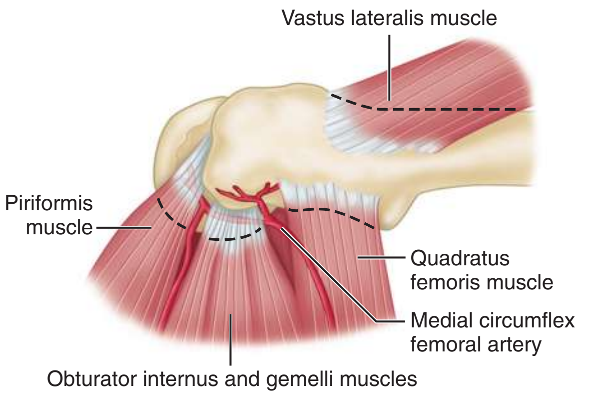

FIGURE 1-75 The relevant deep anatomic structures of posterior aspect of the hip shows the course of medial circumflex femoral artery to the femoral head. (From Nork SE, Schär M, Pfander G, et al: Anatomic considerations for the choice of surgical approach for hip resurfacing arthroplasty, Orthop Clin North Am 36:163, 2005.)

ANTERIOR APPROACHES TO THE HIP

ANTERIOR ILIOFEMORAL APPROACH TO THE HIP

Smith-Petersen improved and revived interest in the anterior iliofemoral approach, and now it is used often. Nearly all surgery of the hip joint may be carried out through this approach, or separate parts can be used for different purposes. The anterior femoral incision exposes the joint but is inadequate for reconstructive operations. The entire ilium and hip joint can be reached through the iliac part of the incision; all structures attached to the iliac crest from the posterior superior iliac spine to the anterior superior iliac spine are freed and are reflected from the lateral surface of the ilium; dissection is carried distally to the anterior inferior iliac spine. Smith-Petersen also modified and improved this approach for extensive surgery of the hip by