Chapter 13
Wound Healing, Suture Material, and Surgical Instrumentation

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DEFINITIONS

Absorbable sutures—Sutures that lose the majority of their tensile strength before 60 days when implanted in body tissues.

Healing by primary intention—Wound healing that occurs if the wound layers are reapproximated following injury.

Healing by secondary intention—Wound healing that occurs if wounds are left open after injury and allowed to close spontaneously from the formation of granulation tissue.

Healing by third intention—Wound healing that occurs when the wound is closed after an initial period of delay of several days also referred to as *delayed primary closure.*

Knot-pull tensile strength—Breaking strength of a suture when tied around a plastic tube using a surgeon's flat knot and stressed from either end.

Nonabsorbable sutures—Sutures that maintain the majority of their tensile strength before 60 days when implanted in body tissues.

WOUND HEALING

Ideally, organic tissue lost by destruction or injury would be replaced with tissue identical in form and function. This process is known as *regeneration.* Although tissue regeneration does occur in lower animals (e.g., salamanders), humans have lost this ability for the most part. With the exception of the epidermis of the skin, mucosa of the intestinal tract, and liver, damaged human tissue heals by the laying down of collagen, a repair process better known as *scarring*. This process is responsible for emergently sealing the wound and ultimately providing longterm structural support for the injured organ but is unable to reproduce other functions of the replaced tissue. As a result, the healing process also leads to disease if an organ becomes unable to function properly owing to extensive replacement of functioning tissue by nonfunctioning scar. Heart failure following a massive myocardial infarction is an example. In other cases, the healing process itself directly produces disease (e.g., postoperative adhesion formation following surgical procedures or tubal occlusion after pelvic inflammatory disease).

Physiology of Wound Healing

The healing of a wound involves several distinct biologic processes: (a) inflammation, (b) epithelialization, (c) fibroplasia, (d) wound contraction, and (e) scar maturation. Although considered distinct, these processes do not occur in a strict sequence but often occur simultaneously with each other. These repair mechanisms are also nonspecific. They are activated whether a wound is made with a surgical scalpel and sutured closed or by trauma and then allowed to heal without surgical closure. However, the nature of the wound influences the degree to which each individual process is involved, and this in turn can affect the ultimate success of the repair.

Inflammation

The inflammatory phase of healing is the initial response to any injury involving more than an epithelial surface. This phase can be divided into two separate but simultaneously occurring responses: a vascular and a cellular

response. Both are initiated by amines, most notably histamine, as well as the kinins and proteolytic enzymes released by the injured tissue. Immediately after injury, a transient vasoconstriction of the local vasculature lasts for 5 to 10 minutes. Vasoconstriction is followed by vasodilatation and an increase in vascular permeability. Edema caused by the escape of plasma through altered vessel walls becomes clinically apparent at this point.

The cellular response is characterized by the migration of leukocytes into the injured area. Although the agents responsible for this active migration of leukocytes remain unclear, chemotactic factors are thought to play a major role. Initially, the polymorphonuclear leukocytes and monocytes in the wound are present in the same concentration as in the systemic circulation. As a result, polymorphonuclear leukocytes predominate for the first 3 days. Because polymorphonuclear leukocytes are relatively short-lived compared with monocytes, the latter stages of the inflammatory phase are characterized by a predominance of monocytes that transform into macrophages. These leukocytes actively phagocytize bacteria, foreign proteins, and necrotic debris. As polymorphonuclear leukocytes die, their intracellular enzymes and debris are released into the wound and become part of the wound exudate. These released enzymes also facilitate the breakdown of material not phagocytized by the leukocytes. This accumulated exudate or pus develops even in the absence of bacteria. Even when this exudate is sterile, the presence of proteolytic enzymes, including collagenase, can interfere with epithelialization and fibroplasia and, thus, interfere with continued wound healing. Poor wound healing, however, is more common in wounds contaminated with bacteria and foreign material. In these cases, the inflammatory response may persist for long periods of time.

Epithelialization

By virtue of their exposed location, the epithelial surfaces of the gastrointestinal, urogenital, and respiratory tract as well as the skin itself are continually subjected to the physical and chemical trauma associated with the activities of daily living. As a result, these surfaces are constantly replacing damaged or destroyed cells through a process known as *epithelialization.* Epithelialization occurs by migration and subsequent maturation of immature epithelial cells from the deeper basal layers of surrounding areas. If the cellular damage is confined entirely to the epithelium, the healing response is merely an exaggerated form of the basic normal replacement process.

If an injury involves the supporting connective tissue beneath the epithelium, however, the other components of the healing processes, in addition to epithelialization, become involved. If the injury severs blood vessels, the vessels retract, and the process of hemostasis is initiated. If bleeding is not too severe, a blood clot soon forms. This clot subsequently contracts, dehydrates, and becomes a scab. Within 12 hours, basal cells from the surrounding epithelial surfaces begin migrating onto the injured surface. Epithelial cells move beneath the scab, detaching it from the wound and sealing the surface. In incised and sutured wounds, epithelialization generally produces a watertight seal within 24 hours of injury. This new layer of epithelial cells is initially thin and poorly attached to the underlying surface, rendering it susceptible to injury from even minor trauma. Final epithelial healing is accomplished by differentiation and maturation of the migrated cells and by scar formation through fibroplasia.

Fibroplasia

The process by which wounds regain strength is termed *fibro-plasia.* Fibroplasia results in the production of the collagen necessary to form a fibrous scar and ultimately determines the final strength of the healed wound. This process begins with the differentiation of mesenchymal cells into fibroblasts. Fibroblasts then migrate into the wound, apparently along fibrin strands produced during clot formation. Once at the injury site, fibroblasts proliferate and manufacture the glycoproteins and mucopolysaccharides that make up the ground substance of connective tissue. Ground substance is an amorphous matrix that is believed to induce aggregation of collagen

subunits and influences the final orientation of the fibers.

Once the ground substance is produced, fibroblasts begin to synthesize the basic building block of collagen-tropocollagen. Tropocollagen is a stiff elongated macromolecule of three helically intertwined chains of amino acids consisting of two identical α1 chains and one α2 chain. Within the ground substance and at the proper pH, osmolality, and temperature, tropocollagen molecules polymerize into collagen fibrils by forming covalent bonds with their neighbor. These fibrils bond with other fibrils to form collagen bundles. It is not until 4 to 5 days after injury that the wound produces enough collagen to result in a measurable increase in wound tensile strength. Before this time, the wound is held together only by fibrous adhesion. This time frame between wounding and an increase in tensile strength originally was referred to by Howes and Harvey as the “lag period” of wound healing.

Wound Contraction

The manner in which tissue heals is dependent on whether tissue integrity is simply interrupted (as in a surgical incision) or tissue is removed (as in an avulsion injury). In both types of injury, tissue seals itself, begins to reepithelialize, and synthesizes collagen for structural support. However, when large amounts of tissue are missing, the edges of the wound must be brought closer together so that the previously noted tissue responses can repair the defect. This process is known as *contraction.* Contraction of wound margins begins about 5 days after injury and corresponds with the fibroplasia phase of healing. Because this process can be inhibited by cytochrome poisons, such as potassium cyanide, and by smooth muscle relaxants, older theories attributing wound contraction to passive collagen changes have been discarded. Instead, wound contraction appears to be an active process produced by contractile proteins within the fibroblasts. If the area is too large for contraction to bring the edges together, the wound remains covered with granulation tissue, or if small enough, it is covered with epithelium only. Epithelialization of such a wound prevents weeping, but without the normal underlying supporting stroma, it remains too fragile to provide lasting protection. Pathologic progression of skin contraction ultimately may result in restriction of joint or limb mobility. This deformity is termed *contracture* and should not be confused with contraction.

Scar Maturation

The bulky scar formed during the fibroplasia phase consists of randomly oriented soluble collagen fibers. This scar has little tensile strength. During scar maturation, the disordered fibers are replaced with fibers arranged in a more orderly fashion, producing a denser and stronger scar. Collagen fibers also continue to form covalent bonds within fibrils as well as between adjacent fibrils and fibers, resulting in a continued increase in wound tensile strength over time. This maturation process may continue for years.

During scar maturation and remolding, the breakdown of old disordered collagen slightly exceeds production of new organized collagen fibers. The resulting new scar is softer and less bulky than is the original scar but also is stronger because of its more organized and extensively cross-linked nature. However, if collagen production exceeds breakdown, then a keloid or hypertrophied scar results.

Surgical Wound Healing

Depending on the manner of wound closure, three types of surgical wound healing are recognized: primary, secondary, and third intention. **Figure 13.1** illustrates these types of wound healing.

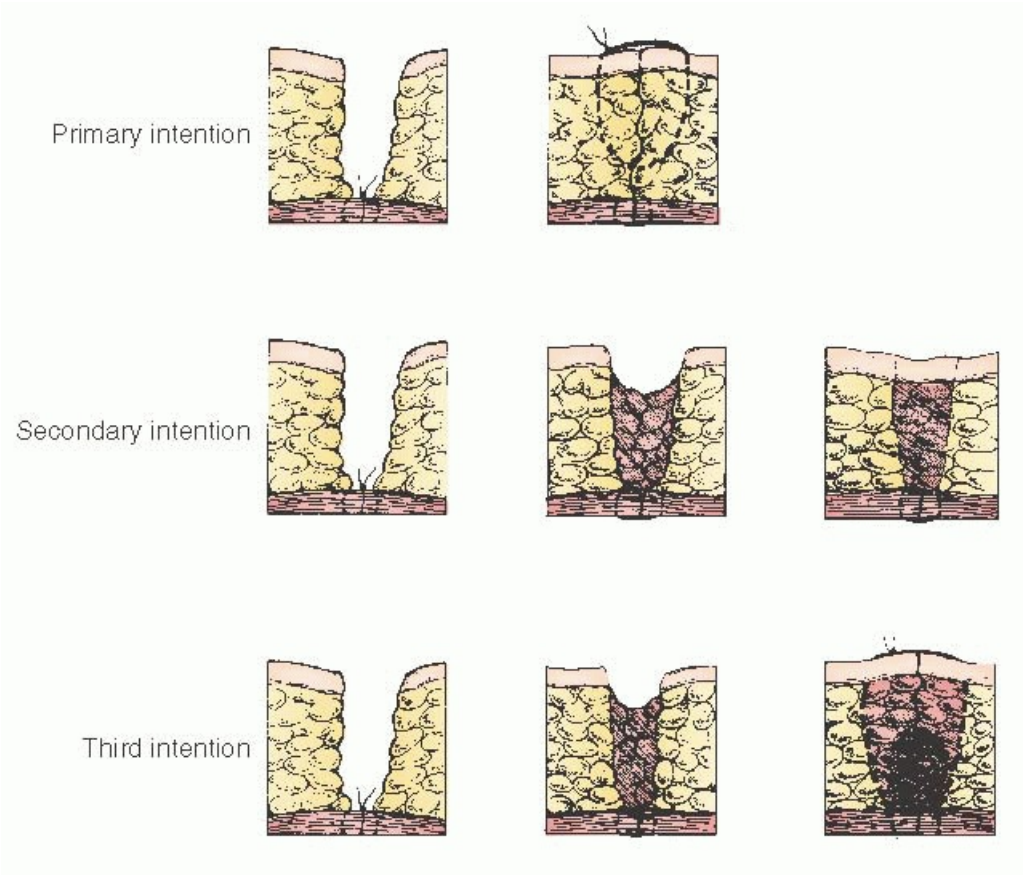

FIGURE 13.1 Types of wound healing.

Primary Intention

Healing occurs by primary intention if the wound layers are reapproximated following injury. This apposition of tissue layers allows healing to occur in a minimum of time, with no separation of wound edges and with minimum scar formation. This is the desired mode of healing for surgical incisions.

Secondary Intention

It has been known for centuries that a wound has a higher resistance to infection when left open rather than closed. This was demonstrated experimentally in dogs by Bilroth, who applied dressings soaked in liquid feces and pus to wounds. Wounds left open remained healthy in appearance, whereas those that were subsequently closed became infected. As a result, contaminated or infected surgical wounds often are left unapproximated and allowed to close spontaneously. This type of wound healing is referred to as healing by secondary intention. This healing process obviously is more complicated and prolonged than that of primary intention. The wound eventually heals by a combination of contraction and the formation of granulation tissue with the wound gradually filling in from the raw surfaces. This type of healing is slow and frequently characterized by formation of excessive scar tissue. Granulation tissue from the healing wound also may protrude above the wound margin during this process. This can prevent final epithelialization of the surface and require further treatment for complete healing.

Third Intention

Wound healing by third intention, also known as *delayed primary closure,* refers to the technique of wound closure after a period of delay. This method often is used after postoperative wound breakdown or as an alternative to healing by secondary intention of wounds that should not be closed primarily, such as grossly contaminated or infected wounds. The timing of closure is important. After delays of 7 to 8 days, the wound

edges become increasingly difficult to approximate because of the increasing collagen content. Edlich and colleagues have suggested that closure on or after the 4th day appears to be ideal. This concept also is supported by Lowery and Curtis, who showed that wounds closed after a delay of between 3 and 6 days have the lowest infection rates. Furthermore, studies by Fogdestam revealed that wounds closed during this time frame also have greater wound strength at 20 days than do wounds closed primarily.

Methods of Wound Closure

Wound dehiscence with evisceration is a serious complication of abdominal surgery. This complication is associated with prolonged morbidity and high mortality. Published mortality figures range from 18% to 35%, with a mean of 20%. Wound dehiscence occurs in 0.5% to 5% of all abdominal surgeries but is less frequent (0.1% to 0.7%) with gynecologic abdominal procedures. Potential reasons for the decreased rate of dehiscence associated with gynecologic surgery include the use of transverse incisions, healthier patients, lower infection rates, and a lower rate of bowel enterotomies.

Traditionally, gynecologic surgeons have been taught that vertical incisions are associated with a greater likelihood of dehiscence than are transverse incisions. Critical review of the earlier data supporting this conclusion reveals that significant confounding variables often were ignored. In general, vertical incisions often were performed emergently on sicker patients or those who had other risk factors for dehiscence, such as cancer. Transverse incisions typically were performed on relatively healthy patients undergoing elective surgery. At least two randomized studies by Greenall and colleagues and Stone and associates have shown no difference in hernia formation or dehiscence between vertical and transverse incisions.

Proper suture selection is critical in preventing wound dehiscence. The wound may break down if the suture has too little initial tensile strength or if the suture is absorbed too quickly before the wound regains enough strength to resist normal stress. The suture also is only as strong as the knots placed in it. If the knot is tied using an improper technique or too few knots are placed, the knot can slip and the suture line fail. The issues involved with proper suture selection and knot security are discussed in detail later in this chapter. Proper surgical technique is one of the most critical factors in preventing wound dehiscence. Several studies have indicated that the most common cause of wound dehiscence is intact sutures pulling through fascia. Animal studies have confirmed that incisions closed with wide loose fascial bites have greater tensile strength than do those closed using smaller fascial bites. Sanders and DiClementi also have shown that tightly tied fascial sutures result in fascial necrosis beneath the sutures. Thus, the old adage that one should “approximate and not strangulate fascia” is well taken.

Although the use of loose, wide fascial bites appears to reduce the likelihood of suture pull-through, the optimum distance sutures should be placed from the fascial edge is unknown. However, data obtained by Campbell and colleagues can provide some guidelines. When the pullout force and pullout energy of sutures placed in cadaver fascia were plotted against bite size, bites of 0.9 cm yielded the maximum pullout force, but maximum pullout energy was obtained with bite sizes of 1.2 to 1.5 cm. Unfortunately, it is unknown whether pullout energy or pullout force is more clinically relevant.

Tera and Aberg, working with human cadavers, have shown that the strength of a sutured midline incision is approximately doubled if sutures are placed lateral enough to include the edge of rectus muscle. Normally a bite of approximately 1.5 to 2 cm is required to include rectus muscle in a midline closure. From these studies, it appears that fascia sutures should be placed at least 1.0 cm from the fascia edge and that bites of 1.5 cm or larger are probably preferable.

The use of large tissue bites may be responsible, in part, for the success of mass closure techniques, such as retention sutures, or the Smead-Jones closure, in which wide sutures are passed through fascia, muscle, and peritoneum. The Smead-Jones mass closure consists of a combination “far” mass closure bite at least 2.5 cm

from the fascial edge on each side of the incision with a second “near” bite through the fascial edge. This far-far/near-near technique is considered the gold standard for vertical closure because it has been shown consistently to be more secure than simple layered closure.

Unfortunately, the Smead-Jones technique is time consuming and requires a large number of sutures. One solution to this problem has been the use of a continuous running mass closure. In gynecologic surgery, abdominal incisions traditionally have been closed in layers with interrupted sutures. The belief that interrupted sutures provide greater wound security than does a continuous suture is not well documented, and there are several well-performed studies using both general surgery and gynecologic oncology patient populations showing continuous closure to be comparable to Smead-Jones closure provided that adequate tissue bites are taken. A recent meta-analysis of available randomized trials suggests that a continuous technique also is associated with decrease in subsequent ventral hernia formation. The continuous technique not only is the most rapid of all the mass closure methods but also

is more rapid than are traditional interrupted layer techniques. One theoretical advantage of a continuous suture line is that any stress on the incision is distributed along the entire suture line and not confined to one loop of suture, thereby potentially decreasing the likelihood of suture pullout.

TABLE 13.1 U.S. Pharmacopeia-Required Knot-Pull Tensile Strength (LB)

ABSORBABLE SUTURES			NONABSORBABLE SUTURES		
SIZE	**NATURAL**	**SYNTHETIC**	**CLASS I**	**CLASS II**	**CLASS III**
4-0	1.7	2.4	1.3	1.0	1.8
3-0	2.7	3.9	2.1	1.5	3.0
2-0	4.4	6.2	3.2	2.3	4.0
1-0	6.1	8.8	4.8	3.2	7.5
1	8.4	11.6	6.0	4.0	10.5

Mass closure techniques classically have used a nonabsorbable permanent suture. The use of nonabsorbable sutures occasionally produces painful palpable knots or results in the formation of suture sinuses. The development of slowly absorbed synthetic sutures has allowed the use of these sutures for running continuous closures, thus avoiding the potential complications of nonabsorbable sutures. Several studies are now available showing excellent results using a continuous absorbable suture line for fascial closure even in high-risk patients. Although the use of continuous polyglycolic acid and polyglactin 910 sutures to close vertical midline incisions has been discouraged by some surgeons, others have obtained good results in patients at low risk for dehiscence. Since these initial studies, other synthetic absorbable sutures (polydioxanone and polyglyconate) that retain their tensile strength much longer than polyglycolic acid and polyglactin 910 have become available. Because of this delayed loss of tension strength compared with other absorbable suture material, polydioxanone and polyglyconate sutures are especially well suited for continuous fascial closure and should be considered the

absorbable sutures of choice for mass closure of patients at high risk for dehiscence.

The manner in which the incision is made also may influence the dehiscence rate. Although no good data are available, it has been suggested that the shearing produced when scissors are used to incise the fascia results in increased fascia necrosis and an increased breakdown rate when compared with incisions produced by a scalpel. Likewise, the use of electrosurgery to incise the fascia has been implicated by some data to result in an increase in the dehiscence rate. These factors are magnified if the fascia then is closed improperly. Because such fascia necrosis generally occurs only at the cut edge of the fascia, the use of generous fascia bites during fascial closure probably is more important in preventing fascial dehiscence than is the manner of opening the fascia.

SUTURE MATERIAL

It is unknown when humankind first learned to use strings or animal sinews to ligate bleeding vessels or approximate tissue. Any material used for this purpose is commonly referred to as *suture,* whereas the act of reapproximating tissue with suture is known as *suturing.* The first recorded use of suture and suturing dates to the 16th century bc in the Edwin Smith papyrus, the oldest record of a surgical procedure. Over the centuries, many different materials have been used as sutures. These materials include metals (gold, silver, and tantalum wire), plant material (linen and cotton), and animal products (horsehair, tendons, intestinal tissue, and silk).

The United States Pharmacopeia (USP) is the official compendium that defines the various classes of suture as well as sets standards for dimensions and minimum tensile strength for each class of suture marketed in the United States. Most sutures today significantly exceed the minimum tensile strength required by the USP **(Table 13.1).**

Sutures are divided into size categories based on diameter as defined by the USP. Sutures progressively larger than 0 are numbered in increasing numerical order; that is, 1, 2, etc. Sizes progressively smaller than 0 are indicated by an increasing number of zeros; that is, 0, 00, 000. The smaller the suture, the more zeros. For simplicity, the smaller numbers often are written numerically as 1-0, 2-0, etc., where the first numeral refers to the number of zeros.

The USP characterizes sutures based on their rate of absorption by bodily tissues. Sutures initially are classed as either absorbable or nonabsorbable. Absorbable sutures lose the majority of their tensile strength before 60 days when implanted in body tissues. Absorbable sutures are further subdivided by the USP into natural and synthetic sutures. **Figure 13.2** illustrates the percentages of tensile strength remaining for common absorbable sutures at various postoperative time intervals.

Nonabsorbable sutures are defined as sutures that maintain the majority of their tensile strength for more than 60 days in body tissue. These sutures are further subdivided by the USP into three classes: class I is composed of silk or synthetic fibers; class II is composed of cotton or linen fibers or coated natural or synthetic fibers, with the coating forming a casting of significant thickness but not contributing appreciably to strength (these coatings typically are added to improve handling characteristics or resist degradation); and class III sutures are composed of monofilament or multifilament metal wire.

Natural Absorbable Sutures

Plain and Chromic Catgut

One of the oldest suture materials is plain catgut. Catgut consists of highly purified strands of collagen obtained from the submucosa of animals. Despite its name, catgut normally is obtained from sheep or cattle intestines. The name is believed to have originated from the Arabic term *kitgut,* which referred to the strings of a musical instrument known as a kit. Kitgut was made from sheep intestines and probably served as a readily available

source of suture material. Over the years, the term has evolved into *catgut.*

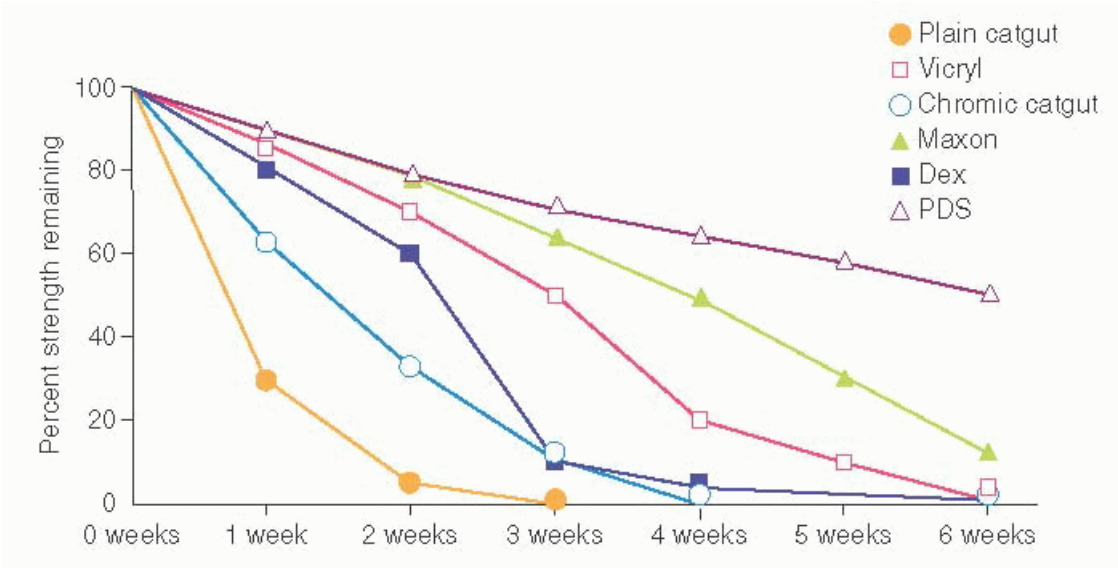

FIGURE 13.2 Percentage of in vivo tensile strength of absorbable sutures remaining at various postoperative times.

Because plain catgut is a foreign protein, it elicits a marked inflammatory response in tissue. It is rapidly degraded by proteolytic enzymes released by white blood cells. This suture loses more than 70% of its tensile strength in 7 days and is totally digested by 70 days. Plain gut is used in tissue in which strength is needed for very short periods of time. It is ideal for Pomeroy tubal ligations because it dissolves rapidly and thus allows the severed ends to fall apart. Less rapidly absorbed sutures, particularly permanent suture, are associated with higher failure rates, probably because of fistula formation.

Chromic catgut is treated with chromic acid salts that bind to the antigen sites in the collagen. The resulting suture elicits less inflammatory response and subsequently is more resistant to degradation. Chromic catgut maintains more than half of its tensile strength at 7 to 10 days, with some measurable strength up to day 21. It is suitable for tissue in which long-term strength is not needed. Examples of such tissue include serosal, visceral, and vaginal tissues. This suture should not be used in skin because the inflammatory response can cause scarring, and the suture often serves as a nidus for infection. Because natural absorbable sutures are degraded by the proteolytic enzymes released by inflammatory cells, these sutures lose strength more rapidly in infected tissue. Because catgut is derived from animal intestines, primarily cow and sheep, there has been increasing concerns over the possibility of theoretical infection with transmissible spongiform encephalopathies (TSE), such as “mad cow.” Intestines are currently classified as tissues of medium infectivity with regard to TSE. Furthermore, because all inactivation processes for TSE cause severe changes to catgut, it is not possible to apply these methods to these sutures to eliminate infectious agents. Risk management is only possible by restricting sources to TSE-free herds. Because of these concerns, catgut sutures have been taken off the market in many countries of Europe as well as Japan. Where available, catgut has become progressively more expensive. Because the primary advantage of catgut over many of the synthetics has been cost, many believe use of catgut sutures will soon become obsolete.

Synthetic Absorbable Sutures

Polyglycolic Acid, Polyglactin 910, Lactomer 9-1, and Glycomer 631

During the 1970s, two synthetic absorbable sutures (polyglycolic acid and polyglactin 910) became available in the United States. These sutures were designed to be stronger, longer lasting, and less reactive than catgut.

Both sutures are composed of braided filaments of a synthetic polymer. Polyglycolic acid (Dexon: Sherwood/Davis & Geck, St. Louis, MO) is a copolymer of glycolic acid, whereas polyglactin 910 (Vicryl: Ethicon, Somerville, NJ) is a copolymer of lactic and glycolic acid. The two sutures have very similar biologic properties. Breakdown is by hydrolysis rather than digestion by proteolytic enzymes. The result is minimal inflammatory reaction and a constant absorption rate. There essentially is no loss in tensile strength in the first 7 to 10 days after implantation. Approximately 50% to 60% of tensile strength remains after 14 days, 20% to 30% after 21 days, and almost no tensile strength at 28 days. The initial tensile strength of both these sutures is significantly greater than catgut suture of equal size. In fact, the tensile strength of the synthetic absorbable sutures is almost equal to the tensile strength of a catgut suture one size larger.

Glycomer 631 (Biosyn: Covidien, Mansfield, MA) introduced in 1995 is a triblock polymer of glycolide, dioxanone, and trimethylene carbonate. Advances in polymer chemistry allowed production of a monofilament suture equivalent to polyglactin 910 and polyglycolic acid. Glycomer 631 maintains its tension strength longer than the two sutures in this class with 75% of the tension strength remaining at 2 weeks and 40% remaining at 3 weeks.

Lactomer 9-1 (Polysorb: Covidien, Mansfield, MA) is a braided absorbable suture composed of glycolide and lactide in a 9:1 ratio. The surfaces of Polysorb have been coated with an absorbable mixture of caprolactone/glycolide copolymer and calcium stearoyl lactylate to decrease their coefficient friction. At 2 weeks, nearly 80% of the tensile strength remains, and approximately 30% of the tensile strength is retained at 21 days. Absorption is essentially complete by days 56 to 70.

One disadvantage of the synthetic absorbable sutures is that they do not handle as well as catgut suture. To counter this difficulty, manufacturers have attempted to enhance the handling qualities of their products by offering versions with various surface coatings or variations with finer and more tightly woven filaments. Although these refinements improve handling characteristics, they increase the tendency of knots to slip. As a result, additional throws may be needed when using these suture versions.

These sutures can be used in most situations in which chromic catgut would be used and have replaced catgut almost entirely for many surgeons. Because they retain tensile strength longer than do natural absorbable sutures, they are acceptable for fascial closure in patients at low risk for fascial dehiscence.

Polyglyconate and Polydioxanone

Sutures of polyglycolic acid and polyglactin are by necessity composed of braided filaments because the inherent rigidity of the polymers produces a monofilament suture too stiff for general

surgical use. A newer class of polymers, first available in the 1980s, allowed the production of pliable monofilament sutures. This type of suture is represented by polyglyconate (Maxon) and polydioxanone (PDS). Although subtle differences exist between the two sutures, they are similar enough to consider them together when discussing the biologic properties of this suture class.

The initial tensile strength of these monofilament sutures is comparable to that of the multifilament absorbable sutures. However, this class of suture undergoes absorption at a much slower rate than do other absorbable sutures. As a result, tensile strength is maintained for a longer period of time. More than 90% of initial tensile strength is maintained by the end of the first postoperative week, 80% at 2 weeks, 50% at 4 weeks, and 25% at 6 weeks. As with the other synthetic sutures, inflammatory response is minimal. An additional advantage is that these monofilament sutures lack interstices that could serve as a nidus for bacterial infection. As a result, chronic inflammation is rarely seen with this class of monofilament sutures. In comparison, infected absorbable braided sutures have been shown experimentally by Buckall to contain bacteria even after 70 days of implantation.

Because of their delayed absorption profile, both polyglyconate and polydioxanone are excellent choices for

fascial closure. Because these sutures are composed of only one fiber, care must be taken to insure that the strand is not inadvertently damaged by instruments, needles, or other sharp-edged material. Such damage may not be easily recognized in the operating room but can seriously weaken a monofilament suture and may result in suture line disruption postoperatively. This precaution is even more critical when a continuous suture line is used. Additionally, the use of the commonly used loop-tostrand closure to end a suture line produces a very weak knot when monofilament suture is used. The use of two sutures, with each starting at one end of the incision and then tied strand to strand, is recommended when monofilament sutures are used in high load-bearing situations such as fascial closure. A more detailed discussion is provided later in this chapter in the discussion of surgical knots.

Poliglecaprone 25, Polyglactin 910 (Rapide), and Polyglytone 6211

With further advances in polymer chemistry, it is now possible to manufacture the synthetic equivalent of surgical gut. First introduced in 1993, poliglecaprone 25 (Monocryl) has the absorption similar to chromic catgut. Unlike natural collagens, poliglecaprone 25 produces highly uniform and predictable absorption patterns. Like the other synthetic sutures, poliglecaprone 25 is absorbed by hydrolysis and thus does not induce the inflammatory response of catgut. This monofilament suture retains approximately 50% to 60% of its original tensile strength at 7 days postoperatively, 20% to 30% at 14 days, and by 21 days has lost essentially all tensile strength. This particular suture has the advantages of chromic catgut suture but without many of the disadvantages (i.e., intense inflammatory response and somewhat unpredictable absorption rate). Although it is similar to chromic catgut in tensile strength and actually maintains its tensile strength longer than does chromic catgut, it is not recommended by the manufacturer for use for fascial closure or in any tissue in which approximation under stress is required.

Polyglactin 910 Rapide (Vicryl Rapide) released in 1995 is identical in chemical structure to polyglactin 910 but is of lower molecular weight. It has been treated with gamma rays to speed absorption. The result is a braided suture with performance characteristics similar to plain catgut. Absorption is rapid, with 70% of tensile strength lost in the first 7 days. After 10 to 14 days, essentially no strength remains. It is intended for use in the superficial soft tissue where only shortterm support is needed. It can be used for skin closure because of its rapid absorption and minimal inflammatory response. The sutures typically begin to fall off at 7 to 10 days. Because sutures remaining in skin longer than 7 days may cause scarring, any suture remaining at this time can be wiped off with sterile gauze or, if necessary, cut. Although this suture does not meet USP strength requirements for synthetic absorbable sutures, its tensile strength exceeds the tensile strength specifications for similar size natural collagen suture.

Polyglytone 6211 (Caprosyn: Covidien, Mansfield, MA) released in 2002 is composed of glycolide, caprolactone, trimethylene carbonate, and lactide. The absorption profile is similar to that of polyglactin 910 Rapide. However, in contrast to polyglactin 910 Rapide, polyglytone 6211 is a monofilament suture.

These sutures are an excellent choice for first- and seconddegree episiotomy and vaginal laceration closure. Because of the intense inflammatory response produced, gut sutures are associated with more significantly postepisiotomy pain than are synthetic sutures, whereas long-delayed absorbable synthetic sutures are associated with the presence of unabsorbed suture and knots after the postpartum period.

Nonabsorbable Sutures

By definition, nonabsorbable sutures are suitably resistant to the action of living mammalian tissue. These sutures, however, are not completely resistant to absorption. Over time, these sutures also lose tensile strength, and in the case of natural fiber, sutures eventually are completely absorbed or digested. Despite beliefs to the contrary, the initial tensile strength of many nonabsorbable sutures is less than that of comparablesize absorbable suture (**Table 13.1**). Nonabsorbable sutures, however, have the advantage of maintaining tensile

strength for long periods of time. Disadvantages of nonabsorbable sutures include the potential suture-related pain, palpable sutures, and occasionally the formation of suture sinuses.

Natural Nonabsorbable Sutures

Modern nonabsorbable natural fiber sutures are composed of either surgical silk or cotton. Silk suture is one of the best handling sutures. The handling and knot-tying characteristics of silk suture remain the standard against which other sutures are judged. This suture has little “memory”; that is, it does not tend to return to its original form after being bent or twisted. As a result, it handles well, ties easily, and possesses excellent knot security. Silk suture loses more than half of its tensile strength after 1 year of implantation and frequently cannot be found after 2 years. In this respect, it can be viewed as a delayed absorbable suture. Because silk is a foreign animal protein, it initiates the greatest inflammatory response of the nonabsorbable sutures. The multifilament nature and the capillary action of this suture make it unsuitable in contaminated tissue or in tissues in which the potential for infection is high.

Cotton is the other nonabsorbable natural suture material still available today. It is rarely used in modern surgical practice. Cotton is the weakest of the nonabsorbable sutures. Cotton loses 50% of its original tensile strength within 6 months of implantation but still has 30% to 40% remaining at the end of 2 years. Unlike silk, which loses tensile strength when exposed to moisture, wet cotton is 10% stronger than dry cotton. Because wet cotton also is easier to handle, it is commonly moistened before use.

Synthetic Nonabsorbable Sutures

A wide variety of nonabsorbable synthetic sutures exist. Nylon is a synthetic polyamide polymer derived from coal, air, and water. It is available both as a braided polyfilament suture (Nurolon, Surgilon) and as a monofilament suture (Dermalon, Ethilon). Monofilament nylon has slightly greater tensile strength than braided nylon, but braided nylon handles better and has better knot security than the monofilament nylon suture. Monofilament nylon suture incites less inflammatory reaction and is less prone to infection than the braided nylon sutures. However, because nylon is relatively inert, all types of nylon suture produce minimal tissue reaction. Nylon undergoes slow hydrolysis in tissue over extended periods of time. It loses approximately 15% to 20% of tensile strength each year.

Polyester sutures are produced only in braided forms. Most differences in the properties of these sutures are determined by whether they are coated and by the type of coating. The uncoated forms (Mersilene, Dacron) generally offer the best knot security. As with synthetic absorbable suture, coatings can improve the handling characteristics of the polyester sutures. Knot security of coated polyester sutures is generally poorer than that of uncoated sutures. Coatings currently used include polytetrafluoroethylene, also known as Teflon (Polydek, Ethiflex, and Tevdek), polybutilate (Ethibond), and silicone (Ti-Cron).

Polypropylene (Prolene, Surgilon) is a monofilament suture composed of a linear hydrocarbon polymer. It has the least tissue reactivity of all nonabsorbable sutures. Although polypropylene has a high memory, it also exhibits a small degree of plasticity. If it is tied carefully and the knots set firmly, a flattening occurs where the strands cross. This flattening helps lock the knot and thus provides somewhat greater knot security than is possible with many other monofilament nonabsorbable sutures. As with the absorbable monofilament sutures, the same precautions to prevent damage to the suture must be observed with the monofilament nonabsorbable sutures.

Metal Sutures

Although silver wire was used by Sims for closure of vesicovaginal fistulas, metal sutures are rarely used in gynecologic surgery today. Historically, metal sutures have been used in infected sites or for repair of wound dehiscence and evisceration. Stainless steel once was used routinely by the military for closure of battle wounds

of the abdomen. Metal sutures have the highest tensile strength of all suture material. They are also particularly nonreactive. Metal sutures, however, are difficult to handle, require the use of special instruments, and tend to puncture gloves and tissue. With the availability of other nonabsorbable suture materials that also offer high tensile strength and low reactivity but are easier to handle, little reason exists to use these sutures in gynecologic surgery today.

Barbed Suture

The barbed suture is a recent development in sutures. The use of barbed suture has particular advantages in laparoscopy and in dermal closure. Since knots are eliminated and an equal level of tissue approximation is applied throughout tissue closure, these sutures may have advantages over smooth suture in many other surgical applications.

In 2004, the Quill bidirectional barbed suture (Angiotech, Vancouver, British Columbia, Canada) became the first barbed suture to be approved by the FDA. In 2009, the FDA approved the V-Loc barbed suture (Covidien, Mansfield, MA). The Quill system is a bidirectional suture with needles swaged to each end of the suture, while the V-Loc system is unidirectional with only one needle with the other end being a closed loop to avoid the need for a knot to initially anchor the suture. Both sutures are available in a variety of both absorbable and nonabsorbable sutures. The Quill system is available with sutures composed of poliglecaprone 25, polydioxanone, nylon, and polypropylene. The V-Loc system is available as the V-Loc 90 composed of glycomer 631, the V-Loc 180 with polyglyconate, and V-Loc PBT composed of polybutester. The numerical designation of the V-Loc 90 and 180 indicates the time to complete suture absorption.

Because effective diameter of the suture is decreased during the manufacturing process, bidirectional suture is rated one USP size smaller than its equivalent smooth suture, that is, a 2-0 smooth suture and a 3-0 bidirectional suture are actually the same diameter. Unidirectional suture is rated equal to its USP smooth suture equivalent.

Choice of Suture for Fascial Closure

Tensile strength is critical, although many factors are important in choosing a suture for fascial closure. As noted, the most common cause of dehiscence is sutures pulling through fascia. Because a fascial closure can only be as strong as the weakest component, suture for fascial closure should maintain a tensile strength greater than that of the fascia through the critical healing period. Because the incidence of wound infection is related to the amount of suture material placed in the wound, it would also seem reasonable to use the smallest suture able to provide this necessary tensile strength.

All sutures marketed in the United States must meet minimum tensile strength requirements as defined by the USP. The tensile strength measurement required by USP is knot-pull tensile strength. In measuring knot-pull tensile strength, the suture is tied around a plastic tube using a flat surgeon's knot with one end held in place and the opposite end attached to a tensilometer. Although these data are easily obtained from the various suture manufacturers and are frequently used in suture advertisements, knot-pull tensile strength is not particularly applicable to actual surgical situations. A more useful measurement of strength is obtained using the knotted loop model as suggested by Herman. In this model, a loop is formed by tying a suture around a glass rod using sufficient square knots to prevent slippage. The rod is removed and the loop placed over two right angle rods gripped in the jaws of a tensilometer. The jaws are then separated at a constant rate until breakage occurs. This model stresses the material and the knot more comparably to actual in vivo situations and also allows estimation of knot security. Assuming no slippage at the knot, tensile strength calculated using the knotted-loop model is approximately twice the knot-pull tensile strength.

The force required to pull a loop of suture through intact fascia (pullout force) is frequently cited as 8.3 pounds. This figure is derived from work on the fascia of dogs by Howes and Harvey in 1929 and does not necessarily

apply to humans. Fortunately, several studies are now available that have measured the strength of human fascia (Campbell et al., Tera and Aberg, and Boerema). Two of these studies, by Campbell and colleagues and Tera and Alberg, were performed using human cadavers. The third study by Boerema measured the pullout force of fascia at the time of surgery on living patients. All three produced data that indicated the pullout force for human fascia was approximately 15.2 to 24.2 pounds.

Fascial incisions regain their strength slowly, achieving approximately 10%, 25%, 30%, and 40% of original strength by postoperative weeks 1, 2, 3, and 4, respectively. The point at which fascia has regained enough strength to resist the stress of daily activities is unknown. Some

estimation of this time frame can be obtained from available data on fascial dehiscence. The majority of fascial dehiscence occurs between 2 and 12 days postoperatively, with a mean occurring around days 7 to 8. Dehiscence rarely occurs after postoperative day 12 but has been reported up to day 18. This suggests that in most patients, fascia has regained enough strength by 2 weeks after surgery to resist reasonable stresses but that in a limited number of patients, fascia may not regain sufficient strength to prevent dehiscence until 3 weeks postoperatively.

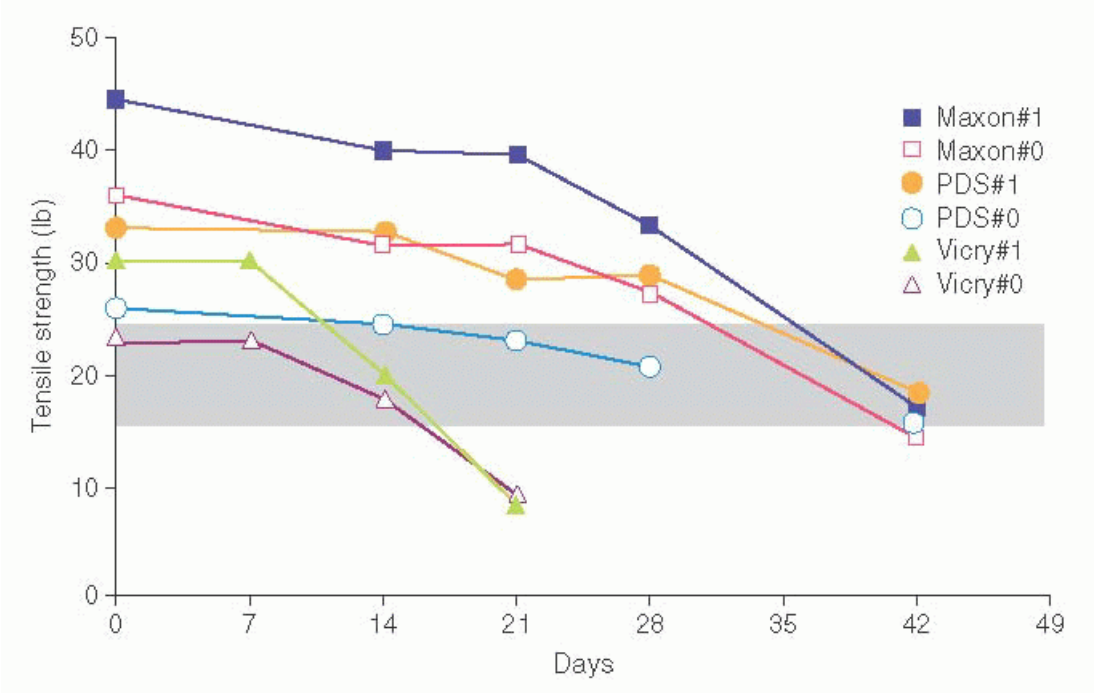

FIGURE 13.3 The tensile strength of various implanted suture materials over time and the point at which tensile strength is less than fascial pullout strength (14.5 to 24.2 pounds).

Using the fascia pullout data, tensile strength as measured by the knotted-loop model following various lengths of implantation in animals, and dehiscence data, the appropriate size absorbable suture for fascial closure can now be estimated. As can be seen in **Figure 13.3**, both 1 and 0 polydioxanone and polyglyconate retain tensile strength greater than the fascial pullout force for 4 to 6 weeks, but polyglycolic acid sutures of the same size maintain adequate tensile strength only for 7 to 14 days. Based on this model, a 1 or 0 polydioxanone or polyglyconate suture appears to be the most appropriate absorbable suture for fascial closure. Unfortunately, although these types of data are theoretically appealing, there are little clinical data to support these conclusions. It must be realized that in most healthy patients, fascial dehiscence does not occur, even when rapidly absorbed sutures are used. Before the development of the synthetic absorbable sutures, 1 and 0 chromic catgut sutures were frequently used for fascial closure. In fact, based on a survey of ob/gyn residency programs, chromic catgut still was being used for fascial closure in 16.1% of vertical fascial incisions and 23.4% of transverse fascial incisions as of 1979. Although fascial dehiscence in healthy patients remained uncommon

after fascial closure with chromic catgut, dehiscence rates of up to 11% were reported for other patient populations. Likewise, polyglycolic acid and polyglactin 910 sutures have been used for fascial closure with good success, even in patients at risk for dehiscence.

Surgical Needles

Needles are necessary to carry suture material through tissue. The specific needle required for a procedure is determined by the tissue type, its location and accessibility, and the surgeon's personal preference. All surgical needles have three basic components: the eye, the body, and the point.

The eye of the needle is the point of attachment for suture. Eyes may be classed as closed, French, or swaged. Closed eyes are similar to those on household sewing needles, whereas French eye needles have a slit with ridges inside the slit to catch and hold the suture. Swaged or eyeless needles have the suture mechanically attached to the end of the needle to form a continuous unit. Eyed needles have several disadvantages over swaged needles, including difficulties with threading and the need to pull a double loop of suture through the tissue. Swaged needles are available with either the suture permanently attached or attached in such a manner that it can be removed from the needle by a slight straight tug on the suture. These controlled-release needles, also known as “pop-off” needles, increase the speed at which interrupted sutures can be placed.

The shape of the body or shaft of a needle determines how easily the needle performs in different applications (**Fig. 13.4**). The longitudinal shape of the body may be straight, half-curved, curved, or compound. Straight needles are used commonly when tissue is easily accessible. This type of needle is rarely used by gynecologists except for skin closure. Half-curved, or ski, needles may be used to close skin but have primarily been used in gynecology to facilitate laparoscopic suturing. Curved needles require less space for maneuvering than do other needles, and thus are ideally suited for most surgical procedures. Curved needles are commonly named based on the percentage of a circle they complete; that is, a 1/2 circle needle is one half of a full circle. Curved needles are available in various curvatures, with the 3/8 circle the most commonly used. The less of an arc the needle completed, the more shallow a bite the needle takes. For example, a 5/8 needle is useful in deep wounds in which a deep, narrow bite is required. Compound curve needles were originally developed for anterior segment ophthalmic surgery and are not used in gynecologic surgery.

The point of the needle begins at the widest part of the needle body and extends to the extreme tip. The two types of needle points are the cutting point and the tapered point (**Fig. 13.4**). Tapered points are used in easily penetrated tissue, such as bowel or peritoneum. A variation of the taper point is the blunt point, which has a rounded blunt tip at the end of a tapered shaft. This needle tip was designed for use in friable tissue but has been advocated by some surgeons for use with other tissues because of its reduced likelihood to penetrate the surgeon's gloves or skin. Cutting needles are used in

tough tissue, such as skin. The most common cutting needle is the reverse cutting needle. Its sharp edge is on the outside of the outer curvature of the needle. Conventional cutting points have the sharp edge on the inside of the curvature. Variations of the cutting point include spatula and lancet points and are used for specialized applications such as ophthalmology.

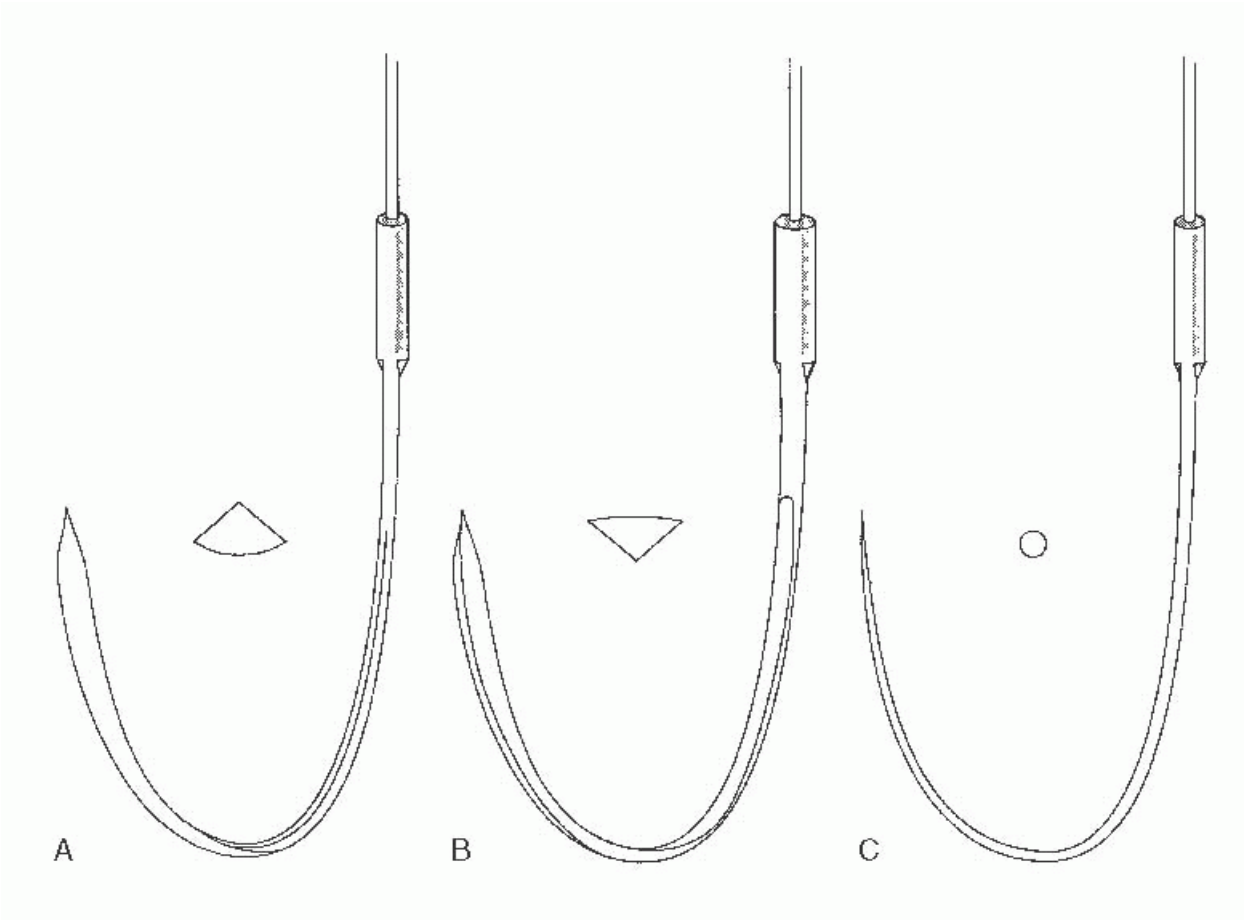

FIGURE 13.4 Common points and body shapes for curved needles.

Needle Holders

Straight needles can be held and pushed through tissue with the fingers. Straight needles can be used only to sew in a straight line, and only then when the tissue is easily accessible. When straight needles are used, sewing is done in a direction away from the operator.

In the depths of a wound, curved needles are needed. A needle holder is required when curved needles are used. All needle holders have a broad head with a variety of surfaces to prevent the needle from slipping or rotating. Needle holders may be large and heavy, or small and delicate, depending on the size needle to be used. Many needle holders have ring finger grips and locking mechanisms. Two common types of basic needle holders used in gynecology are Wagensteen (straight) or Heaney (angled) (**Fig. 13.5**). Curved needle holders are especially useful in vaginal surgery, for which the angled head allows easier needle placement. The needle is loaded so that the angled tip is pointed toward the needle eye and not the tip. Sewing using needle drivers is performed toward the operator.

Surgical Knots

The surgical knot has been described as the weakest link in any knotted suture, regardless of the knot configuration and the type of suture used. If tied improperly, a surgical knot will fail before the tensile strength of the suture is reached. Even when performed perfectly, the mere placement of a knot in suture reduces its overall tensile strength by 30% to 35%. Therefore, some knowledge of surgical knots is imperative for all surgeons.

All surgical knots can be divided into two basic groups: flat knots (square, surgeon's, and granny) and sliding knots

(identical and nonidentical) (**Fig. 13.6**). Flat knots are formed with half hitches tied with equal tension on the

ends of the suture. Surgeon's knots are formed by adding an additional loop to the first throw of the half hitch. Sliding knots are two half hitches either nonidentical (square knot) or identical (granny knot), tied with greater tension on one segment than the other.

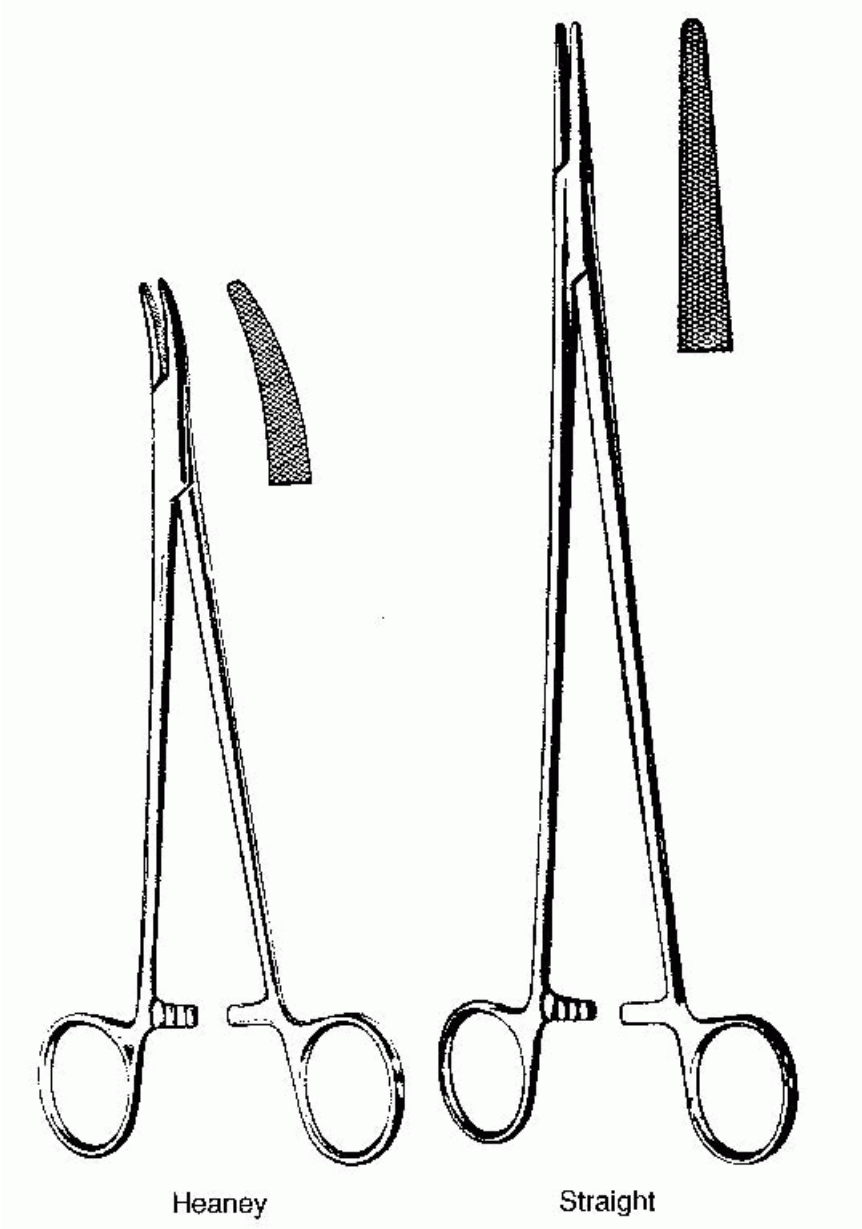

FIGURE 13.5 Needle holders. (Courtesy of Zinnanti Surgical Instruments, Inc., Chatsworth, CA.)

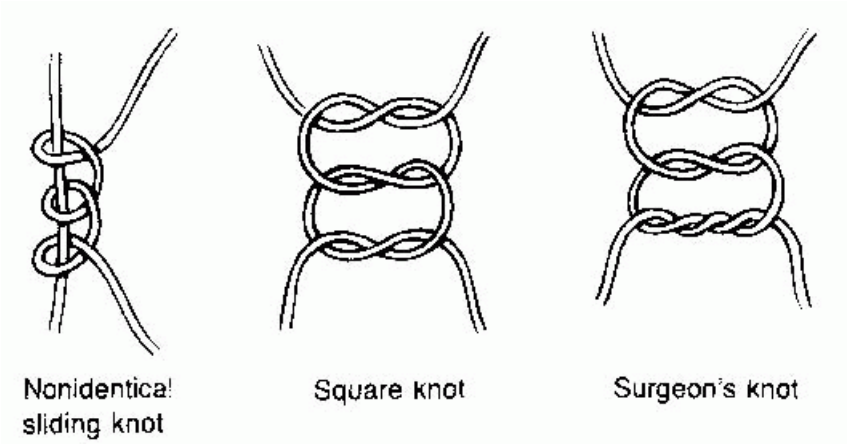

FIGURE 13.6 Flat and sliding knots.

The term *sliding knot* suggests the tendency of the knot to slip compared with the flat, but this is not completely true. Simple sliding knots of two or three throws do slip often and should not be used as surgical knots. Brouwers and colleagues have shown, however, that flat knots with only two throws also tend to slip rather than break.

The flat square knot is the most secure of all the surgical knots and theoretically the most desirable knot for tying suture. However, according to a study by Trimbos, sliding knots are used more commonly by gynecologists than are square knots. It has been shown also that many surgeons actually tie sliding knots despite being convinced they tie flat knots. Sliding knots frequently are used in actual surgical practice for two reasons. The crossing of the surgeon's hands needed to tie square knots unavoidably releases tension on the knot, and this can lead to knot slippage. The tying of deep ligatures is most easily performed by keeping constant tension on one suture. Thus, sliding knots may be preferable to square knots in certain situations. Whichever knot is used, the operator should be aware of the knot being used and the number of throws needed to obtain maximum knot capacity.

The number of throws required for knot security is frequently debated. Too few throws and the knot is weaker than the suture; additional throws above that needed to equal the sutures tensile strength adds unneeded suture to the wound and may increase the infection rate. When flat square knots are used, Brown has shown that maximum knotholding capacity was achieved with four throws in all noncoated suture tested. In fact, three throws were sufficient to achieve maximum knot-holding capacity except for sutures composed of nylon (both monofilament and braided). The addition of coating to improve handling characteristics also decreases knot security. In a 1983 study, Rodeheaver and colleagues showed that coated suture required two additional flat throws to equal the maximum knot-holding capacity of uncoated suture. In a similar study by Van Rijssel and colleagues, the knot-holding capacity of a sliding knot with one extra throw equaled that of square knots in smaller gauge (3-0) suture. In larger sutures (0), square knots remained stronger than sliding knots with an extra throw, but sliding knots with more than five throws were not tested. From these studies, it appears that a surgical knot of four to six throws is adequate for most sutures. The exact number of throws required, of course, depends on the type of suture and whether a flat or sliding knot is formed.

It is common practice for some surgeons to leave suture tails long to prevent knot disruption should the knot slip. As might be expected, the usefulness of this practice is dependent on the type of suture involved. It has been shown that any knot slippage in nylon, polydioxanone, and polypropylene sutures results in total knot disruption. In other sutures (polyglyconate and polyglactin), initial knot slippage is followed by knot recomposition. The reconstituted knot remains intact until greater force is applied. A long suture tail is only helpful in preventing knot disruption in this latter class of suture.

Knot security is of utmost importance when using a continuous suture line. This is of critical importance if a monofilament suture is used in a strength critical suture line. It is common practice for many surgeons to form the terminal knot in a continuous suture line by tying the ending single strand to the last loop of suture. This “loop-to-strand” knot is a potentially weak configuration. Unlike multifilament sutures that lock in place with each throw, monofilament sutures do not lock and are prone to slippage. Unless multiple square knots are used, the single strand may slip from the knot when placed under tension. As a result, the entire suture line disrupts. At reoperation, the strand may appear broken, but, in fact, one of the three terminal knot ends has slipped through what appears to be an intact knot (**Fig. 13.7**). A safer method for tying continuous suture is to run two sutures to the midpoint of the incision and tie the two single strands to each other, thus avoiding the “loop-to-strand” knot. Alternatively, polydioxanone is available in a looped version that eliminates the initial knot and permits ending the suture line in a strand-to-strand configuration. The disadvantage is the large increase in the mass of suture placed into the wound.

SURGICAL INSTRUMENTATION

A multitude of surgical instruments are designed to perform one unique function or slightly improve on the

performance of another instrument. This section is not intended to be a comprehensive list of all instruments available but a review of the basic surgical instrumentation needed for most common gynecologic procedures.

Scalpel

The scalpel is the first instrument used in most surgeries and remains the best instrument for dividing tissue with minimal trauma to surrounding tissue. Scalpel blades come in various sizes and shapes to allow performance of different tasks (**Fig. 13.8**). The basic scalpel blade has a straight ribbed back and an oval cutting surface. This basic blade is commonly available in sizes 10, 15, 20, and 22. The 10 scalpel blade is the most versatile and the most commonly used size. The smaller blades are used for fine dissection and when precise turns are required in making the incision—that is, plastic surgery—although the larger blades are used to rapidly perform an incision. Blades such as the 11 and 12 are designed for specific purposes. The 11 blade is bayonetshaped and used to perform stab incisions for drains and in draining abscesses. The 12 blade is hook-shaped and was originally used for myringotomies. It is infrequently used by gynecologists.

Scissors

The scissors are the second most commonly used instrument to divide tissue. In addition to cutting, scissors also can be

used for blunt dissection by opening the scissors after the tips have been inserted into a tissue plane. The basic scissors designs used in gynecology surgery are the Mayo, Metzenbaum, and Iris scissors. All come in both straight and curved versions (**Fig. 13.9**). Curved scissors allow horizontal cutting deep in a wound and thus improve visibility. Curved scissors also are used to cut tissue in a smooth curve, such as for incising the vaginal cuff in an abdominal hysterectomy.

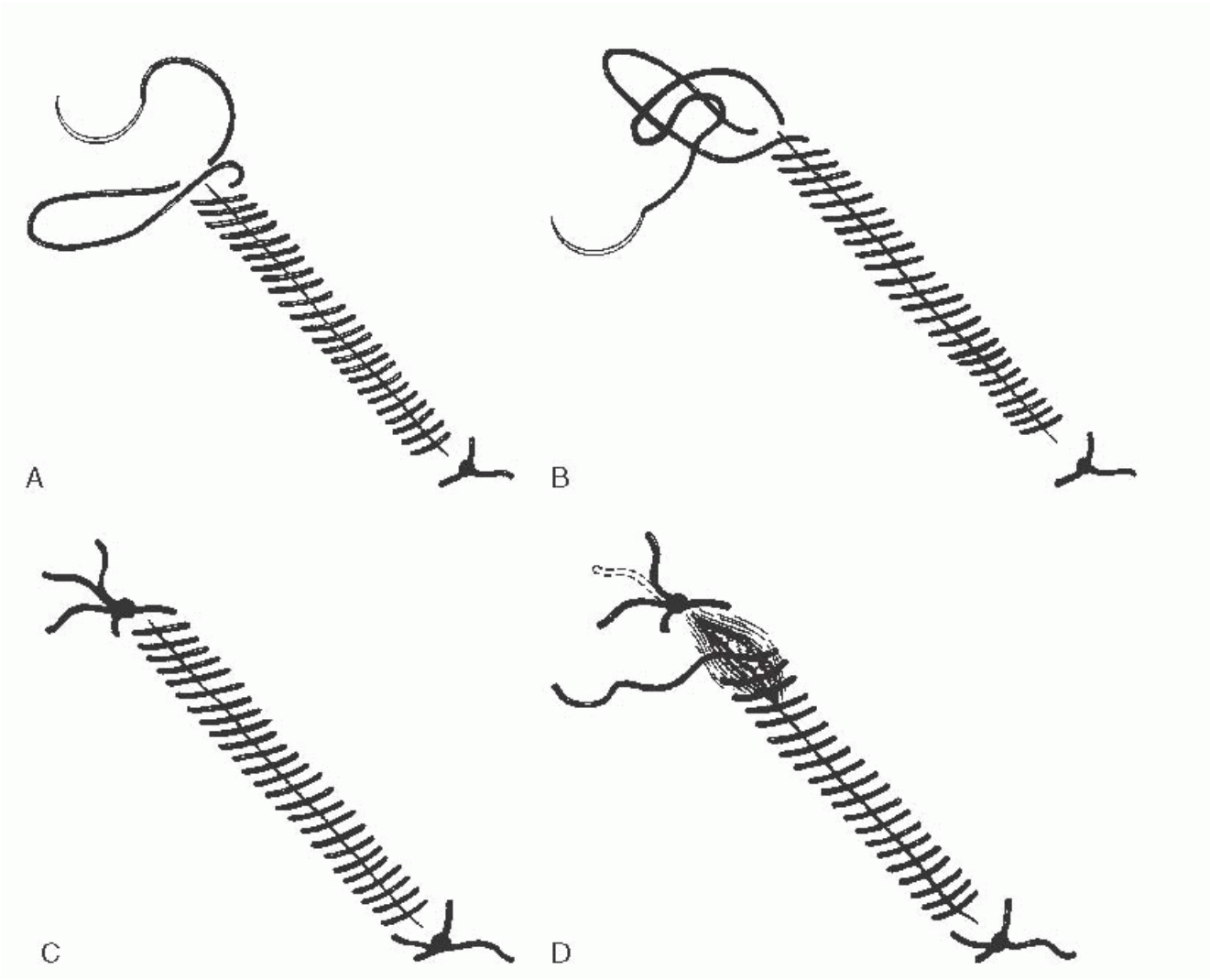

FIGURE 13.7 Development of suture line.

Mayo scissors are used when dividing tough tissue, such as the rectus fascia, parametrial tissue, or vaginal cuff. Metzenbaum scissors are more delicate than are the heavier Mayo scissors and are used for cutting thinner tissue, such as peritoneum and adhesions. Metzenbaum scissors are frequently use for retroperitoneal dissection or for developing tissue planes in adhered or distorted tissue.

Iris scissors are small scissors used for delicate dissection. Originally designed for ophthalmic surgery, they are used in gynecology for precise vulvar and vaginal surgery, such as fistula repair or colporrhaphy.

Suture scissors are used only to cut suture and never tissue. Suture scissors are general-purpose scissors with blunt ends to avoid the possibility that the tips will injure structures distal to the suture.

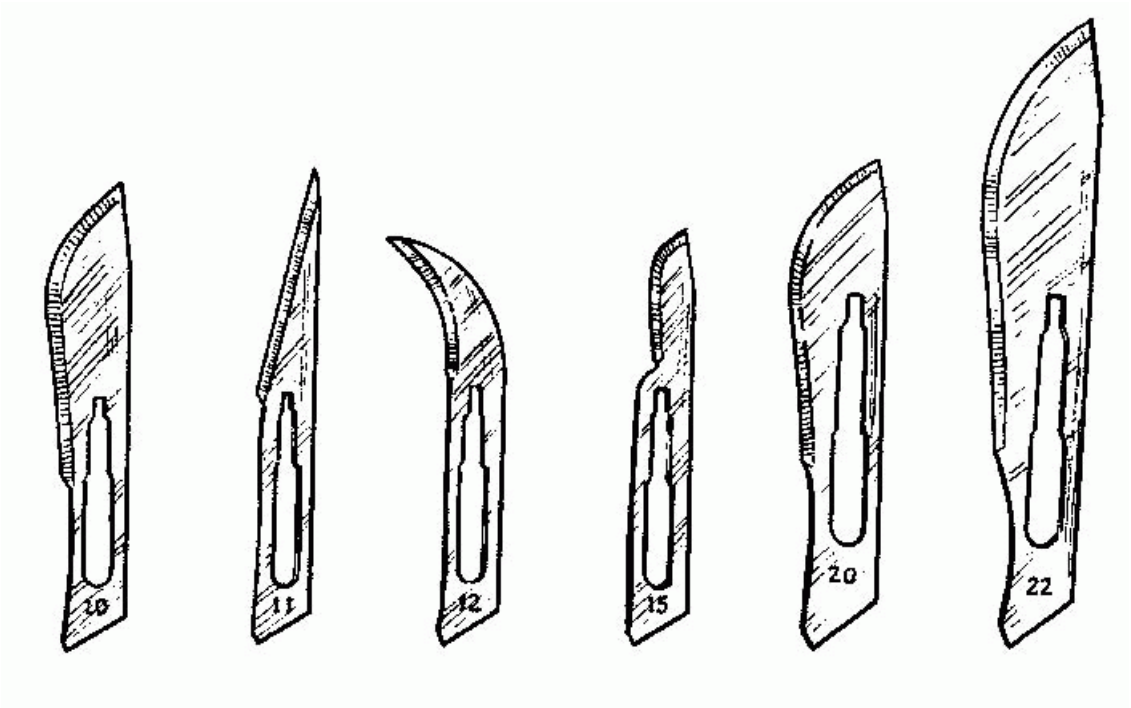

FIGURE 13.8 Surgical scalpel blades.

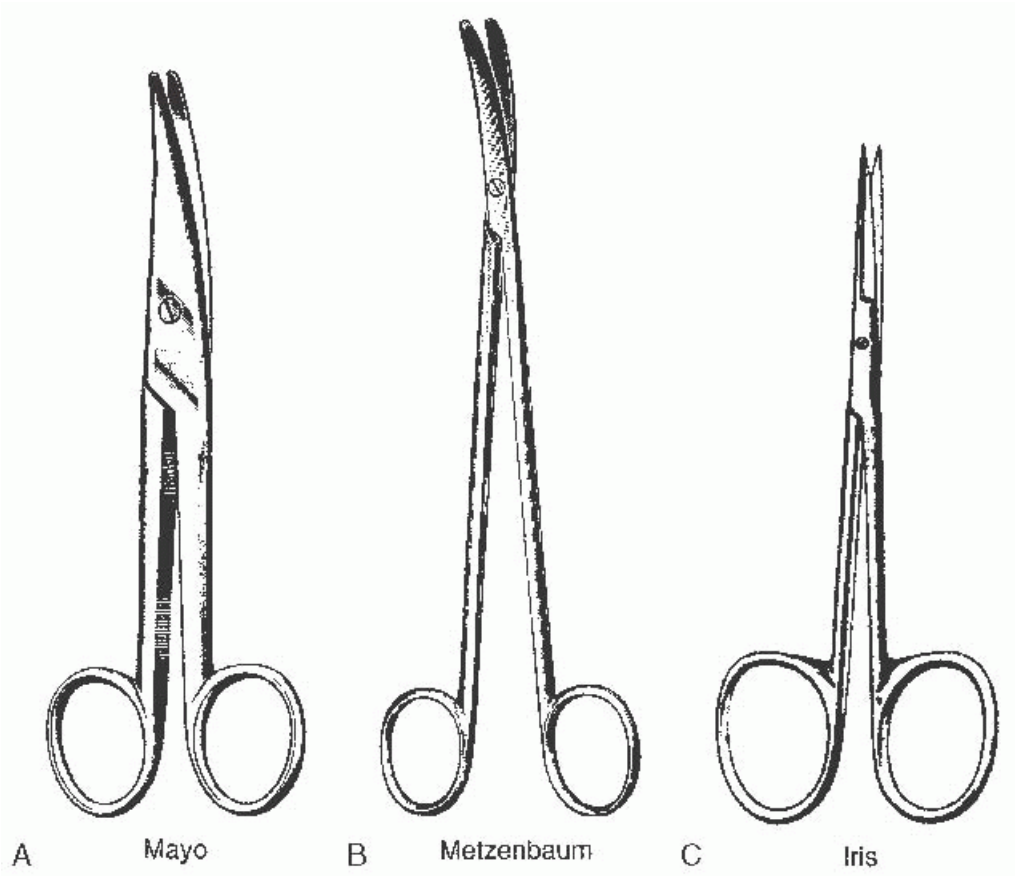

FIGURE 13.9 Surgical scissors. (Courtesy of Zinnanti Surgical Instruments, Inc., Chatsworth, CA.)

Tissue Forceps

Tissue or thumb forceps consist of two strips of metal joined at one end (**Fig. 13.10**). The opposable ends of the forceps are used to grasp and hold tissue during dissection, suturing, or cutting. These ends are of varying shapes and configuration, depending on the purpose for which the forceps are intended. The most common

alteration to the ends is the addition of teeth. Smooth forceps without teeth are used when handling friable or delicate tissue. DeBakey forceps have long fine smooth tips that provide precise control of small or delicate tissue deep in the wound. They are commonly used in vascular surgery or retroperitoneal node dissection. Toothed forceps bite into tissue, providing a firm grip with minimal pressure. The teeth can vary from one to many and be fine or large. Adson forceps are equipped with fine teeth and are commonly used to approximate skin for staple or suture placement. Ring-tipped and Russian forceps increase the grasping force without using teeth by increasing the surface area of the grasping tips. These forceps are used when a secure hold is needed on structures that would be traumatized by toothed forceps. Bonney tissue forceps are heavy-toothed forceps with serrations along the shaft for maximum gripping power. They are used when sewing fascia.

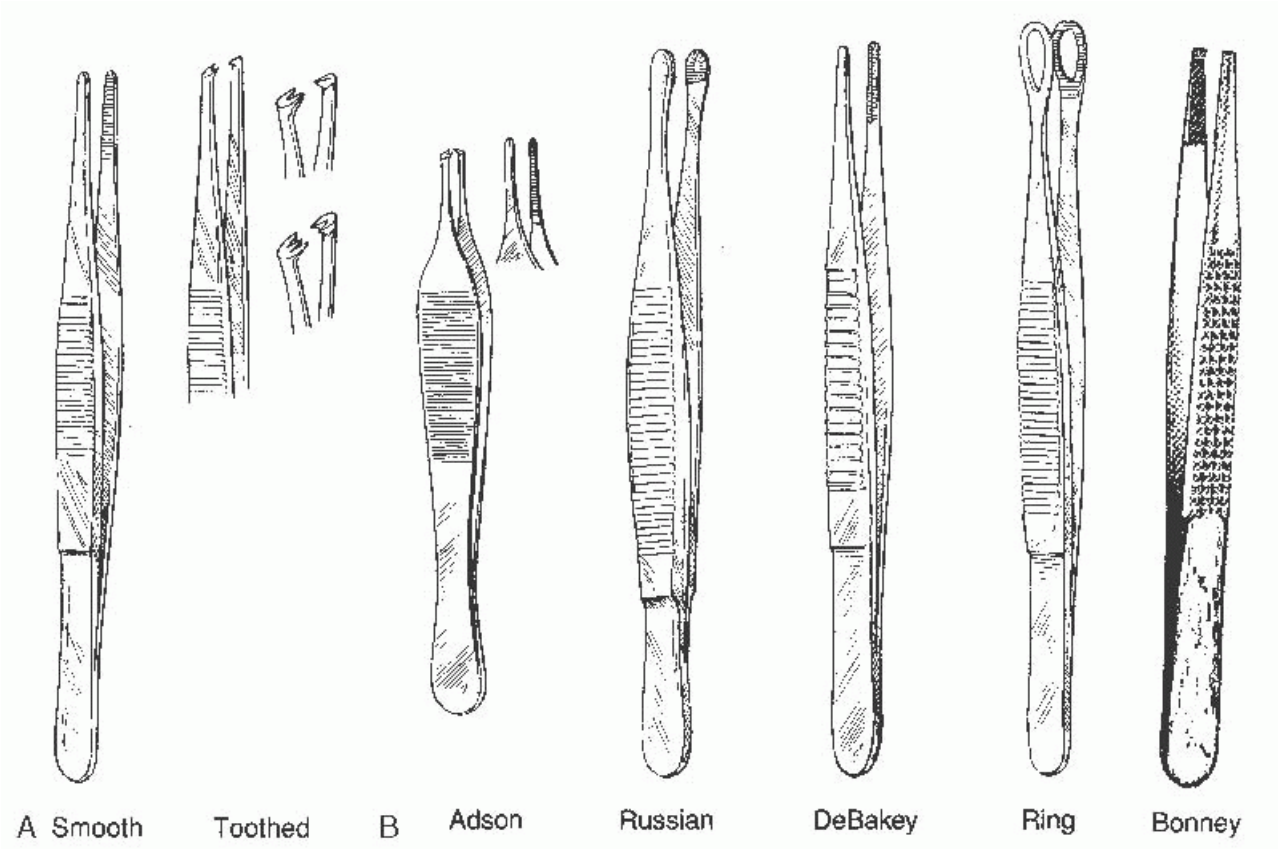

FIGURE 13.10 Tissue (thumb) forceps. (Courtesy of Zinnanti Surgical Instruments, Inc., Chatsworth, CA.)

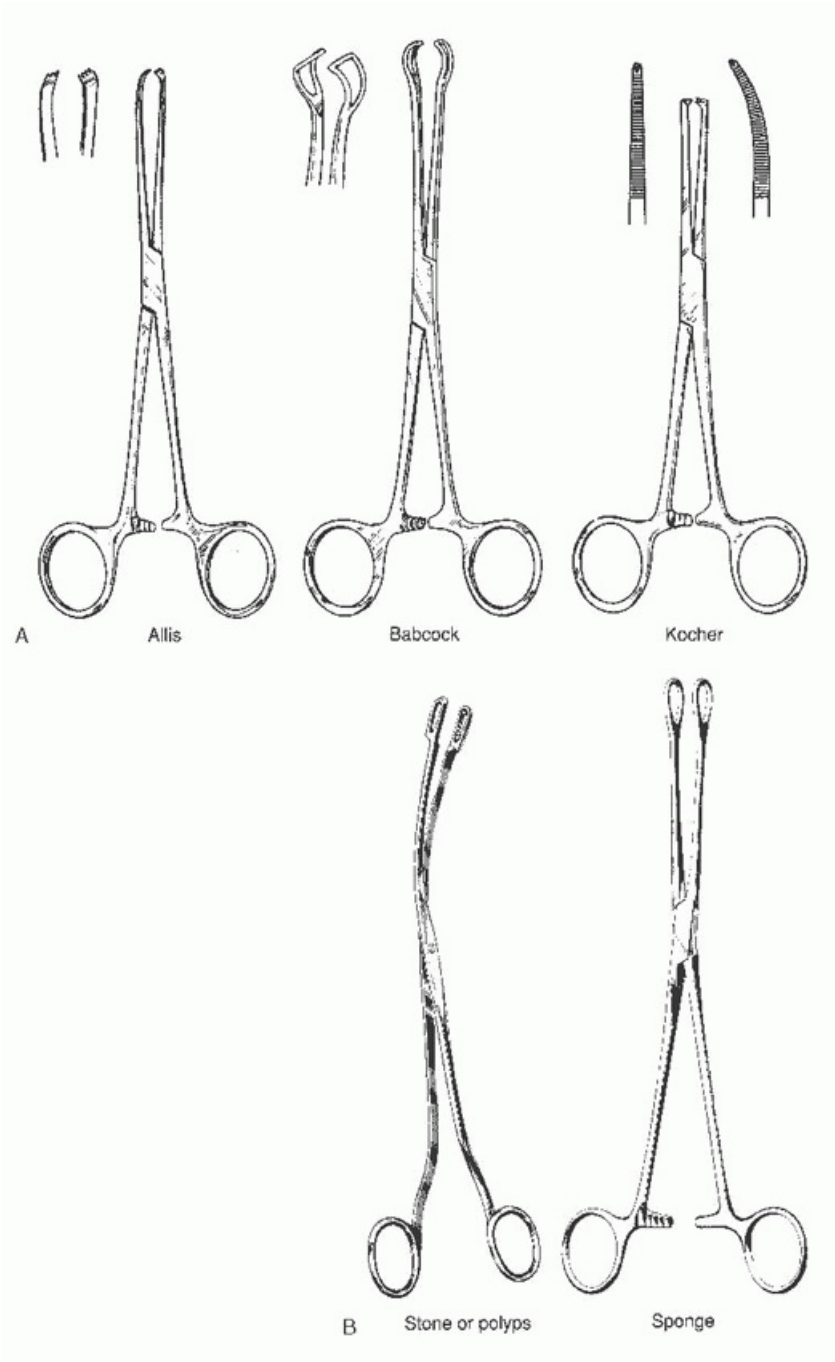

FIGURE 13.11 Tissue clamps. (Courtesy of Zinnanti Surgical Instruments, Inc., Chatsworth, CA.)

Clamps

Grasping forceps, commonly referred to as clamps, are designed to grasp and apply traction to tissues (**Fig. 13.11**). All have finger rings and a locking mechanism. Babcock clamps have no teeth and are atraumatic. These clamps can grasp and hold delicate tissues such as fallopian tube or bowel without causing damage. Allis clamps have serrated edges with short teeth. This clamp has much more grasping power than does the Babcock clamp. Kocher/Ochsner clamps have transverse ridges along the shaft and interlocking teeth at the tip. Because of their design, tissue within the clamp is unlikely to slip. These clamps are frequently used to grasp heavy tissue such as fascia and occasionally are used as hysterectomy clamps. Ring forceps can be used like ring-tipped

tissue forceps but more commonly are used to hold folded sponges. In this fashion, they can be used to retract tissue, sponge fluid or blood, or apply solutions to the skin in preparation for surgery. Renal stone forceps were designed to remove stones from the renal pelvis but are commonly used by the gynecologic surgeon to explore the uterine cavity for polyps or retained tissue. When used in this capacity, they are inserted, opened, rotated

180 degrees, closed, and withdrawn.

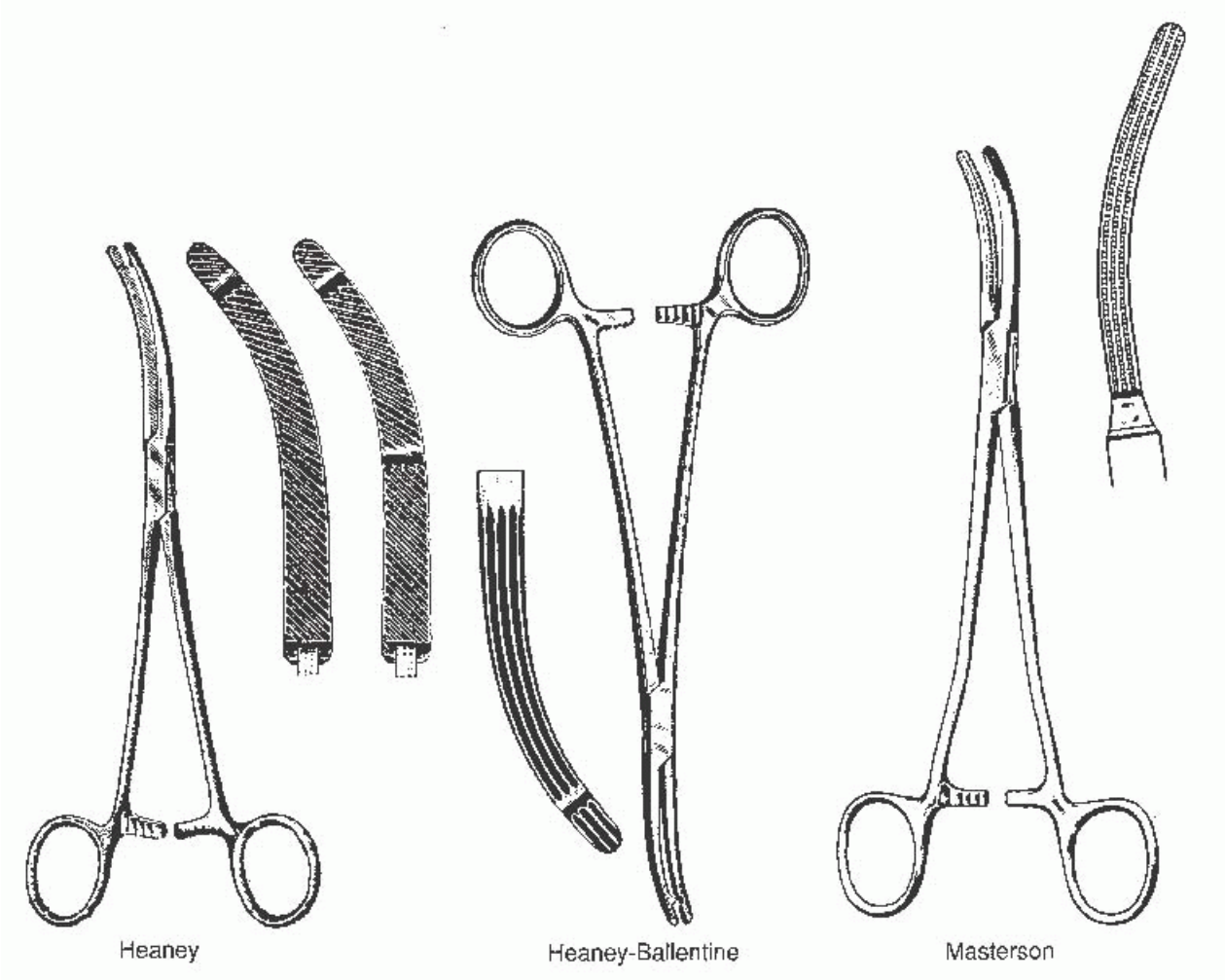

FIGURE 13.12 Hysterectomy clamps. (Courtesy of Zinnanti Surgical Instruments, Inc., Chatsworth, CA.)

Heaney, Heaney-Ballentine, and Masterson clamps are the commonly used clamps for clamping the parametrial and paracervical tissue during hysterectomy (**Fig. 13.12**). Hysterectomy clamps are heavy crushing clamps with ridged shafts. The classic clamps (Heaney, Heaney-Ballentine) also have toothed tips. The more recent Masterson clamp lacks a toothed tip and was designed to generate the least amount of crushing force.

Retractors

Retractors are used to hold tissue out of the operative field to improve exposure during surgical procedures (**Fig. 13.13**). Retractors are either held by an assistant (manual retractors) or use counterpressure from other tissue (self-retaining retractors) to hold themselves in place.

Self-retaining retractors frequently are used to hold the sides of the incision apart during gynecologic surgery. Gynecologists seem to favor the O'Conner-O'Sullivan retractor when performing pelvic surgery. General surgeons, on the other hand, prefer the Balfour retractor. The O'Conner-O'Sullivan is a circular retractor with four blades, two permanently attached lateral retractors to retract the sidewalls, and a removable upper and lower blade to retract the bowel and bladder, respectively. This retractor is available with large or small lateral blades, whereas the removable blades come in several sizes. The Balfour retractor also has two lateral blades but only one additional retractor blade. This blade normally is employed as an upper blade with a manual retractor used for bladder retraction if needed. However, if the bowel is carefully packed away with laparotomy packs, the third blade can be used as a bladder retractor. All blades of the Balfour retractor are removable and available in different sizes.

The Bookwalter retractor is the most versatile of retractors, providing excellent exposure to the operative field. It consists of a circular metal ring to which a wide variety of retractors can be attached at any point. Its best use is during radical pelvic surgery or when operating on massively obese patients. In extremely obese patients, it may be necessary to attach the Bookwalter retractor to the operating table.

Manual retractors allow maximum flexibility in providing exposure (**Fig. 13.14**). They can be used alone or as a supplement to self-retaining retractors. Common manual retractors include the Heaney, Deaver, and Richardson retractors. Specialized retractors include the Briesky-Navratil (used during sacrospinous vault suspension), Army-Navy, and Parker retractors (used for skin and subcutaneous tissue).

Dilators

Dilators are metal or plastic cylinders used to dilate the cervical os to sufficient size to admit other surgical instruments (**Fig. 13.15**). Dilators may have tapered (Hank and Pratt) or rounded (Hegar) tips. Dilators with tapered tips require less force to perform dilatation than do dilators with rounded tips. The sizes are measured either by diameter or by circumference. The unit of measurement for diameter is millimeters, whereas the unit of measurement for circumference is in French calibration. The relationship of the two measurements can be calculated by the formula for the circumference of a circle where

the diameter times pi (3.14) equals the circumference. For comparison purposes, approximately 3 French equals 1 mm of diameter.

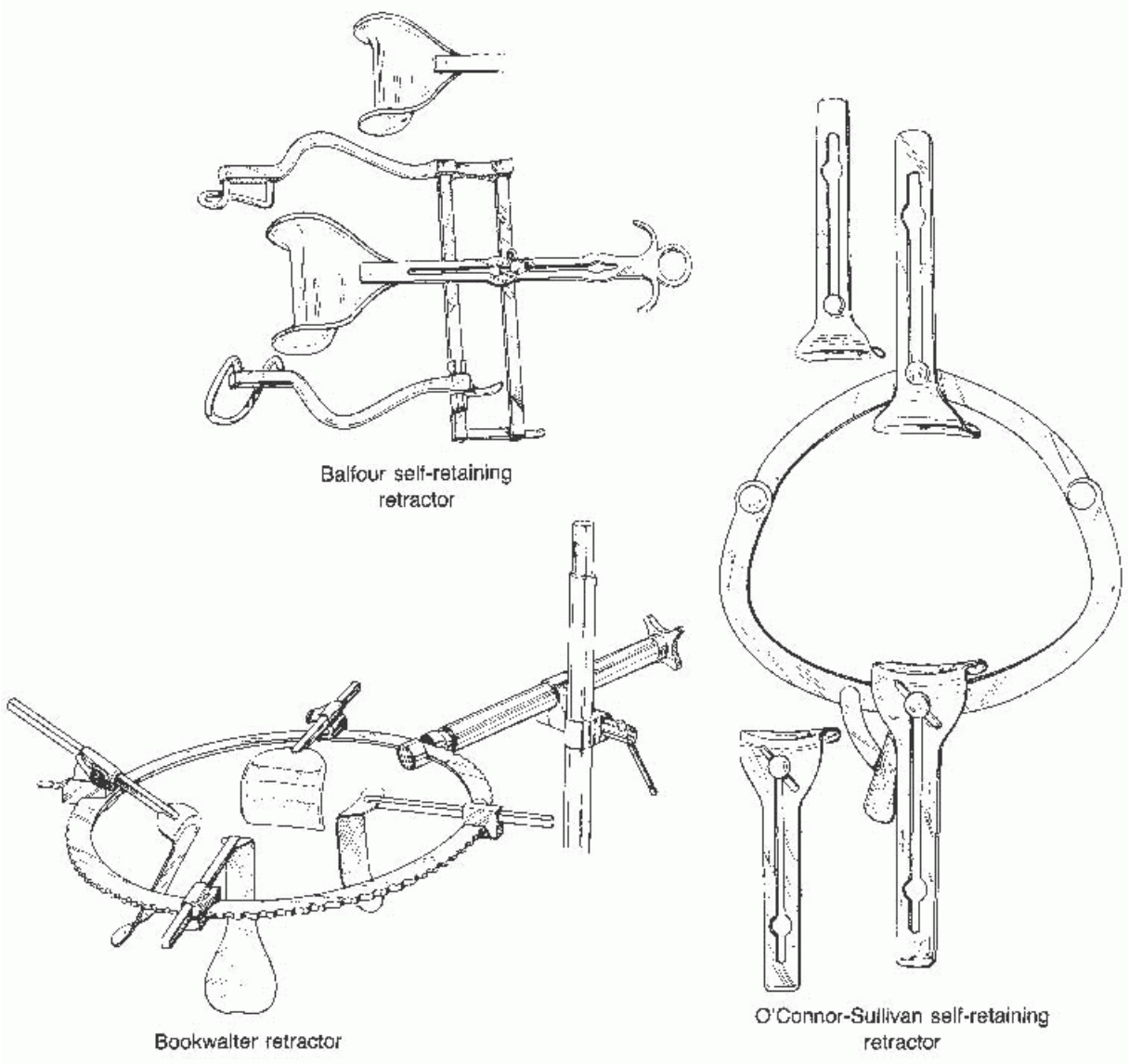

FIGURE 13.13 Retractors. (Courtesy of Zinnanti Surgical Instruments, Inc., Chatsworth, CA.)

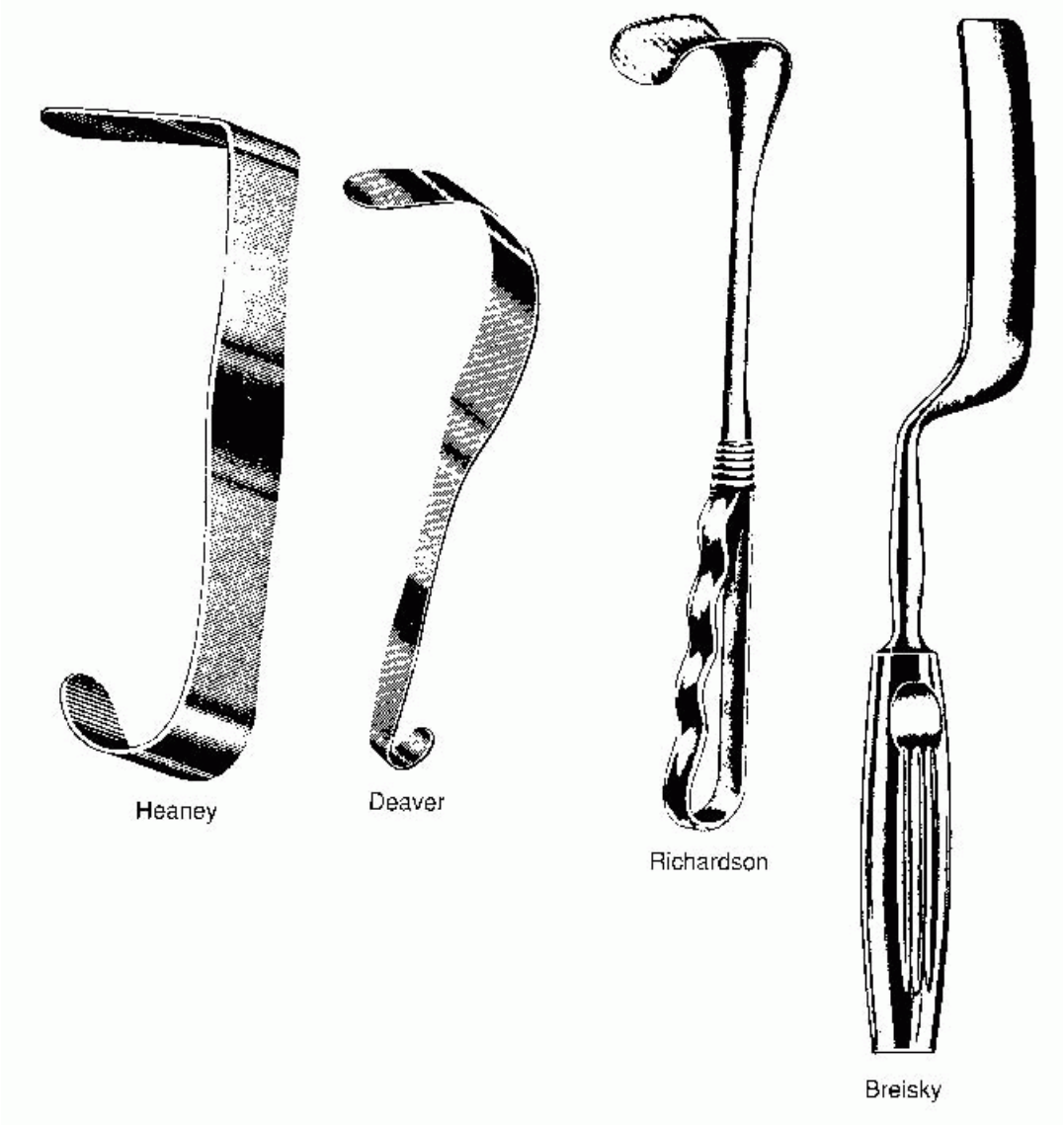

FIGURE 13.14 Manual retractors. (Courtesy of Zinnanti Surgical Instruments, Inc., Chatsworth, CA.)

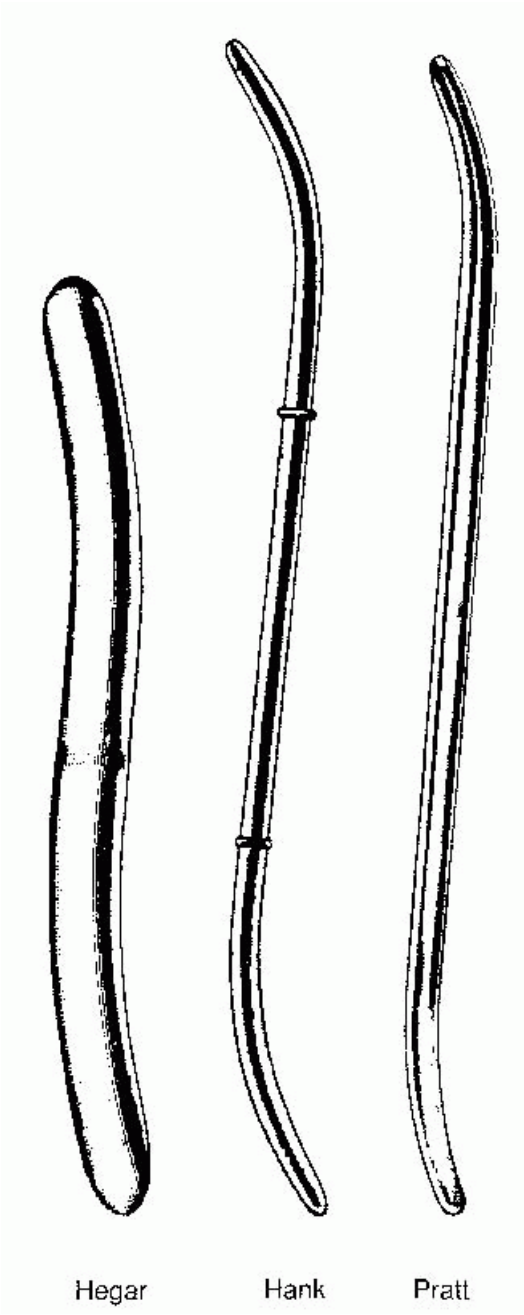

FIGURE 13.15 Common cervical dilators. (Courtesy of Zinnanti Surgical Instruments, Inc., Chatsworth, CA.)

CONCLUSION

This chapter has attempted to present an introduction to the mechanisms of wound healing, wound closure, suture material, and instrumentation. It is hoped that this chapter will be a useful resource not only for those embarking on a surgical career but also for experienced surgeons as well.

BEST SURGICAL PRACTICES

- Secondary wound closure should ideally be performed on day 4.
- Proper surgical technique is one of the most critical factors in preventing wound dehiscence.
- Abdominal wall fascia should be loosely closed with suture bites of 1 to 1.5 cm.
- The use of mass closure techniques using long-delayed or permanent suture to close fascia is recommended to reduce fascial dehiscence.

- The use of catgut sutures has been limited in many countries because of increasing concerns over the possibility of theoretical infection with TSE, such as “mad cow” disease.
- Suture knots produced by tying a loop of suture to a single strand are less secure than are those tied using a strand to strand. This is particularly critical when using monofilament suture.

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