AOTRAUMA

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David A Volgas | Yves Harder

Manual of Soft-Tissue Management in Orthopaedic Trauma

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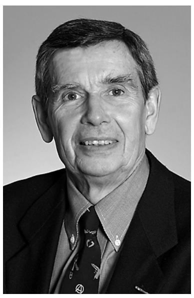
Preface



Thomas P Rüedi, MD, Professor, FACS
Founding and honorary member
of the AO Foundation

Is there really an interest in or a need for an AO Manual on the management of soft tissues? Especially in view of the fact that most fractures are being stabilized by so-called minimally invasive surgical techniques, which supposedly do less harm than conventional surgery? Even so, it is unfortunately often forgotten or at least neglected that "a fracture first and foremost is a soft-tissue injury, in which the bone happens to be broken". This simple statement actually seems to justify the publication of this textbook as a useful and valuable adjunct to the manuals on operative fracture fixation.

We can and do teach on a broad scale, both in theory and in practical workshops, how to apply nails, screws, plates, and other implants to the most complex fractures of almost any bare, synthetic bone or joint. However, there is as yet no way to simulate the often tricky reduction maneuvers, as they are encountered regularly in the operation room, nor can we teach how to assess, evaluate, and handle the injured soft tissues on realistic models or on an individual basis.

Although the founders of the AO—from the very beginning of their teaching—stressed the importance of preserving the vascularity of the soft tissues and bone, too much attention and emphasis was—and still is—addressed to the mechanical aspects of an anatomical reconstruction and absolute rigid fixation of a fracture. This has contributed to the tendency for approaches that are much too extensive, unnecessary exposures, and rough manipulation of the fracture fragments as well as careless stripping of periosteum. Neglecting the biology in general and, in particular, underestimating the vascularity of the soft parts and bone, has all too often resulted in necrotic bone, delayed healing or no healing at all, infection as well as other complications.

In open fractures the immediate debridement and surgical stabilization—as proposed and initiated by the AO more than 50 years ago—proved to be of great benefit for the recovery of the damaged soft tissues surrounding the fracture. However, careful assessment of the injury, correct timing and planning of the procedure followed by experienced surgery remain of crucial importance for the successful outcome for all fractures—open as well as closed. Furthermore, critical soft-tissue conditions, loss of skin, or large tissue defects demand special interest and much expertise in order to handle or cover the damaged area.

The goal of this manual on soft-tissue management in trauma of the extremities is to provide a scientific background, validated basic instructions, and practical hints by experts on how to handle the soft tissues and especially the skin. After correct debridement, only vital and healthy tissues providing an intact coverage are able to guarantee a safe barrier against infection or the basis to successfully fight a residual infection inside an injured limb. Similarly, an associated fracture will only be able to heal if the soft-tissue envelope is viable.

The two editors–David A Volgas, an American orthopaedic trauma surgeon with a special interest in soft-tissue surgery and Yves Harder, a Swiss plastic and reconstructive surgeon with a broad background in general surgery, trauma and research—have been able to convince a number of experts from around the world to contribute their knowledge and experience to this textbook, which is addressed mainly to those surgeons—young or older—involved and interested in the overall management of trauma of the locomotor system.

The first chapters of this book have been reserved for the principles of soft-tissue handling, the anatomy of the soft parts and bone as well as their healing patterns, the mechanisms of injury and the assessment and classification of the injury. Next, the focus is on treatment strategies as well as the stabilization and conditioning of the wound, followed by chapters that discuss the principles and techniques of wound closure and coverage including the most common local and regional flaps for extremity trauma. The use of free flaps and other less frequently applied flaps is mentioned, but not addressed in detail, as this should remain the domain of the specialists. Finally, postoperative care, as well as hazards and complications round off the content. In support of the text, illustrations, tables, and video clips have been produced and as a special feature, a number of instructive case reports are provided as examples of how to manage individual situations. Cases are presented progressively from those requiring simpler surgical skills to those that should only be carried out by a specialized surgeon familiar with reconstructive procedures, including microsurgery.

While this textbook is no substitute for what a skilled surgeon should be learning at the operation table, it is intended to help improve the understanding of the principles and philosophy of soft-tissue management in trauma.

Maienfeld, June 2011

Acknowledgments

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From the time this project was first conceived, Thomas P Rüedi has been a facilitator, mentor, and friend, providing encouragement and support. Throughout his long career as a dexterous and dedicated surgeon with a special interest in trauma surgery and as a founding member of the AO Foundation, he has emphasized and taught the principles of soft-tissue handling to the residents and fellows fortunate enough to learn in his operating room. He helped bring this project to fruition, brought the editors together, and assisted with the refining and proofreading of chapters. His help has been invaluable and the editors would like to thank him heartily for his guidance throughout the project.

The editors also wish to express their gratitude to the many authors who wrote chapters, taking time away from their very busy clinical practices. We are convinced that this effort will significantly further the education of surgeons. We would also like to thank all surgeons who provided material such as photographs, or whose skills in the operating room helped us produce instructive learning material such as case reports. Dr Ladislav Nagy is one of them.

The AO team has provided resources, expertise, and opportunities, without which this book would not have been possible. Urs Rüetschi and Kathrin Lüssi have continued to support and put their faith in this book. Special thanks go to Sigrid Unterberg, who proved tireless in planning, managing, and advising this complex project. She was instrumental in overcoming obstacles whenever they arose. Thanks go to all illustrators, in particular Jecca Reichmuth as the main illustrator, Simone Monhart Wüthrich, and Susanne Stettler. Roger Kistler and Tom Wirth did a tremendous job in typesetting, while Carl Lau and Barbara Gernert helped with the proofreading. From the video team, Mike Laws has been most helpful in the production process, and Robin Greene generously lent us his voice to produce instructive learning material. Further thanks go to nougat GmbH, Basel.

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Abbreviations

ABI	ankle-brachial index
ATLS	advanced trauma life support
bFGF	basic fibroblast growth factor
BMI	body mass index
CRP	C-reactive protein
CT	computed tomography
DSA	digital subtraction angiography
ED	emergency department
FDA	Food and Drug Administration
FGF-2	fibroblast growth factor-2
FTSG	full-thickness skin graft
GCS	Glasgow coma scale
HFS	Hanover fracture scale
HIT	heparin-induced thrombocytopenia
HPL	high-pressure lavage
IL	interleukin
INR	international normalized ratio
IV	intravenous
LDF	laser Doppler flowmetry
LEAP	lower extremity assessment project
LISS	less invasive stabilization system
LMWH	low-molecular-weight heparin
LPL	low-pressure lavage
LSI	limb salvage index
MESS	mangled extremity severity score
MIF	macrophage migration inhibitory factor
MRI	magnet resonance imaging
MRSA	methicillin-resistant *Staphylococcus aureus*
MSC	mesenchymal stem cell
NISSSA	nerve, ischemia, soft-tissue, skeletal, shock, and age score
NPWT	negative-pressure wound therapy
ORIF	open reduction and internal fixation
PDGF	platelet-derived growth factor
PDS	polydioxanone
PLA	polylactic acid
PMMA	polymethyl methacrylate
PMN	polymorphonuclear leukocyte
pO2	partial oxygen pressure
psi	pounds per square inch (1 psi = 0.07 atmospheres)
PU	perfusion unit
SPARC	secreted protein acidic and rich in cysteine
SSRI	serotonin reuptake inhibitor
STSG	split-thickness skin graft
TGF-β	transforming growth factor β
TNF-α	tumor necrosis factor α
UFH	unfractionated heparin
VAC®	Vacuum Assisted Closure
VEGF	vascular endothelial growth factor
VRE	vancomycin-resistant enterococcus

Table of contents

PRINCIPLES

1 Principles of good soft-tissue technique

1.1 Importance of correct handling of soft tissues

Author James N Long

Fractures are nearly always associated with some degree of soft-tissue injury. Often they are merely soft-tissue injuries with an associated hard-tissue injury. While surgeons cannot change the amount of damage caused by the initial injury, they can, through skillful use of instruments and retraction, avoid further injury to these traumatized tissues. Conversely, in the quest to achieve anatomical restoration of a fracture, surgeons too often have ignored the iatrogenic injury caused by wide exposure of the fracture. Even more commonly, surgical assistants have caused further injury to tissues by careless application of retraction. However, extensive soft-tissue injury can also occur without a fracture, and incorrect handling can eventually lead to functional impairment such as loss of range of motion and chronic pain.

Contributing to this problem is a tendency of surgeons to focus on the care of the fracture while in training. Soft-tissue techniques are not described in detail in classic textbooks and often senior surgeons delegate the surgical approach and debridement to junior members, thereby foregoing the opportunity to teach good soft-tissue handling. This chapter will teach the fundamentals of instrument handling and retraction. Suture techniques will be discussed in chapter 10.1.

1.2 Preparation for surgery

Author James N Long

1.2.1 Skin preparation

While there are several different solutions available for effective skin disinfection, it seems important that their application is carried out according to the specific instructions of the producer and the guidelines of the hospital. The solution must have completely dried before the skin is incised. In general, open wounds should be debrided of large foreign bodies such as dirt, large pieces of gravel and leaves prior to surgical prep because they have to be removed anyway and it is difficult to fully decontaminate them.

Superficial abrasions with embedded gravel, rocks or other foreign debris require special attention. The wound may be gently debrided prior to surgical scrub with a scrub brush of the type used to scrub the surgeon’s hands. Care must be taken to ensure that no additional damage to the soft tissue is caused by overly aggressive, course debridement. The goal is to remove loose material, which might come free during the surgical scrub. However, in some cases, material has become embedded in the full thickness of the dermis and should be removed during the surgical debridement.

Iodine-containing preparations (ie, Betadine®, Braunol®) are relatively toxic to underlying soft tissues and thus are often avoided in cases of open wounds. They also impair osteogenesis and should not be used on exposed bone. Alcohol-based preparations can basically present a risk of fire when electrocautery is used and the alcohol has not dried.

1.2.2 Use of the tourniquet

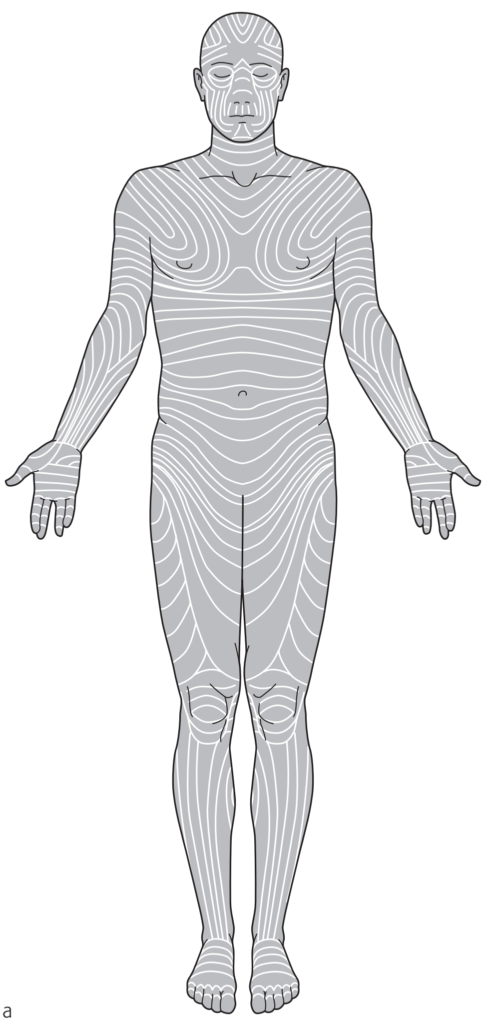
Tourniquets are often used in extremity surgery to reduce bleeding and to facilitate difficult preparation, for example when dissecting a flap, its pedicle or the recipient vessels. With careful intraoperative hemostasis, however, a tourniquet is not routinely required, particularly during the debridement procedure. Continuous assessment of punctate bleedings during debridement is essential to decide whether the tissues are viable or not. The prolonged application of a tourniquet may increase edema formation after its release due to reperfusion of the limb, exacerbating the edema, which will occur as a result of the fracture. This differs from elective surgery, where there is no preexisting edema or inflammation.

1.2.3 Planning incisions

The skin incision should provide the most adequate and least harmful exposure for the planned fixation of a specific fracture. It should be extensile, which is best done with straight incisions rather than curved ones. Most described approaches make use of Langer lines, sometimes also called cleavage lines. They are topological lines drawn on a map of the human body along which the skin has the least flexibility. They correspond to the natural orientation of collagen fibers in the dermis. These lines represent small folds in the skin, which allow stretching of the skin perpendicular to the lines. They can easily be seen by gently pinching the skin or by examining areas such as joints where they allow flexion and extension of the joint (**Fig 1.2-1a–b**). If a surgeon can choose where and in which direction to place an incision, he or she may decide to cut in the direction of Langer lines. Incisions made parallel to Langer lines may heal better and produce less scarring than those cutting across and thus minimize contracture and restriction of motion. The orientation of stab wounds relative to Langer lines can have a considerable impact upon the presentation of the wound.

Ideally, the incision should not cross bone prominences such as the olecranon or medial malleolus, but rather gently curve around them to avoid having a scar on a potential pressure area. The surgeon should also take into consideration the possible need for later surgery, ie, secondary knee arthroplasty after a proximal tibial fracture or a secondary closure of a defect with a local or regional flap (chapter 10.4, 10.5).

If more than one incision is planned, care should be taken not to compromise the vascularity of the skin bridge. Generally, a skin bridge should be performed as wide as possible,



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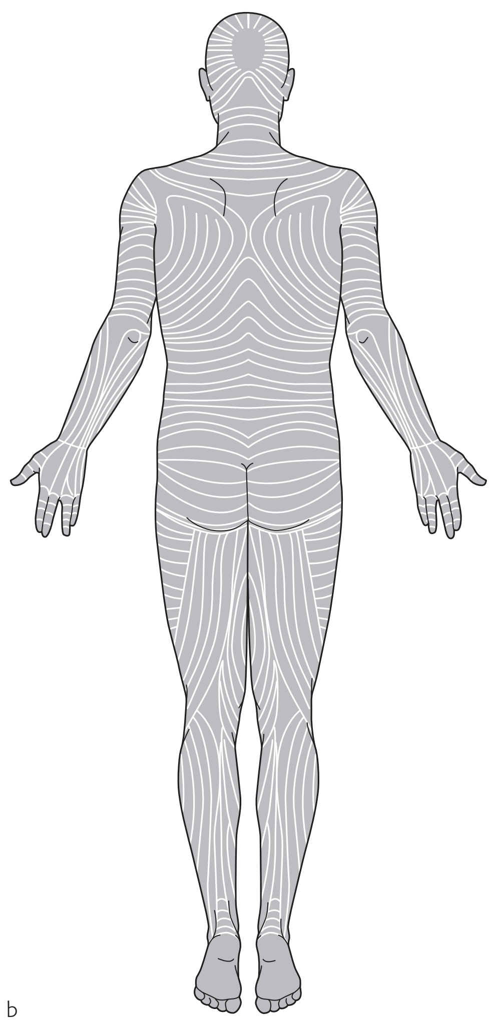


b

Fig 1.2-1a–b Distribution and orientation of Langer lines (ie, cleavage lines) in the adult.
a Anterior view.
b Posterior view.

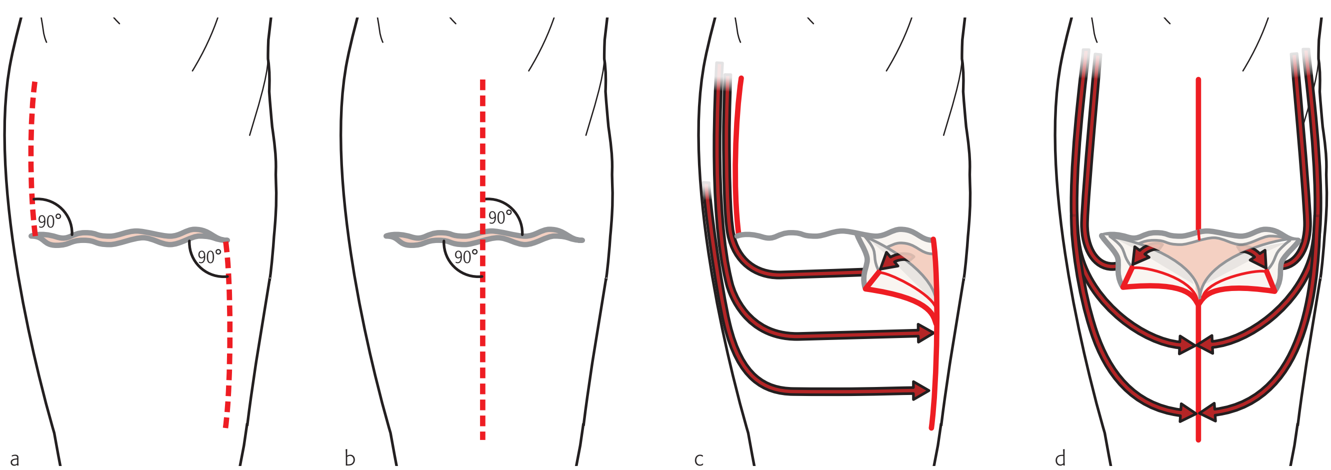
bearing in mind an adequate width-to-length ratio of the randomly perfused flap (chapter 10.3). This ratio will vary depending on the flap's location (eg, lower extremity versus upper extremity, thigh versus lower leg). The surgeon should be aware that swelling, bruising or internal degloving of the tissue between incisions are cause for concern. Also, the location of the incisions must be considered with regard to closure and the resulting scar. Skin which overlies bone prominences is less resistant to shear because there is less subcutaneous tissue. The resulting scar is often prone to hypersensitivity and tends to be unstable.

Surgeons may also be confronted with an old scar or skin graft near the site they would like to make a new incision. If the scar is more than 6 months old, surgeons may safely proceed to make a new incision where they deem necessary without regard for creating a nonviable skin bridge. Skin grafts may be incised as soon as they have completely taken (generally 6 weeks after application), though the graft should not be undermined.

A situation which often arises is the issue of a transverse laceration. This laceration compromises the skin distal to it because it disrupts the longitudinal blood flow within the fascia. However, usually there is also an associated fracture or tendon laceration. This requires extension of the wound to allow adequate exposure for inspection, debridement and eventually repair. Extension can be performed in two ways. The surgeon may decide to extend in a Z-fashion (**Fig 1.2-2a**) or in a T-fashion (**Fig 1.2-2b**). The theoretical advantage of extending the incision perpendicular to the transverse incision is to reestablish blood flow by ingrowth of vessels adjacent to the zone of injury as the blood flow to the skin distal to the laceration is compromised. The distance from healthy skin to the edge of the incision is longer in a Z-incision than in a T-incision as shown in **Fig 1.2-2c–d**. Extension of the wound using a perpendicular incision is preferred. Acute angles should be avoided.

Despite the benefits of a minimally invasive approach [1], short incisions are not necessarily better than longer ones. Too much traction on the wound edges and extensive subcutaneous dissection can result in poor healing and scarring. Furthermore, the surgeon should be aware that stab incisions for placement of percutaneous screws may put nerves in jeopardy (eg, superficial fibular nerve). For the management of open fractures consult chapter 7.

Finally, it is generally agreed that the less time skin is open, the lower the risk of infection, especially in cases of trauma. However, this should not imply that a less than ideal reduction of the joint should be accepted for the sake of shorter operative time. Organizing an experienced team, not delegating the procedure to less-experienced colleagues, and moving purposefully through the case are ways to decrease operative time without compromising outcome.



a b c d

Fig 1.2-2a–d Management of a transverse wound.
a Transverse wound extended in a Z-fashion (red dotted line = planned incision).
b Transverse wound extended in a double opposing T-fashion (red dotted line = planned incision).
c Perfusion of a skin flap using a Z-like extension technique. Note that blood flow must traverse the entire zone of elevated skin flap (arrows).
d Perfusion of a skin flap using a double-opposing T-like extension technique. Note that the distance, which must be perfused (arrows) to reach the incision, is halved in comparison to that in **Fig 1.2-2c**.

1.3 Intraoperative principles

Author James N Long

1.3.1 Choice of instruments

Introduction

Instruments (**Video 1.3-1**) are an extension of the surgeon's hands used to manipulate the tissues, expose the surgical field or reduce and fix a fracture. They should be carefully chosen to minimize damage and tension to the skin and all other tissues, while providing adequate exposure for surgery. Each surgeon has a preference for which instrument to use in a given situation. However, there are some guidelines and caveats regarding instruments, which can be generalized.

Forceps or pick-ups

There are numerous types of forceps (**Fig 1.3-1a–g**) commonly used in orthopaedic surgery. Large forceps such as rat-tooth forceps are used for heavier tissue such as muscle fascia, bone fragments or tendon. Large forceps such as Ferris-Smith forceps are used for the heaviest tissues such as fascia lata and tendon insertions. Small forceps such as Adson forceps are used for skin and delicate tissues such as peritoneum or perineurium. DeBakey forceps are typically used when dissecting neurovascular structures. Smaller forceps apply less force to tissues than large forceps when used in appropriate tissues. Large, toothed forceps such as rat-tooth or Ferris-Smith forceps should not be used on skin.

Beside the different sizes for more delicate or heavier tissues, the structure of the teeth—smooth or sharp (V-groove)—will influence the amount of force or squeeze required to hold a specific tissue. Smooth-toothed forceps (Cushing, Adson-Brown) depend on compression force to grasp tissue and, therefore, will require more force to grasp than sharp-toothed forceps (rat-tooth, Ferris-Smith), which grasp by penetrating the tissue with their teeth. Large forceps such as Russian forceps are used primarily for placement of bone grafts, sponges, etc into a wound or defect, rather than for grasping.

Video 1.3-1 Assortment of instruments needed for soft-tissue surgery.

Scissors

Scissors (**Fig 1.3-2a–f**) should be selected according to the tissue that is being separated or divided. They should be well maintained with a smooth action and should be regularly sharpened or replaced. Dull scissors will crush tissue rather than cleanly divide it and should be avoided, especially in traumatized tissue.

Small tenotomy and Reynolds scissors should be used exclusively to dissect delicate structures such as nerves or vessels, while large Metzenbaum scissors are appropriate for heavier tissues such as the fascia lata. A separate pair of scissors should be used to cut suture, because this will rapidly dull scissors.

Sharp-pointed scissors are typically used to divide tissue while blunt-pointed scissors are more often used to spread tissue.

Tissue clamps

Tissue clamps are similarly structured as forceps— with sharp teeth (Kocher, Mikulicz) or smooth (Pean)—and come in different dimensions. The most delicate clamps and forceps are designed for vascular surgery and called "nontraumatic" as they do not damage the vessel wall, which they gently occlude during vascular reanastomosis.

Retractors

There are many different types of retractors. Some have a ratchet device on the handle, which allows them to be self-retaining. Others are held by hand. Retractors are used to provide exposure of the target area such as a fracture.

Some retractors are smooth and depend on downward pressure on the retractor to contain the tissue they retract. Blunt retractors such as US-Army or Faraboeuf retractors (**Fig 1.3-3a–i**) are commonly used for retraction of small to moderately large tissue masses. Toothed or sharp retractors such as Kilner, McIndoe, or Volkmann hooks and retractors (**Fig 1.3-4a–d**) have hooks or sharp teeth, which bite into soft

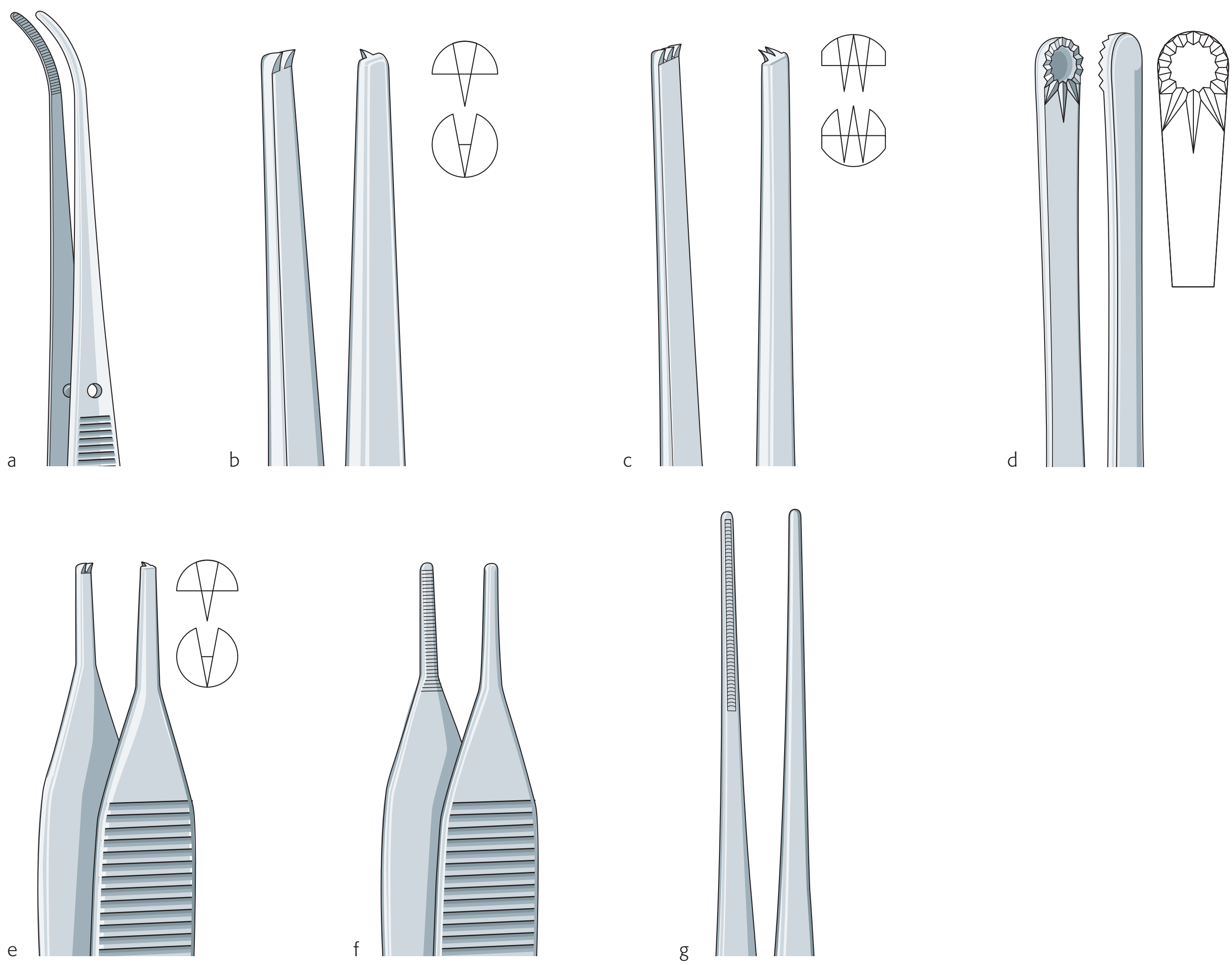


Fig 1.3-1a–g Assortment of forceps commonly used in orthopaedic surgery.

- **a** Cushing forceps (straight or curved), available as noninsulated or insulated (electrocautery) forceps.
- **b** Rat-tooth forceps.
- **c** Ferris-Smith forceps.
- **d** Russian forceps.
- **e** Adson forceps (surgical forceps).
- **f** Adson-Brown forceps (anatomical forceps).
- **g** DeBakey forceps (vascular forceps).

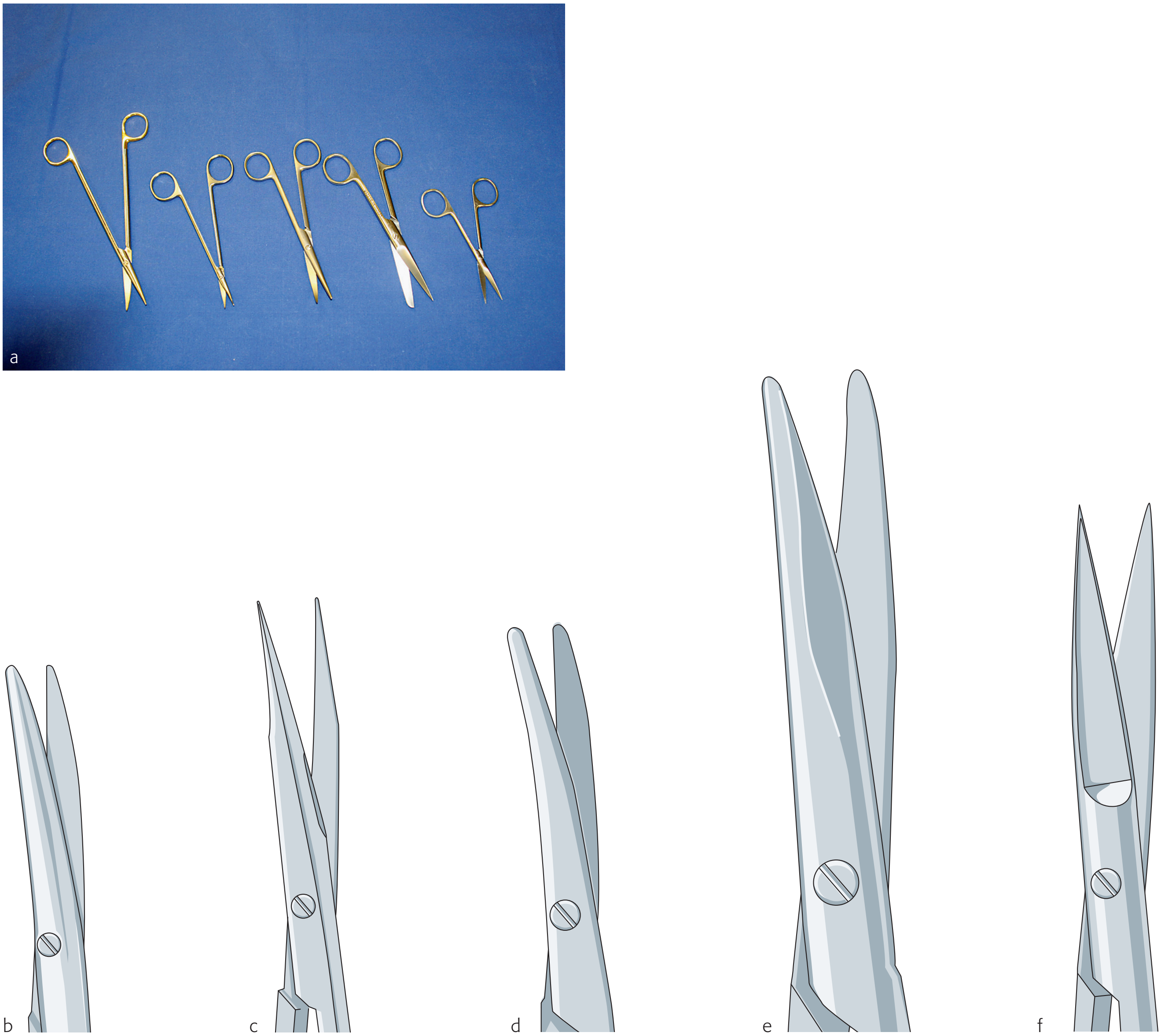


Fig 1.3-2a–f Assortment of scissors commonly used in orthopaedic surgery.

a Overview.
b Tönnis-Adson scissors.
c Reynolds scissors.
d Metzenbaum scissors (curved).
e Mayo scissors (straight).
f Sharp-pointed small scissors that may be used for sutures.

tissue to retract skin (Kilner, McIndoe) or subcutaneous and muscle tissues (Volkmann). They are potentially more damaging to soft tissue but may require less retraction force. Retractors such as Hibbs retractors are a hybrid between the two, with a broad, smooth blade and small teeth at the base of the blade.

Self-retaining retractors (**Fig 1.3-5a–c**) also come in sharp or blunt varieties. These retractors are used when the surgeon requires another set of hands. Some, such as Weitlaner retractors, distribute force across a large area and expose more underlying tissue, whereas others such as Gelpi retractors concentrate force in a narrow area.

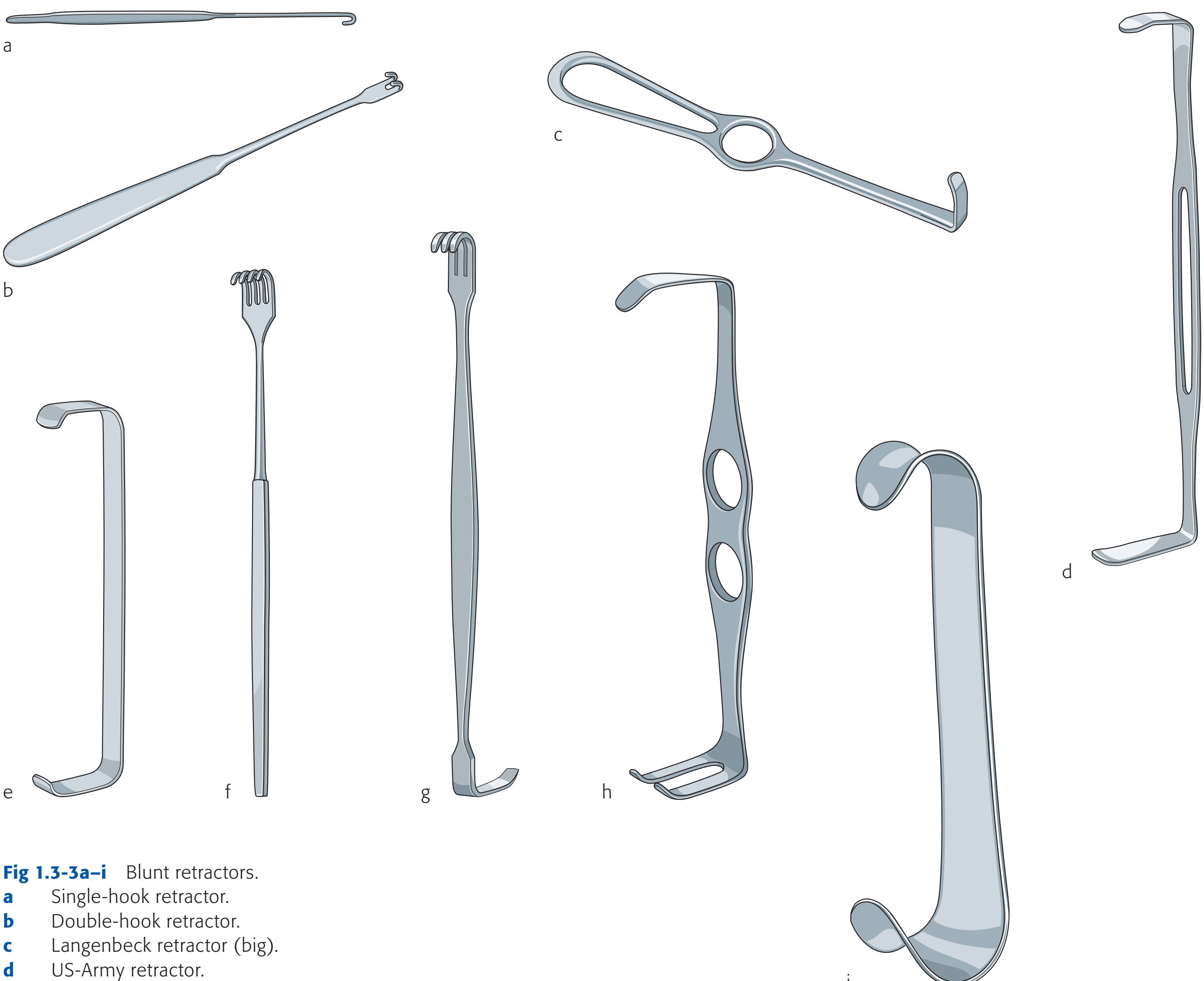


Fig 1.3-3a–i Blunt retractors.
a Single-hook retractor.
b Double-hook retractor.
c Langenbeck retractor (big).
d US-Army retractor.
e Faraboeuf retractor.
f Multiple-hook retractor.
g Senn-Miller retractor.
h Mathieu retractor.
i Roux retractor.

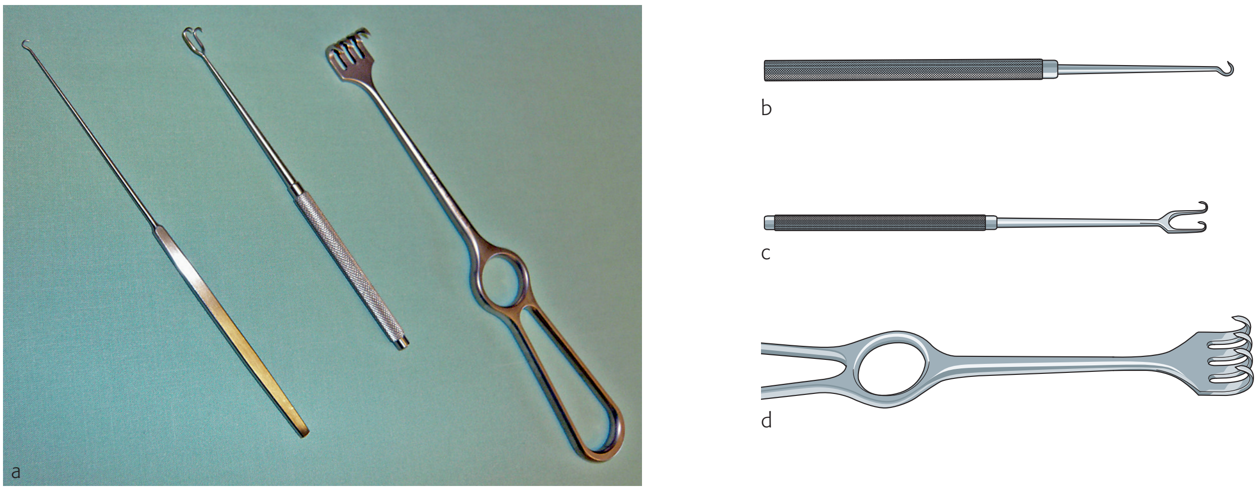


Fig 1.3-4a–d Assortment of sharp retractors commonly used in orthopaedic surgery.
a Overview.
b Kilner retractor (ie, single skin hook).
c McIndoe retractor (ie, double skin hook).
d Volkmann retractor (ie, multi-hook retractor).

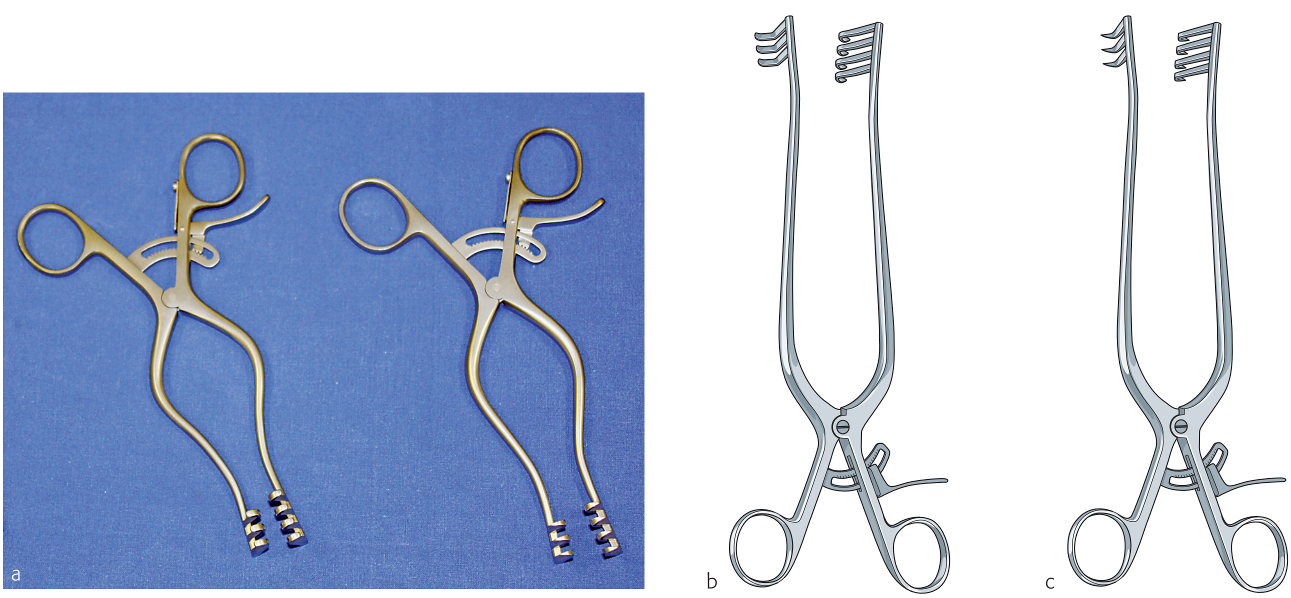


Fig 1.3-5a–c Assortment of self-retaining retractors commonly used in orthopaedic surgery.
a Overview.
b Weitlaner retractor (blunt).
c Weitlaner retractor (sharp).

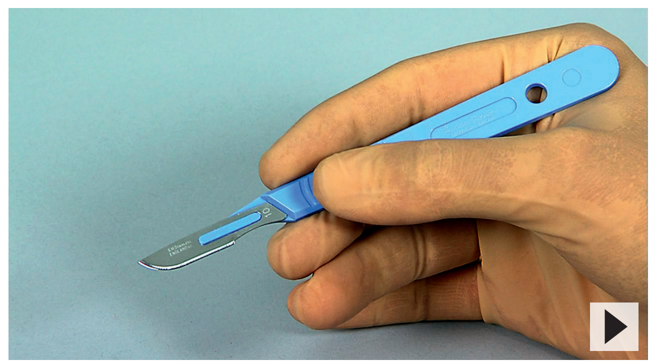
Finally, lever retractors (**Fig 1.3-6a–d**) such as Hohmann, Bennett, and double-angle Schumacher retractors are designed to be placed around bones with leverage applied to retract tissue. They are commonly used when plating long bones or pelvic fractures.

1.3.2 Handling of instruments

Scalpel (Video 1.3-2)

For the skin incision, the scalpel blade must be new and sharp. It must be held perpendicular to the skin surface and incise the skin completely on the first pass of the blade, rather than making multiple small and partial incisions through the dermis. Large scalpels such as #10 and #21 are typically used for incision of the skin, while #10 and #15 blades are generally used for smaller incisions and dissection in deeper planes (**Fig 1.3-7a**). For most orthopaedic procedures, the scalpel is held as one would hold a pen, between the thumb and index finger (**Fig 1.3-7b**). Skiving and undermining of the skin must be done parsimoniously, as this compromises its vascularity and healing capacity (**Fig 1.3-7c**). The dip of the scalpel is not used, except when making stab incisions for percutaneous pins, screws, etc.

Depending on the surgeon's preference, scalpels may also be used for tissue dissection in deeper layers than the skin. A separate blade than that used for skin should be used, because cutting skin rapidly dulls the blade and, moreover, may potentially contaminate deeper structures due to the first cut through the skin. Sharp dissection with a scalpel tends to cause less tissue damage than sharp dissection by scissors, because the latter tend to locally crush tissue.



Video 1.3-2 Correct versus incorrect use of the scalpel.

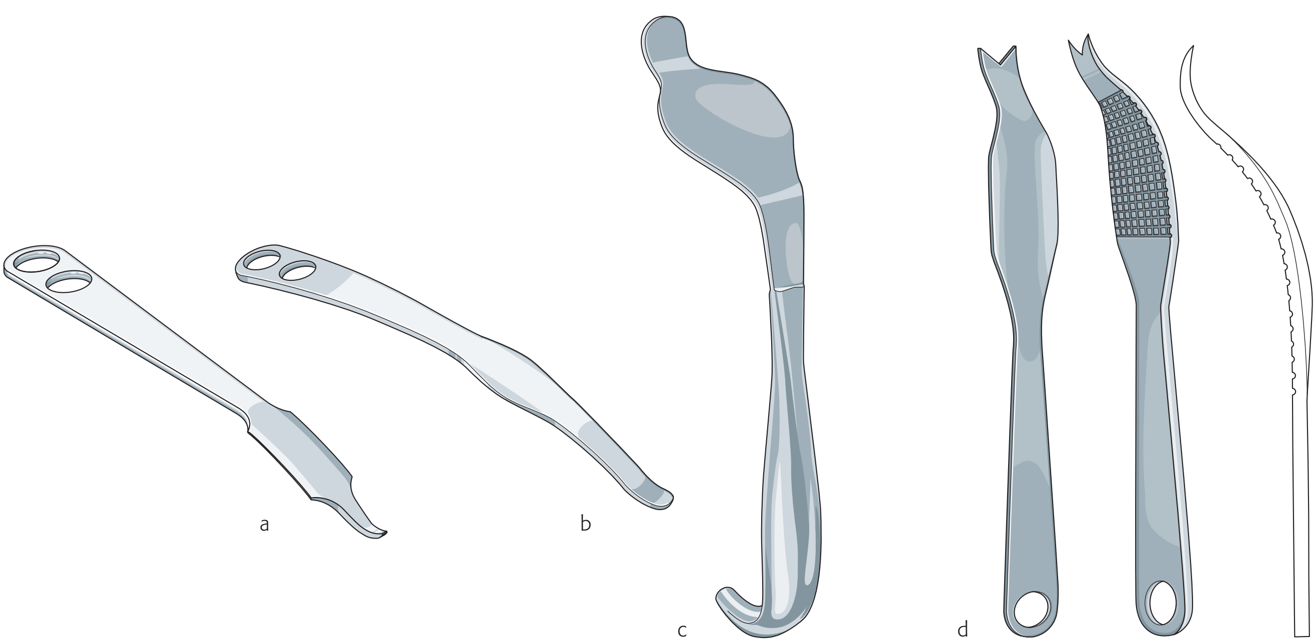


Fig 1.3-6a–d Assortment of lever retractors commonly used in orthopaedic surgery.
a Hohmann retractor (sharp).
b Hohmann retractor (blunt).
c Bennett retractor.
d Schumacher retractor.

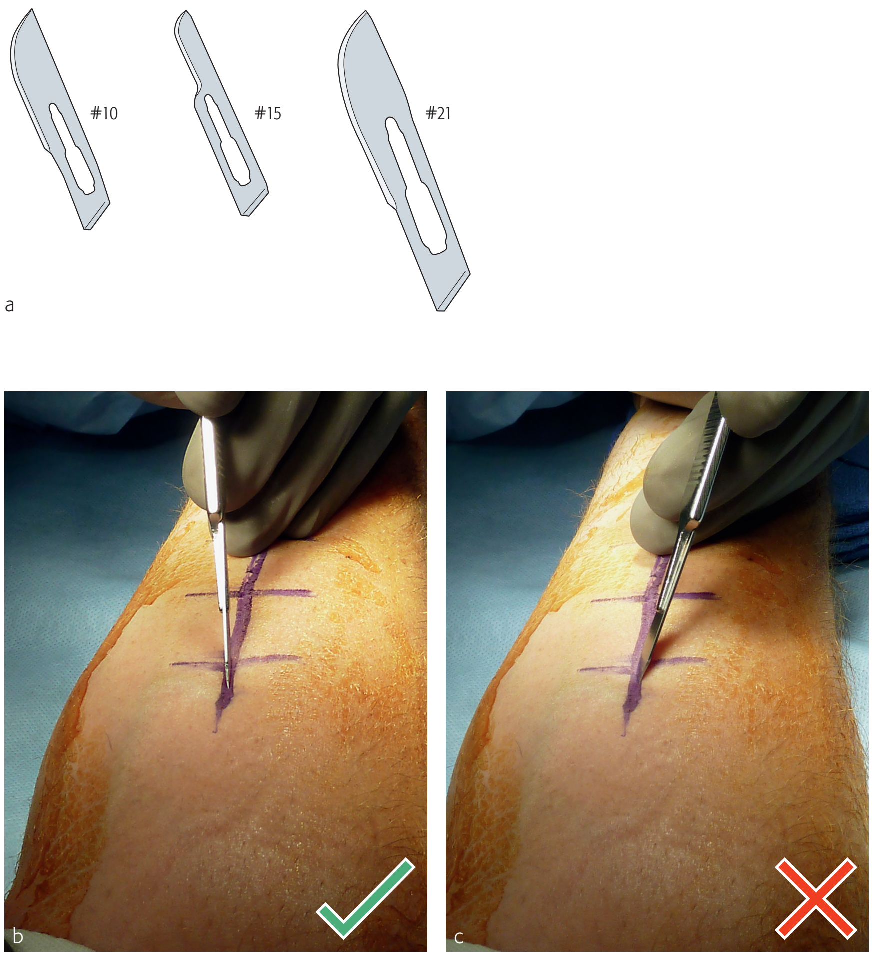


Fig 1.3-7a–c Use of the scalpel.

- **a** Common blades: size #10 and #21 for skin incisions; size #10 and #15 for subcutaneous dissection.
- **b** Hold the scalpel correctly between thumb and fingers like a pencil and make sure the blade stays perpendicular to the tissue.
- **c** Incorrect use of the scalpel. Always avoid skiving (cutting obliquely to) the skin.

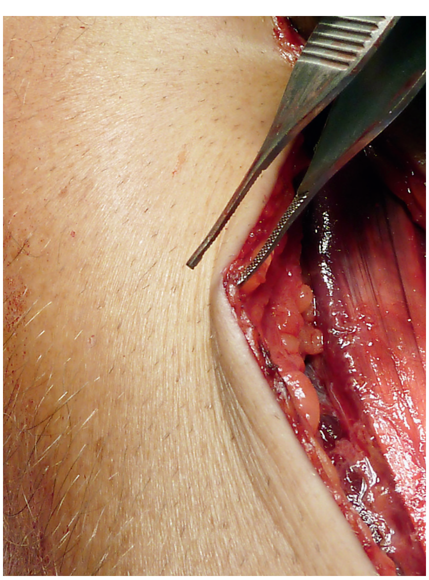


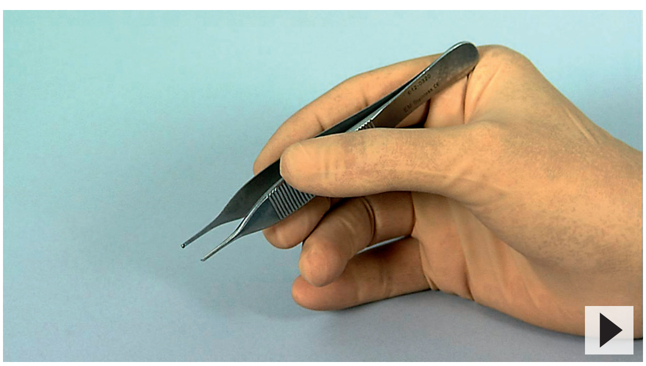
Fig 1.3-8 Use of forceps to lift skin for placement of sutures without grasping the skin edge.

Forceps or pick-ups (Video 1.3-3)

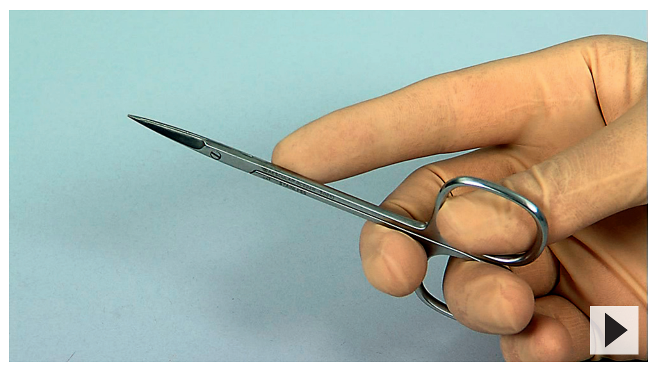
Forceps are used to lift or grasp tissue. All forceps require some pressure between the tips in order to grasp tissue. However, the surgeon must always be always mindful of the degree of pressure which is applied, since crushing of tissue may cause permanent injury. This is especially true in traumatized tissue. Use only enough force to not allow the tissue to slip. Toothed forceps can be used to lift tissue without pinching it (**Fig 1.3-8**). Use small forceps for skin and subcutaneous tissue. Large forceps can be used on heavy fascia. Forceps should also be routinely used to handle suture, rather than grasping the needle with the fingers, in order to avoid needle puncture injuries.

Scissors (Video 1.3-4)

In some cases, scissors will be used to cut through tissue, in others, for example in loose connective tissue, scissors may also be used for blunt dissection. Dissection by scissors should be in a vertical direction (**Fig 1.3-9a–b**) and should follow anatomical structures and cleavages. Longitudinal dissection along the course of nerves and vessels helps reduce injury to skin vessels and nerves. Horizontal dissection between dermal layers and subcutaneous layers or between muscle fascia and subcutaneous tissue should be avoided whenever possible. Similarly, muscles and tendons should not be cut unless inevitable. Muscle insertions to bone are often better released by tangential osteotomy than by tissue transection (ie, tip of trochanter or olecranon).



Video 1.3-3 Correct versus incorrect use of forceps.



Video 1.3-4 Correct versus incorrect use of scissors.

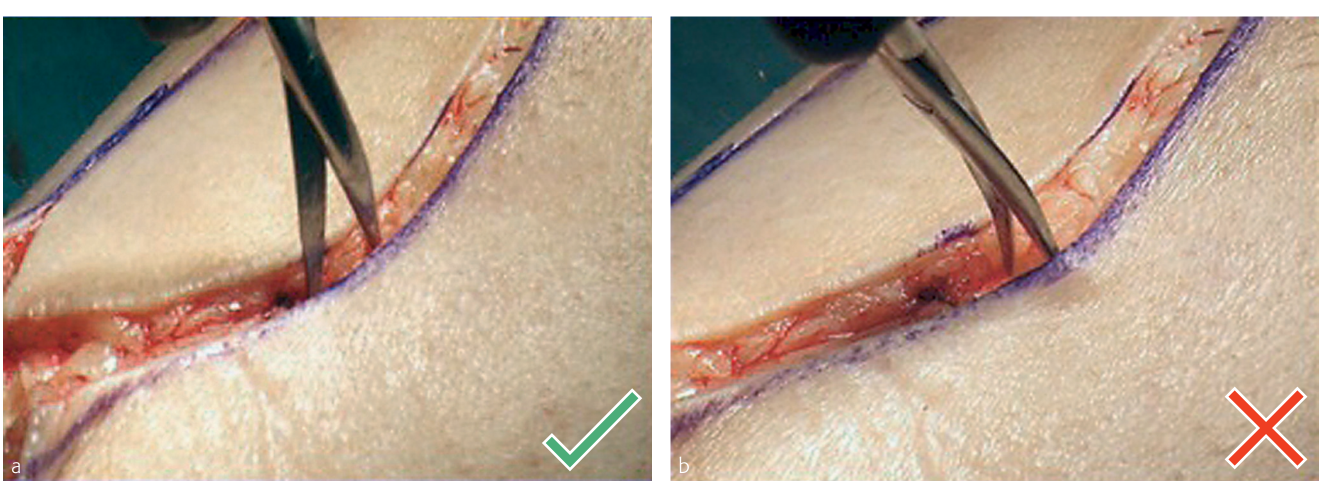


Fig 1.3-9a–b Dissection of subcutaneous tissue.
a Correct: dissection following the line of incision.
b Incorrect: crosswise dissection within the incision.

Retractors (Video 1.3-5)

Using retractors, the surgeon needs to find a balance between adequate exposure and avoiding injury to the tissues under strain. Assistants should always be conscious of how much pressure is being applied to the already traumatized soft parts. When the surgeon is not actively working in the wound, retraction must generally be released in order to allow the tissues to relax and reperfuse. Great care should be taken not to place excessive traction on neurovascular structures.

Just as important as the pressure applied to retractors is the length of time in which they are actually retracting. When a retractor is being used, local microvascular ischemia is created because of direct pressure on capillaries. Therefore, when the surgeon does not need to view the area exposed by the retractor, its hold should be released.

Whenever possible, retractors should be placed as deeply as possible. Virtually never should retractors be placed between the epidermal and dermal layers of the skin. While the assistant(s) usually hold the retractor, it is the responsibility of the surgeon to bring the retractor into the correct position and to instruct and supervise its careful use.

Special care should be used when employing lever retractors. These retractors can provide a great deal of pressure on the soft tissues, yet are relatively easy for the assistant to hold. Thus, they tend to be retracted too much compared to other handheld retractors. Likewise, self-retaining retractors may also be dangerous because there is a tendency to forget releasing them once they are placed but are no longer needed. They may also be a tendency to forget them after being placed as widely spread as possible, although this may only be required during a small part of the procedure.

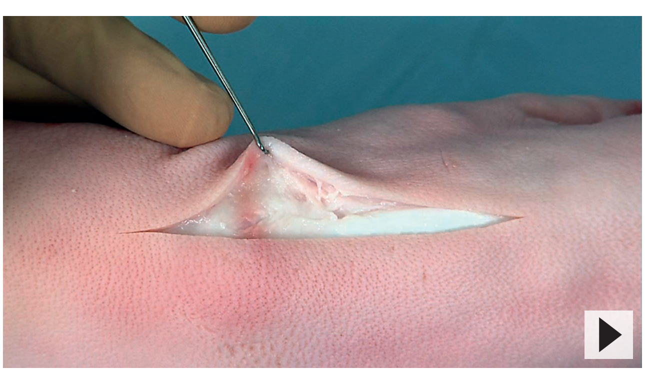
Sharp retractors are more likely to cause damage to adjacent neurovascular structures because their teeth are buried in tissue. They should be used with care around these structures.

When working without an assistant, a suture may be placed through the wound edge and then brought through adjacent skin to provide retraction.

1.3.3 Achieving hemostasis (Video 1.3-6)

Hemostasis is an important part of surgery. Poor hemostasis not only obscures the operative field but also may cause excessive intraoperative blood loss. It can also lead to wound complications due to hematoma, postoperative pain and infection. Meticulous hemostasis will considerably help to prevent hematoma formation and allow the wound to heal without the need to enzymatically degrade hemoglobin by-products and to deprive bacteria of a potential growth medium, which decreases the risk of infection [2]. Hemostasis may be achieved by the use of direct or indirect compression, electrocautery or vascular occlusion (ie, vessel ligation, vascular clip).

All students are taught to use direct pressure to control bleeding by clot formation. However, this may only be temporarily effective and makes it difficult to see the bleeding vessel in order to cauterize or ligate it. Therefore, local



Video 1.3-5 Correct versus incorrect use of retractors.

Video 1.3-6 Correct versus incorrect hemostasis techniques.

compression is more useful for emergency control of larger vessels, which are subsequently ligated or clipped. To control small bleeders, pressure is applied to the skin adjacent to the bleeding vessel. This allows the surgeon to identify and grasp the vascular stump selectively with an Adson forceps and cauterize it precisely. In deeper tissues, a sponge can first be applied to the bleeding area, which is then gently rolled away from the lacerated vessel to expose it. Although this seems intuitively obvious, it is often neglected and large areas of tissue are cauterized uncritically, inducing areas of tissue necrosis. Indirect pressure may be applied to the skin by using a self-retaining retractor, which—although not very elegant—may stop skin bleeders long enough to allow clot formation.

Bipolar electrocautery is used in areas where there is risk of damage to adjacent sensitive tissues, such as in hand surgery. Bipolar electrocautery is more precise because current only flows through the tissue between the electrodes. It does not have as wide an area of effect, though and typically uses lower current. For this reason, with larger vessels, it may not be as effective as tying off the vessel.

Care should also be taken to avoid inadvertent injury to the skin when the forceps are allowed to rest against the skin while electrocautery is applied. Furthermore, electrocautery should be precise, targeting only the individual vessel, rather than an entire area of tissue. As an alternative and for larger vessels ligation or clipping may be safer than electrocautery.

1.3.4 Removal of blood from the operative field (Video 1.3-6)

Blood may be removed from the operative field either by absorptive sponge or by suction. When utilizing suction, it is important to note any bleeding vessels and cauterize actively bleeding vessels, rather than to continue to suction blood. Sponges can be used to apply direct pressure to small bleeding vessels long enough to stop bleeding. They should be used to blot rather than rub or swipe the tissue, in order to avoid knocking loose any clot, which may have formed.

References and further reading

[1] **Helfet D, Suk M** (2004) Minimally invasive percutaneous plate osteosynthesis of fractures of the distal tibia. *Instr Course Lect;* 53: 471–475.

[2] **Lorenz HP, Longaker MT** (2006) Wound healing: repair biology and wound and scar treatment. *Mathes SJ (ed), Plastic Surgery, Vol. 1.* 2nd ed. Philadelphia: Saunders Elsevier, 209–234.