Surgical Knots
and
Suturing Techniques

5th Edition

Includes Basic Sterile Techniques

F. D. Giddings

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Giddings Studio Publishing
1514 Latitude Circle
Anacortes WA 98221
Phone: 970-226-8587
e-mail: GiddingsStudio@comcast.net

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The fifth edition of *Surgical Knots and Suturing Techniques* has a new home in the Pacific Northwest. Giddings Studio Publishing has moved from Fort Collins, Colorado to Anacortes, Washington. This refreshing change, from semidesert to rainforest precipitation, stimulated the desire to refresh this handbook.

The fifth edition includes the Aberdeen knot, updated information on suture materials, sterilization techniques, and instrument handling. For the left-handed student, illustrations regarding tying of the Aberdeen knot, and proper instrument grip and release have been added. The techniques of knot tying continue to be the primary focus of the handbook.

This handbook will assist those studying to become a veterinarian, physician, nurse practitioner, physician's assistant, emergency medical technician, midwife, podiatrist, research specialist or food animal producer. Equally important, the book has information for the outdoor enthusiasts or those simply wanting to learn the skills of surgical knot tying. Information about cleaning, sterilization and preparing a surgical field for closing acute wounds and incisions is included. Much of this information was previously available in *The Pocket Manual of Basic Surgical Skills*, Mosby, 1986.

The professional medical and paramedical curricula includes aseptic and sterile techniques as well as wound closure and management. Animal science curricula includes livestock and domestic animal management but leaves the problems involving the health of the animals to the veterinary profession. Occasionally the livestock producer, sea captains and mates, back country travelers and their animal companions are confronted with problems needing immediate attention. This handbook can be helpful in preparing these individuals for such crises.

Learning surgical knot tying and suturing techniques is challenging and much practice is required to develop proficiency. This handbook is a guide explaining and demonstrating the principle maneuvers of surgical knot tying along with step-by-step instructions. The illustrations make each step of knot tying understandable and easier to learn.

Instruments and supplies can be found in first-aid kits and through medical school facilities, veterinary suppliers and online.

Giddings

F. D. Giddings, AMI

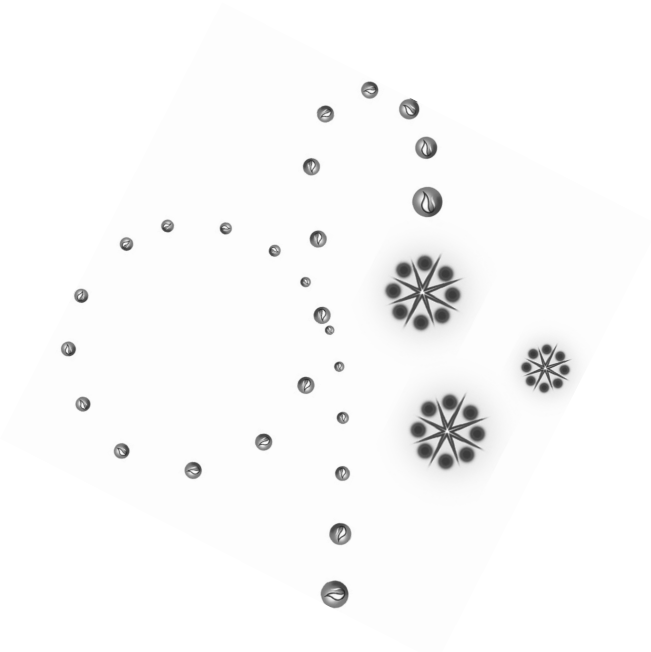
Medical Illustrator Emeritus

College of Veterinary Medicine and Biomedical Sciences

Colorado State University, Fort Collins, Colorado

The dragon characters and symbols were created in 1993 for the book *Frozen Fire* which was written and illustrated by F. D. Giddings for his bone marrow recipient. The book was donated to the Be the Match Organization for encouragement to the children undergoing the bone marrow transplant procedure.

Contents



Section I

Anatomical and Surgical Knot Tying Fundamentals

Describing surgical knot tying requires precise terminology. Terms of position and direction applied to the hands must be clear. The hand will be referred to as it appears in the *anatomical position*, standing in erect posture with feet together, arms hanging at the sides with thumbs pointing away from the body.[4]

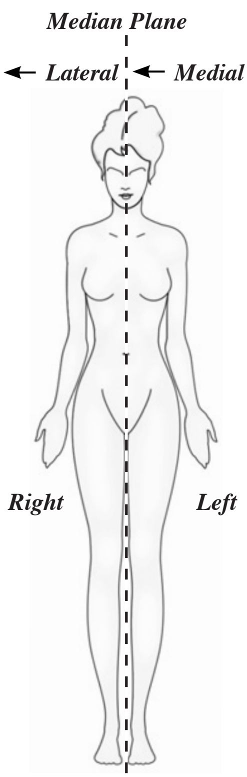
The *median plane,* also called the mid-sagittal plane, divides the body vertically into right and left halves.

The terms *medial* and *lateral* refer to structures nearer to or farther away from the median plane.

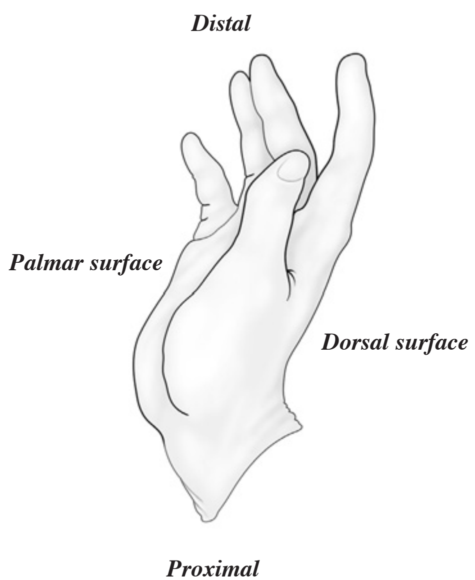
The terms *proximal* and *distal* indicate a direction nearer to or farther away from the attached end of a limb, origin of a structure, or the center of the body.

The terms *palmar* and *dorsal* refer to the front and back of the hand.

Illustrations depicting directional terminology:

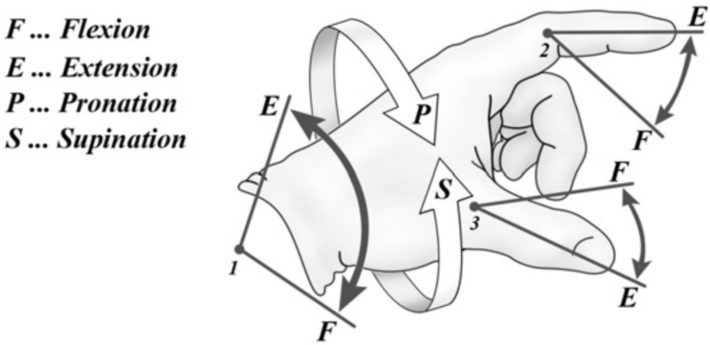


Anatomical Position



Lateral View of Right Hand

The terms describing the actions of the wrist, fingers and thumb are explained and illustrated using the lateral view of the left hand.



Flexion is to bend a joint and *extension* is to straighten a joint. The dots indicate the pivot point for each joint. In this illustration three joints are used for demonstration:

1 ... Radiocarpal joint of the wrist

2 ... First interphalangeal joint of the index finger

3 ... Metacarpophalangeal joint of the thumb

The dark arrows indicate flexion and extension.

Pronation is rotation of the forearm and hand toward the body midline and *supination* is rotation of the forearm and hand away from the body midline. The large white arrow indicates pronation and supination.

Terms used when referring to knot tying procedures:

Knot / Half-knot / Throw / Cycle / Bight / Turn

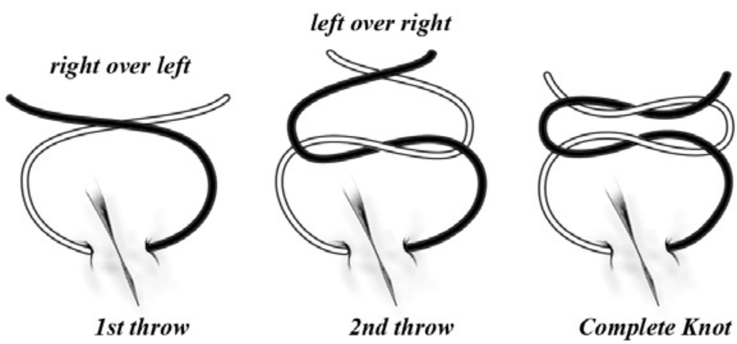
When a surgeon refers to the number of knots used, the reference is to the number of half-knots or throws, not the number of completed knots. A half-knot or throw is a complete twist of two strands in the square knot and a complete cycle in the Aberdeen knot. A complete square knot consists of two throws and is sometimes referred to as two knots.[1] A bight has two meanings in knot tying. It can mean the central part of a suture strand or an arc in the suture strand. In both meanings, a bight is a length of suture strand that does not cross itself.[11] A turn means one pass around the suture strand itself or an object.

Four knots commonly used in surgery:

- **Square Knot**
- **Surgeon's Knot**
- **Granny Knot or Slip Knot**
- **Aberdeen Knot**

The *square knot* is tied by crossing the right strand over the left strand in the first throw followed by the left strand over the right in the second throw (*right-over-left, left-over-right*). If the square knot is started by crossing the left strand over the right, it must be completed by crossing the right strand over the left. When this sequence of throws or half-knots is performed the square knot will not slip.

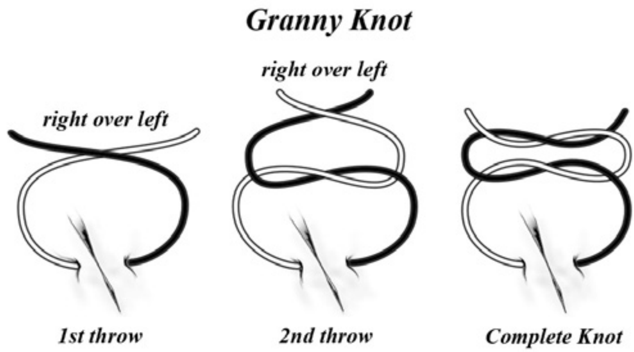
Square Knot



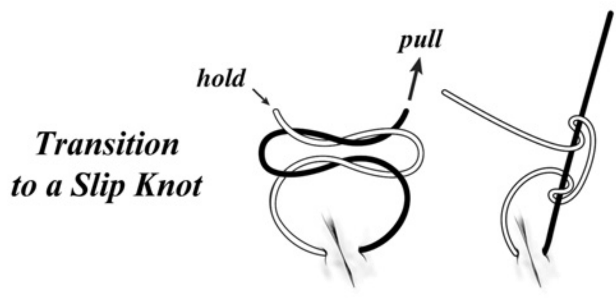
The *surgeon's knot* is a square knot which contains a double turn in the first throw. The double turn makes the first throw of the knot less likely to slip while the second throw is being tied.

Surgeon's Knot

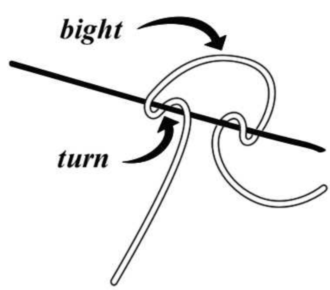
The *granny or slip knot* is a pseudosquare knot. The strands of the second throw cross in the same sequence as the strands of the first throw *(right-over-left, right-over-left)*. The result is a *slip knot* which is useful when the completed knot must be slipped down for tightening in deep cavities. Holding qualities are not good and the granny knot should be backed up with a square knot or an Aberdeen knot.



Pulling on one strand of a granny knot demonstrates how the knot transforms into a slip knot.[1]



The *Aberdeen knot* is described using the terms **bight and turn.** It is less complex than a square knot or a surgeon's knot and in some situations is superior to the square knot as it has been shown to be stronger and more secure for ending a suture line.



Book Sections:

Section I: Anatomical and Surgical Knot Tying Fundamentals

Section II: Surgical Knot Tying Techniques

Section III: Suture Materials, Surgical Needles and Forceps

Section IV: Suturing Methods

Section V: Suture Patterns and Suture Removal

Section VI: Basic Sterile Techniques

The suture material in the knot tying directions has been illustrated in two colors and in a size large enough to permit visualization of the dark and light strands. Actual suture material is much smaller and looks like fine thread.

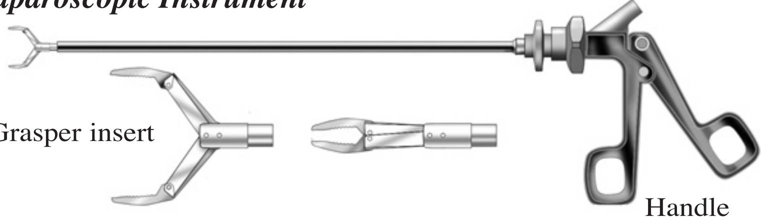
Surgical knots are described as *Two-Handed, One-Handed, and Instrument ties*. In all methods there is a *tying hand* and a *non-tying hand*. The tying hand is usually the non-dominant hand while the free end of the suture is controlled with the non-tying hand. A right handed individual uses the left hand as the tying hand.[1] This handbook shows the left hand tying the knots.

The two-handed square knot may be easier for beginning students to tie because it uses less finger action and more wrist and arm action.

Three techniques for the one-handed square knot are described. Technique I followed by Technique II will produce a square knot. Technique III followed by Technique II will produce a square knot.

The instrument tie for the square knot is described using a hemostat. The Aberdeen knot can also be tied using laparoscopic instruments or conventional surgical instruments.

Laparoscopic Instrument



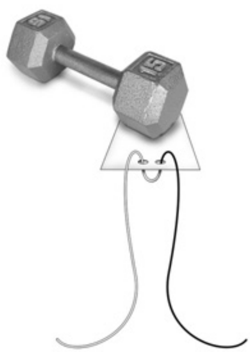
The dominant knot in surgery is the square knot. It has 80-90% tensile strength of the suture material. However, when it is critical that a knot remain tight, the Aberdeen knot is recommended.

The Aberdeen knot is attributed to Sir James Learmonth, a Professor of Surgery at Aberdeen University, 1932–1938. He is considered to be the first surgeon to determine that it used less thread than the contemporary surgeon's knot.[9]

The Aberdeen knot finishes smaller than a square knot. Clinically, it has proven to be a useful alternative without sacrificing knot integrity[8] when finishing a suture pattern. The configuration of the Aberdeen knot is not clear however research shows that three cycles and two turns produces an optimally secure knot.[7]

To practice the knot tying techniques, suture materials and practice pads can be found online or make your own by punching two holes one centimeter apart and one centimeter from the edge of a note card. Pass a piece of string approximately 76 cm (30") long through one hole and out the other resulting in two tying strands. Secure the card with a weight as shown.

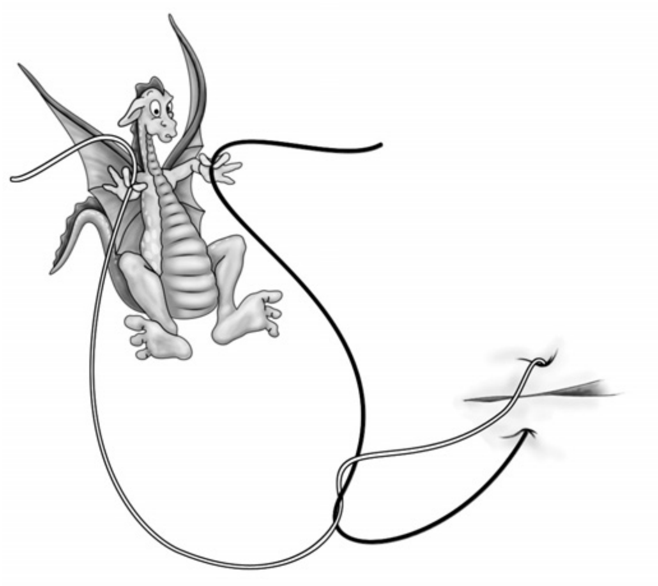
Alternatively, tie a shoelace around tacks in a board and place the tying strand under the shoelace. When the practice knots are tightened, the laces will close like an incision. Darken half of the tying strand with a felt tip marker to match the dark and light tying strands seen in the illustrations in this handbook.



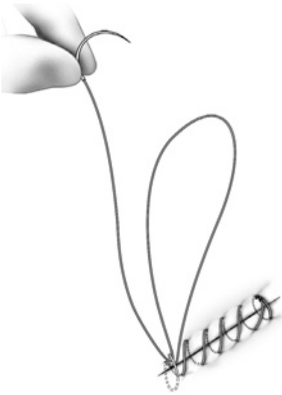
Sterile technique eliminates infectious microorganisms from wounds and instruments. The difference between sterile and aseptic is subtle. *Aseptic* is the complete absence of living microorganisms brought about by physical means such as autoclaving or gamma irradiation. *Sterile* also refers to the complete absence of living microorganisms but this state can be produced using disinfectants or chemical agents.[1]

Section II

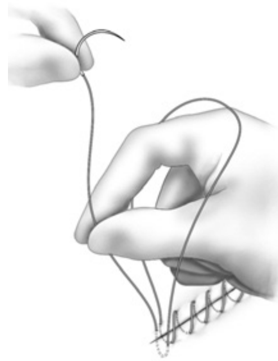
Surgical Knot Tying Techniques



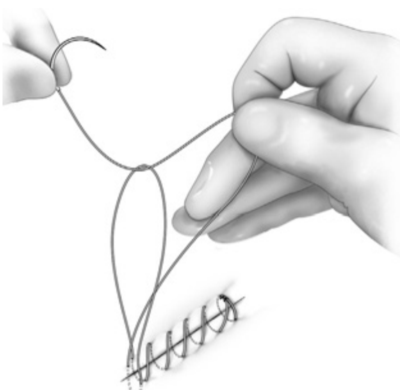
Aberdeen Knot



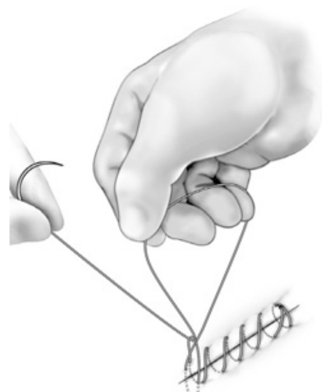
Step 1. Finish the suture pattern with a stitch that forms a loop.



Step 2. Reach through the loop and grasp the suture between thumb and index finger.



Step 3. Pull the suture through the loop forming a bight. At the same time engage the lower part of the bight with middle and ring fingers.



Step 4. Use the middle, ring and little fingers to tighten the first cycle.

Step 5. Leave a loop large enough to accommodate a second cycle. The needle strand will remain free to be pulled under the first throw.

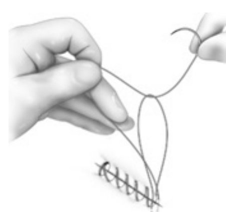
Step 6. Repeat steps 2-5 at least two more times before turning the terminal end of the suture through the loop. Three cycles and two turns appear to be the strongest configuration.[7]

This knot is easy to tie with the right or left hand however left-handed individuals may prefer the following left-hand view.

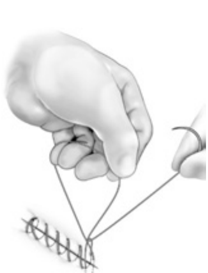
Aberdeen Knot Tying Steps for the Left-Hand

Step 1

Step 2



Step 3

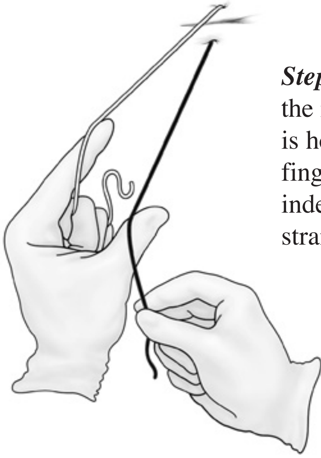


Step 4

Step 5

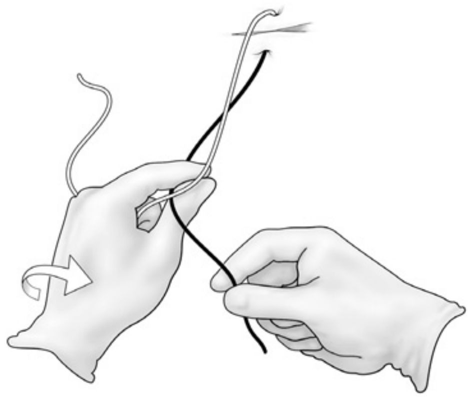
Square Knot
Two-Handed

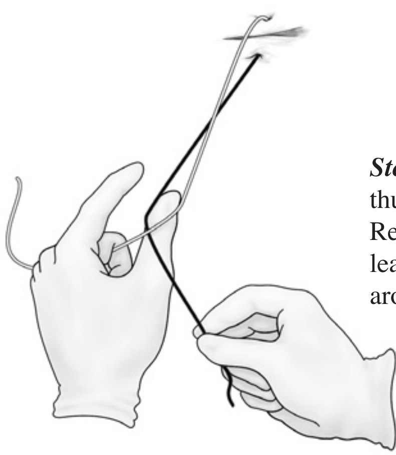
First Throw



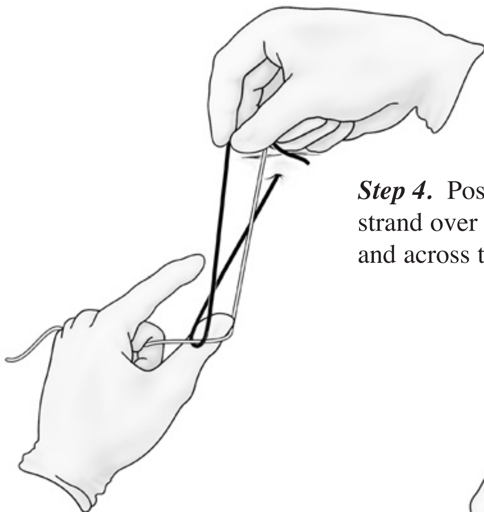
Step 1. Hold the dark suture strand in the right hand. The light suture strand is held under the left middle and ring fingers. Keeping the left thumb and index finger apart, place the suture strands as shown.

Step 2. Touch the left thumb and index finger. Pronate the left hand to form an opening between the suture strands.

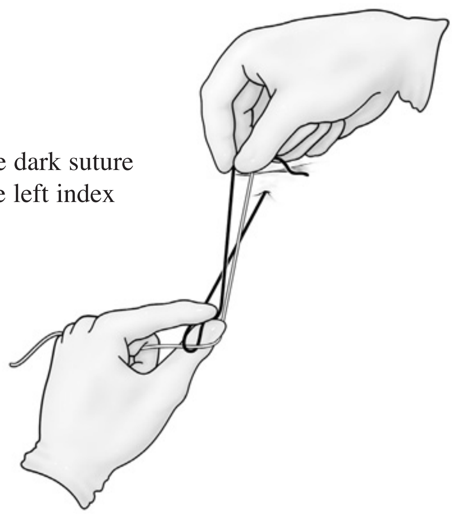




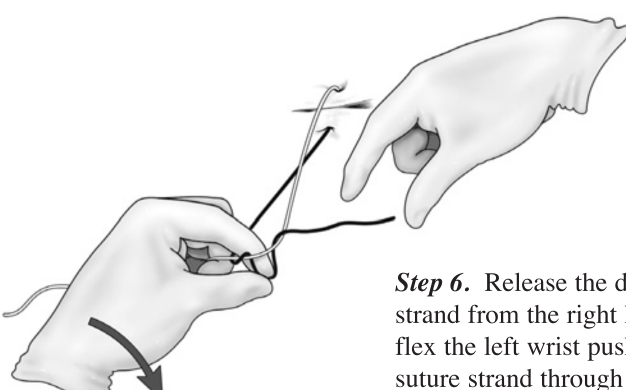
Step 3. Elevate the left thumb through the opening. Release the left index finger leaving the suture strands around the thumb.



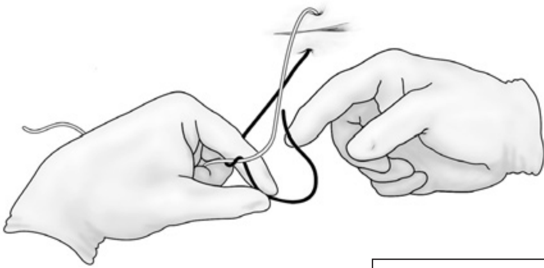
Step 4. Position the dark suture strand over the light suture strand and across the thumb pad.



Step 5. Secure the dark suture strand between the left index finger and thumb.

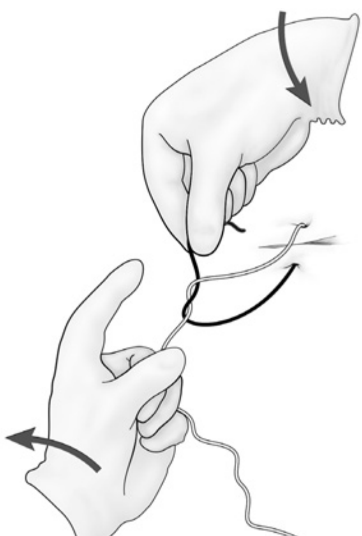


Step 6. Release the dark suture strand from the right hand and flex the left wrist pushing the dark suture strand through the opening with the left index finger.



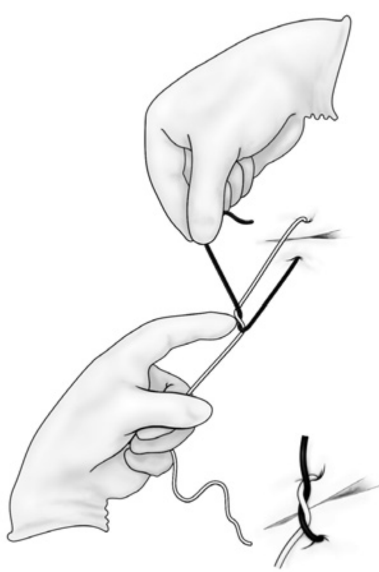
Step 7. When the dark suture strand has passed completely through the opening, it is again picked up with the right hand.*

** When tying a surgeon's knot, make a double twist by repeating steps 4-7 before tightening the first throw.*

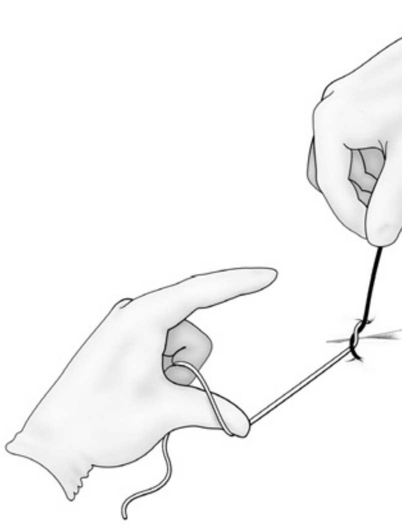


Step 8. Move the right hand distally and flex the wrist. Extend the left wrist. The hands are now in position to tighten the throw.

Step 9. Use the left index finger to tighten the throw. This action also facilitates tightening throws in deep cavities. The inset shows the suture lying flat to prevent slipping of the completed throw.

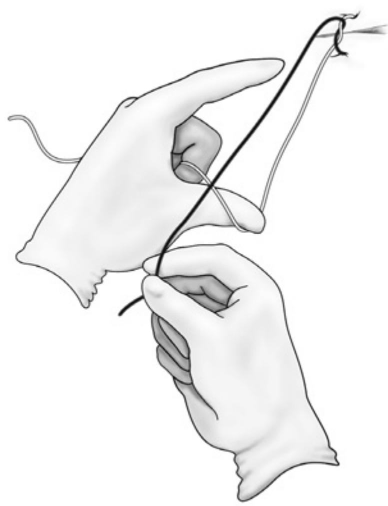


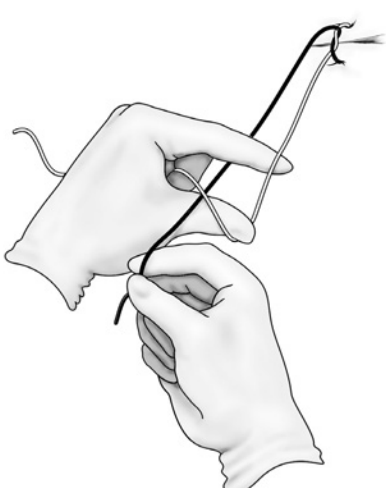
Second Throw



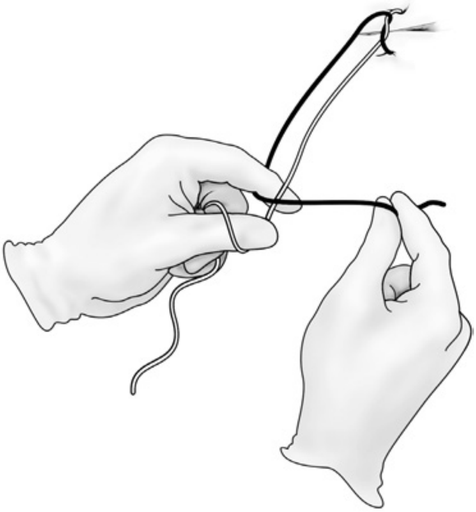
Step 10. Withdraw the left index finger. Keep holding the light suture strand under the left middle and ring fingers. Begin the second throw by securing the light suture strand with the left thumb.

Step 11. Bring the dark suture strand across the light suture strand between the left thumb and middle finger. Take care not to pull the suture strands too tight to avoid the possibility of dislodging the first throw.

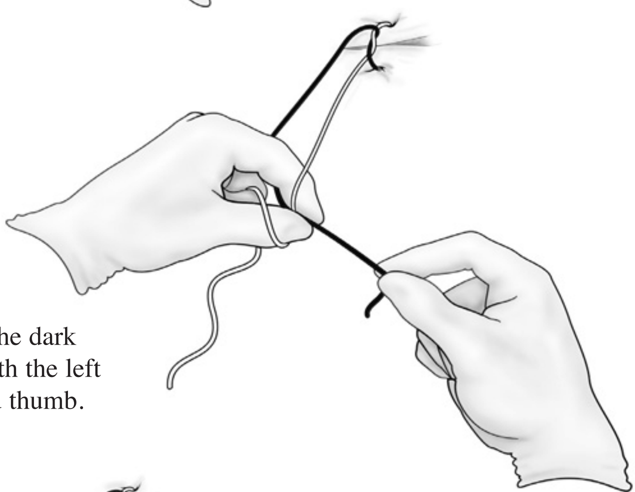




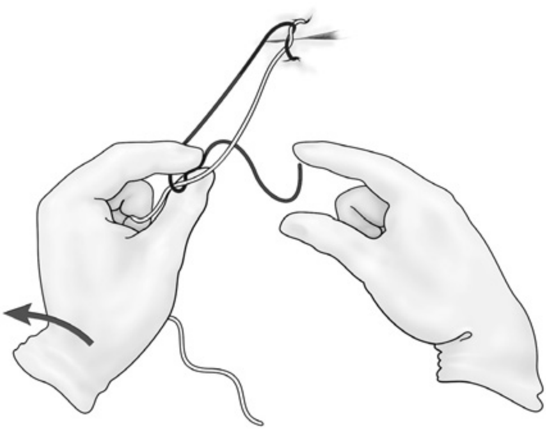
Step 12. The left index finger will pass over the dark suture strand and into the newly formed opening between the dark and light suture strands.



Step 13. Position the dark suture strand over the light suture strand and across the pad of the left index finger.

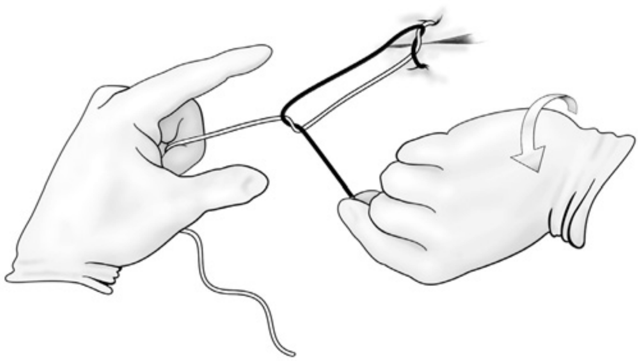


Step 14. Hold the dark suture strand with the left index finger and thumb.

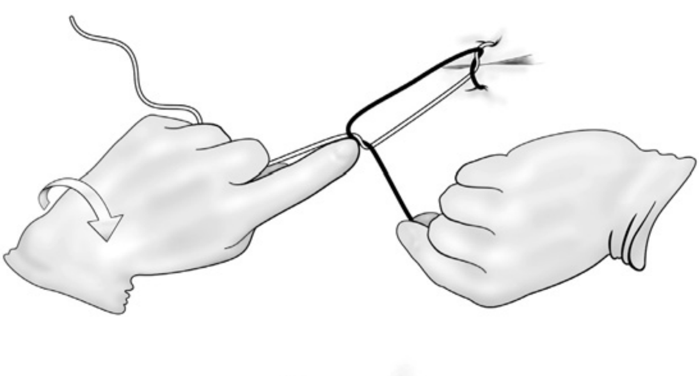


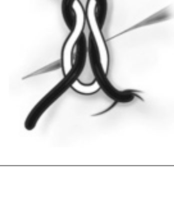
Step 15. Release the dark suture strand from the right hand and push it through the opening with the left thumb by extending the left wrist.

Step 16. Pronate the right hand and move it toward you while holding the end of the dark suture strand with the thumb and index finger. This action will remove suture twisting and allow the knot to lie flat.



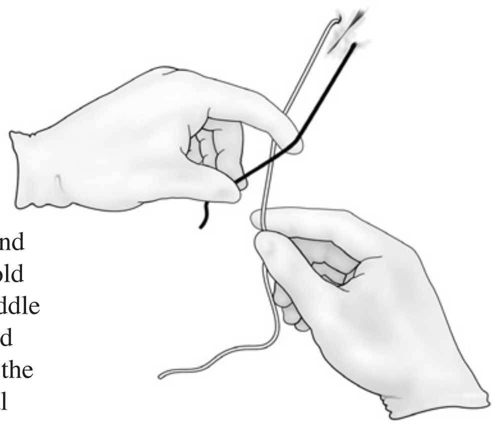
Step 17. To complete the knot, pronate the left hand pushing the throw flat with the left index finger. This action will remove suture twisting and allow the knot to lie flat. The inset shows the completed knot before it is drawn tight.



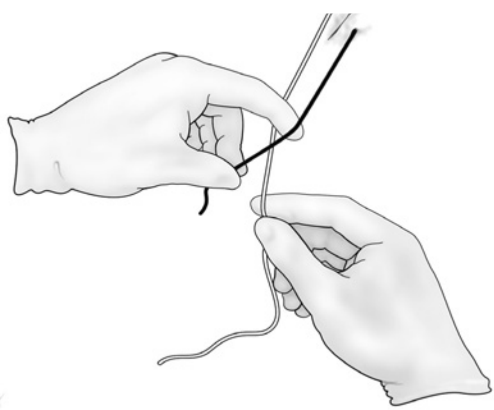


Square Knot
One-Handed, Technique I

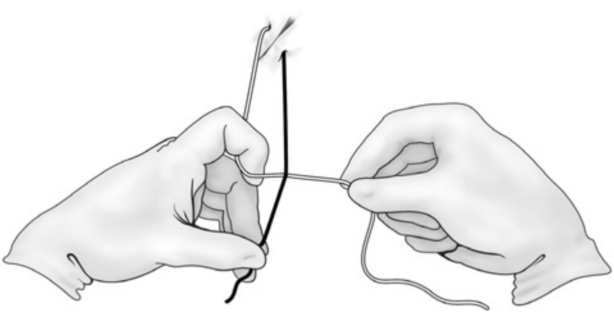
Three one-handed techniques are illustrated. Technique I followed by Technique II will produce a square knot. Technique III followed by Technique II will also produce a square knot.



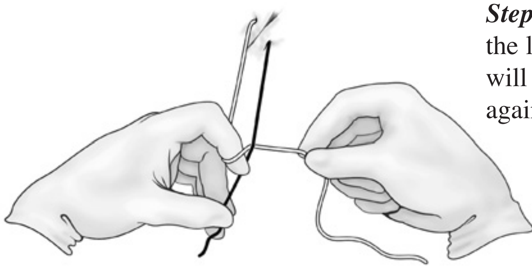
Step 1. Cross the dark strand over the light strand and hold with the left thumb and middle finger. Hold the light strand in the right hand. Position the dark strand along the lateral side of the left index finger.



Step 2. Position the light suture strand on the medial side of the left index finger.

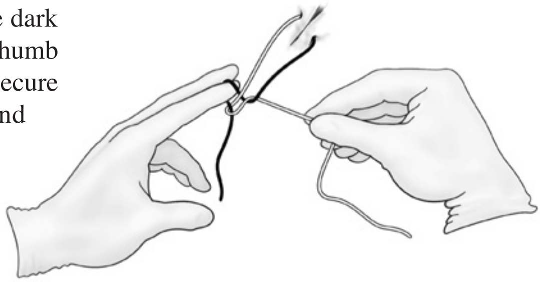


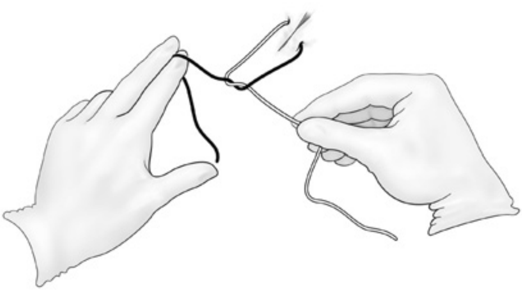
Step 3. Flex the left index finger engaging the light strand on its palmar surface.



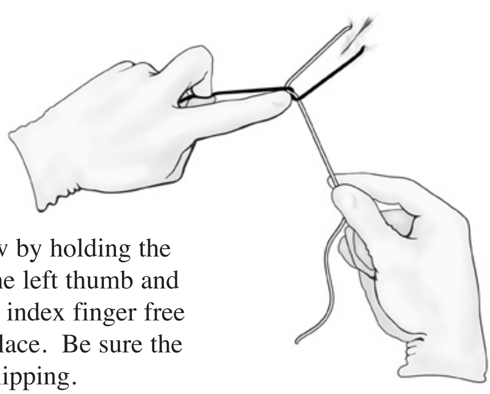
Step 4. Partially extend the left index finger which will position its medial side against the dark suture strand.

Step 5. Fully extend the left index finger, release the dark suture strand from the thumb and middle finger and secure it with the left index and middle fingers.





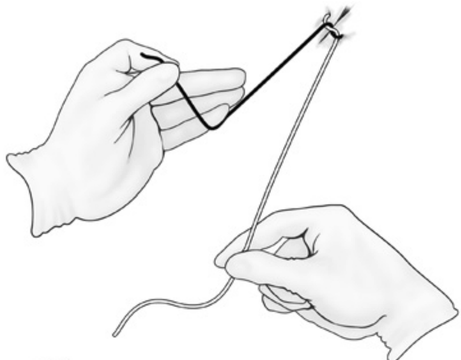
Step 6. Pull the dark suture strand through with the left index and middle fingers.

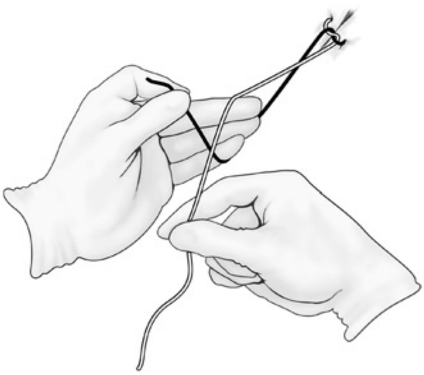


Step 7. Tighten the throw by holding the dark suture strand with the left thumb and middle finger leaving the index finger free to guide the suture into place. Be sure the suture is flat to prevent slipping.

Square Knot
One-Handed, Technique II

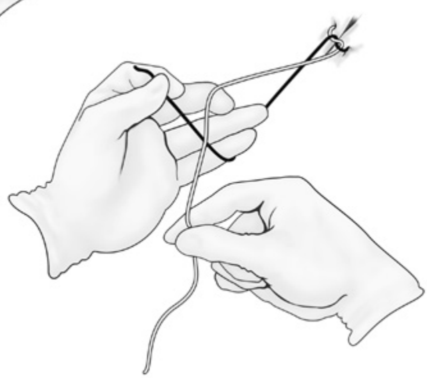
Step 1. With the palm of the left hand facing up, hold the dark suture strand between the thumb and index finger having the suture strand pass across the palmar surface of the other three fingers.

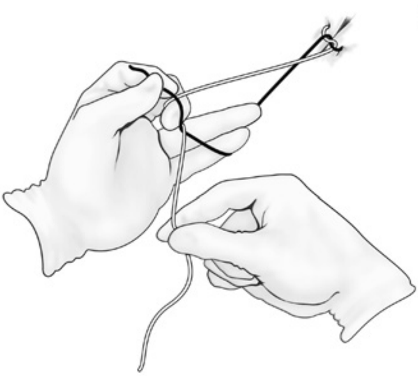




Step 2. Position the light suture strand on the lateral side of the left middle finger then across the dark suture strand between the ring and little fingers.

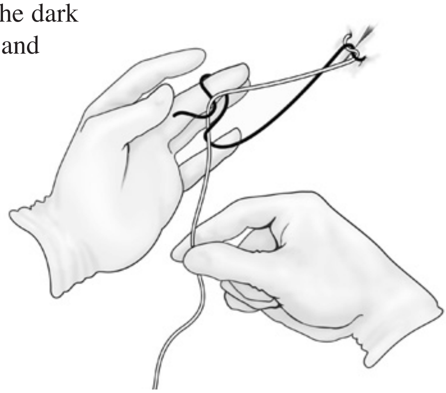
Step 3. Flex the left middle finger to engage the light suture strand.



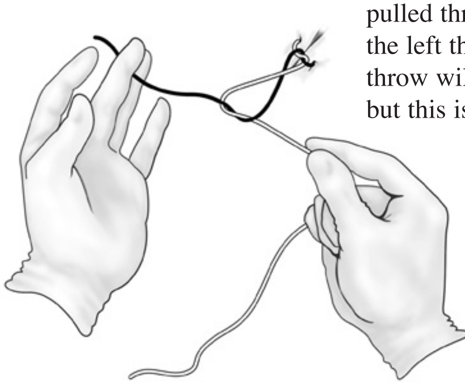


Step 4. Continue flexing the left middle finger to engage the dark suture strand on its dorsal surface.

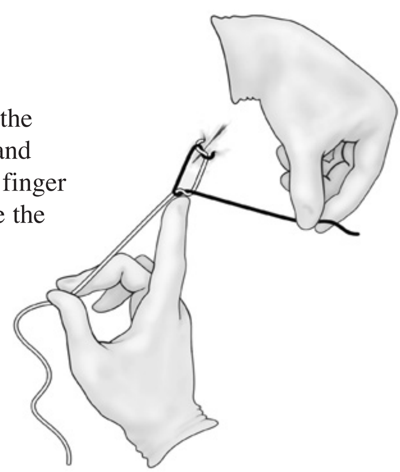
Step 5. Extend the left middle finger and secure the dark suture strand between it and the left ring finger. Release the dark suture strand from the left thumb and index finger.



Step 6. The dark suture strand is pulled through and again grasped with the left thumb and index finger. The throw will be twisted and backward but this is corrected by the next step.



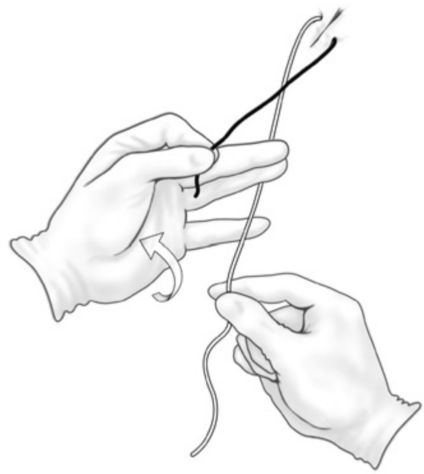
Step 7. Move the left hand distal to the right hand. Hold the light suture strand between the right thumb and middle finger leaving the index finger free to guide the throw down completing the knot.



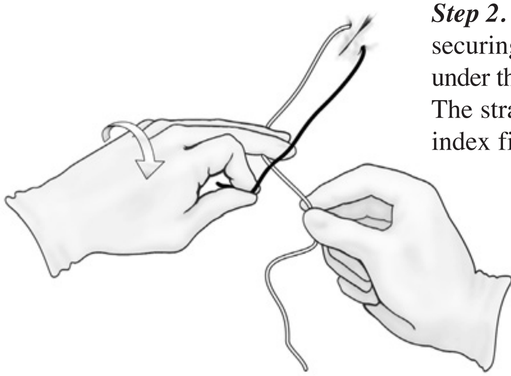
Square Knot

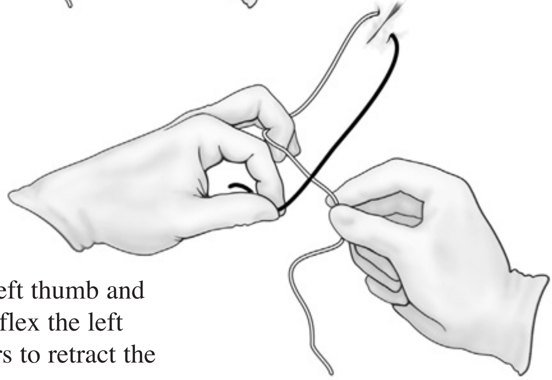
One-Handed, Technique III

Step 1. Cross the dark suture strand over the light suture strand and hold with the left thumb and index finger. Hold the light suture strand in the right hand. Supinate the left palm and place the light suture strand on the medial side of the left ring finger.

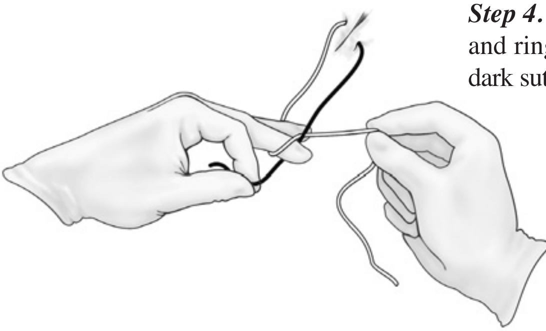


Step 2. Pronate the left hand securing the light suture strand under the middle and ring fingers. The strands cross distal to the left index finger.



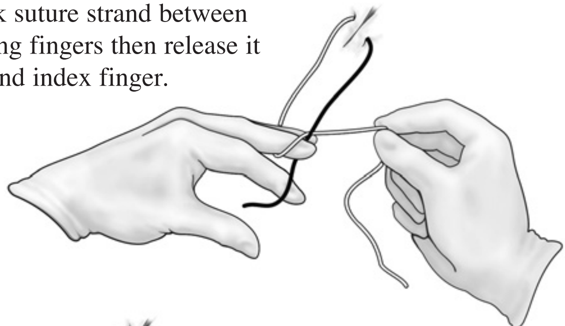


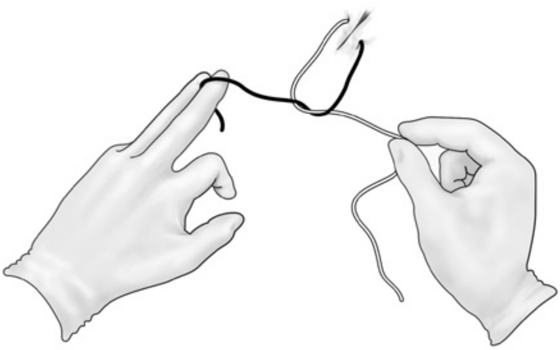
Step 3. Keeping the left thumb and index finger together, flex the left middle and ring fingers to retract the light suture strand.



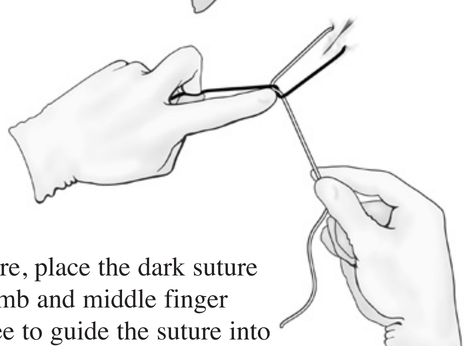
Step 4. Extend the left middle and ring fingers securing the dark suture strand between them.

Step 5. Hold the dark suture strand between the left middle and ring fingers then release it from the left thumb and index finger.





Step 6. Pull the dark suture strand through.

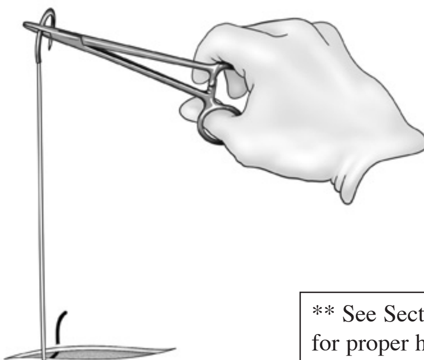


Step 7. To tighten the suture, place the dark suture strand between the left thumb and middle finger leaving the index finger free to guide the suture into place. Be sure the suture is flat to prevent slipping.

Square Knot
Instrument Tie

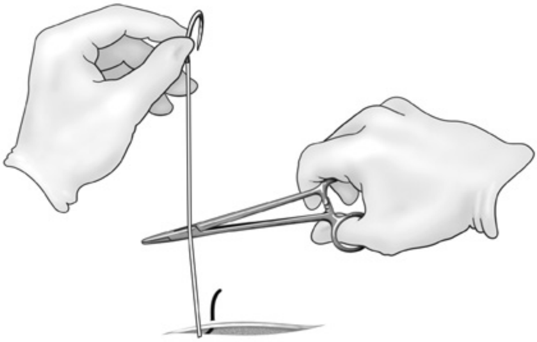
First Throw

Step 1. With the needle holder ** in the right hand, place the needle through the tissue. Pull the suture strand through leaving 2 centimeters for tying.

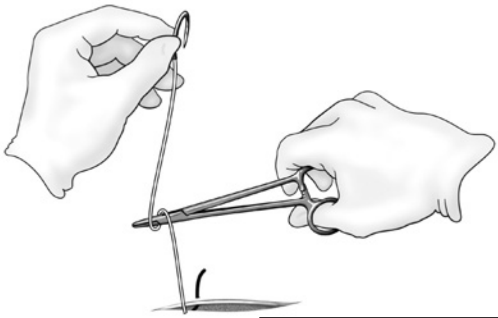


** See Section IV, pages 40-41 for proper handling of hemostats and needle holders.

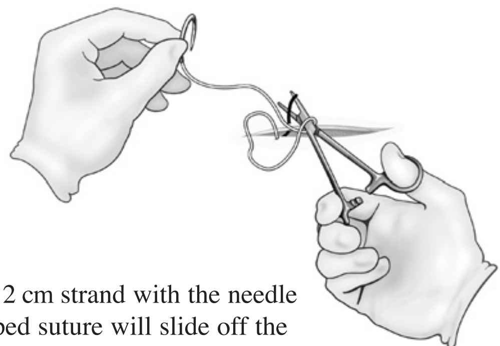
Step 2. Release the needle from the holder and grasp it with the left hand. Position the needle holder against the far side of the suture strand near its midpoint.



Step 3. With the left hand, wrap the suture strand around the needle holder once for the first throw of a square knot. *

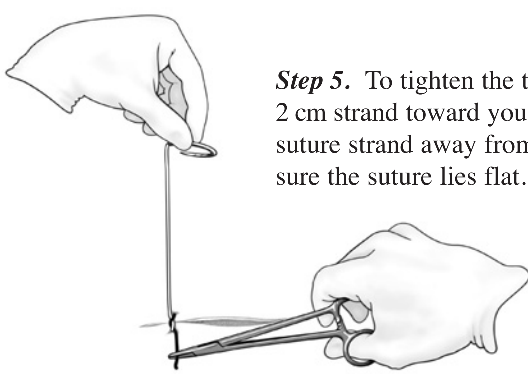


** A double wrap around the needle holder will produce a surgeon's knot.*



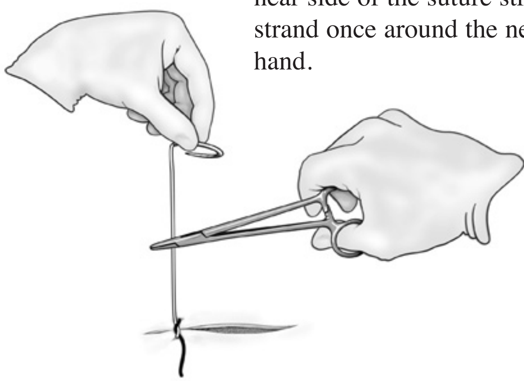
Step 4. Grasp the 2 cm strand with the needle holder. The wrapped suture will slide off the holder to encircle the 2 cm strand.

Step 5. To tighten the throw, pull the 2 cm strand toward you and the long suture strand away from you making sure the suture lies flat.

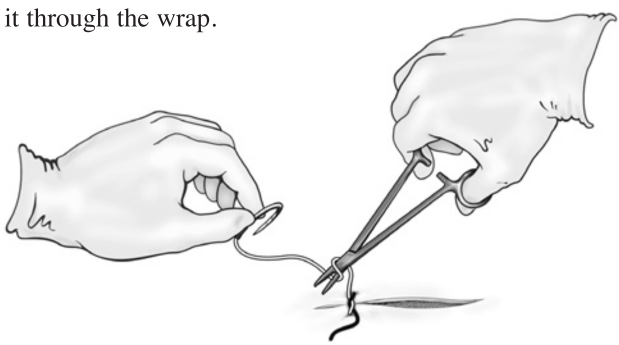


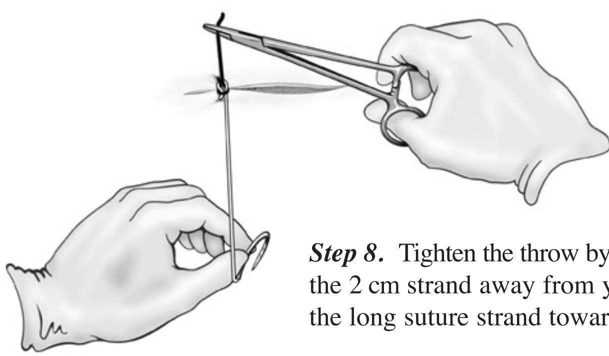
Second Throw

Step 6. Release the 2 cm strand from the needle holder. Position the needle holder against the near side of the suture strand and wrap the suture strand once around the needle holder with the left hand.



Step 7. Grasp the 2 cm strand in the needle holder and pull it through the wrap.



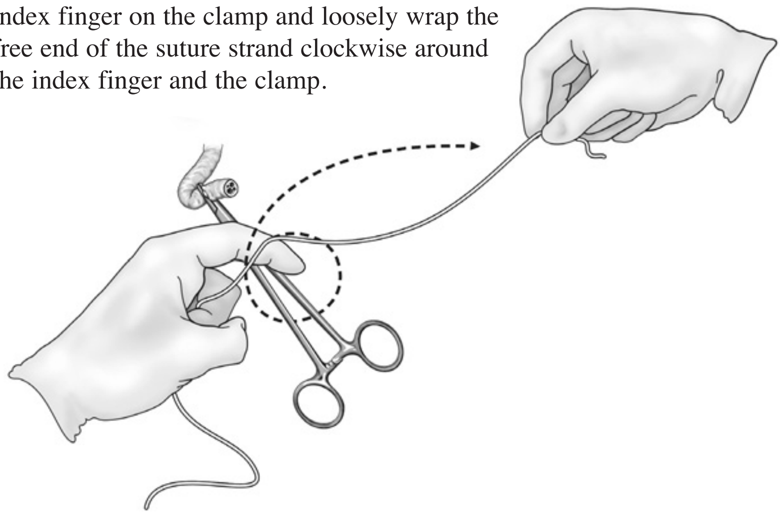


Step 8. Tighten the throw by pulling the 2 cm strand away from you and the long suture strand toward you.

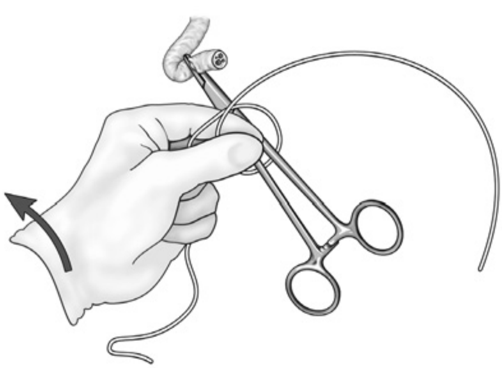
Miller's Knot

The Miller's knot is tied over a clamp before being transferred to a pedicle, like a cut umbilical cord. The knot can also be tied directly on the pedicle or small stalklike structure.

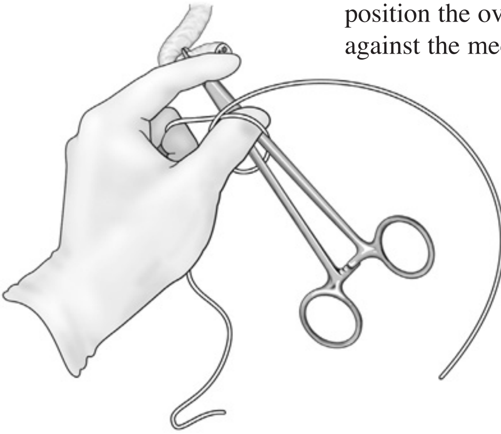
Step 1. Hold one end of the suture strand in the left hand under the middle, ring and little fingers. Control 8" of free suture strand with the right hand. Place the medial side of the left index finger on the clamp and loosely wrap the free end of the suture strand clockwise around the index finger and the clamp.



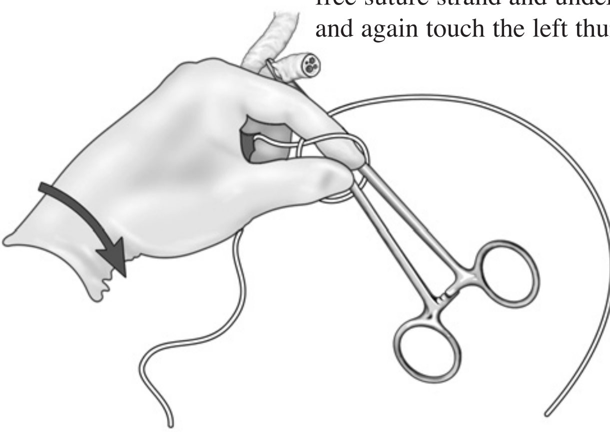
Step 2. Bring the left thumb and index finger together and extend the left wrist. This action will bring the thumb through the wrap.



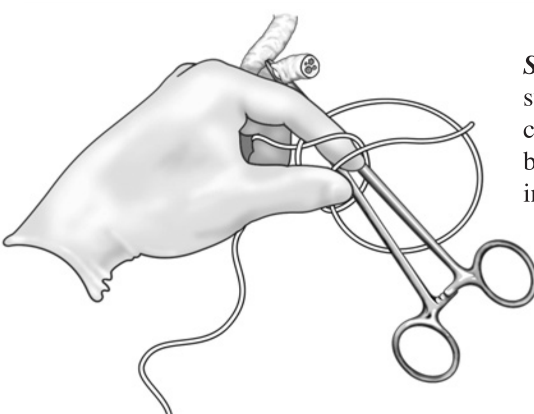
Step 3. Extend the left index finger and position the overlapping suture strand against the medial side of the thumb pad.

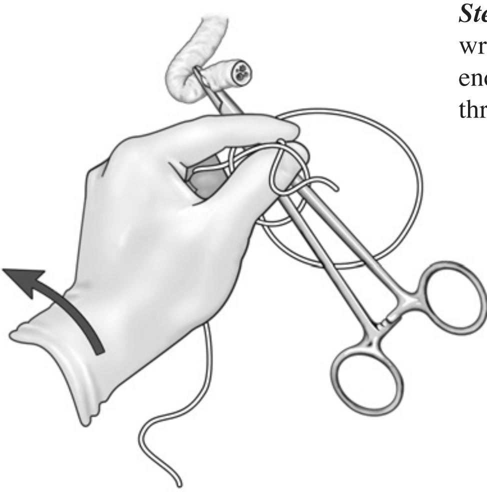


Step 4. Flex the left wrist to bring the tip of the left index finger in front of the 8" free suture strand and under the first wrap and again touch the left thumb.



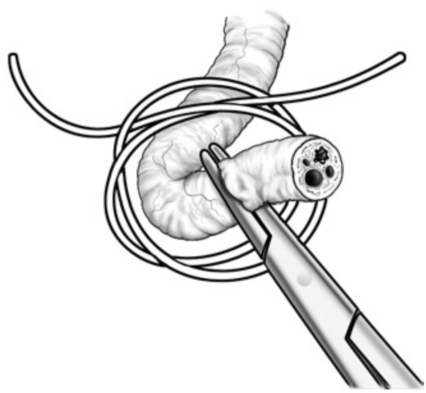
Step 5. Wrap the 8" free suture strand around the clamp again securing it between the thumb and index finger.

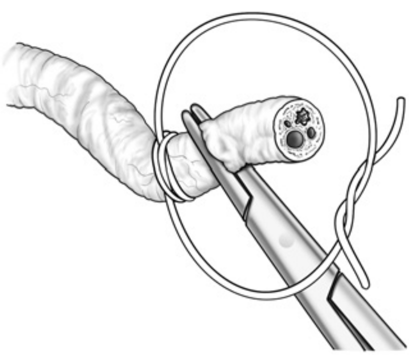




Step 6. Extend the left wrist to bring the free end of the suture strand through the wrap.

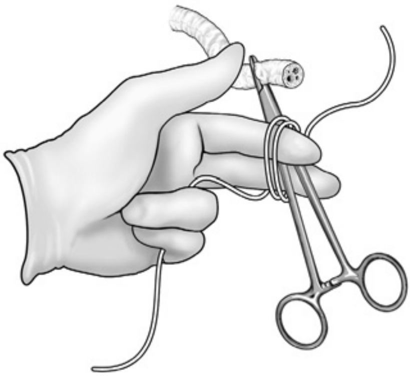
Step 7. Slide the knot off the end of the clamp onto the pedicle. To tighten the knot, pull evenly on both strands of the suture. The knot is secure and will compress the pedicle and will not loosen at this point.





Step 8. Both suture strands should be taken 180º around the pedicle and secured with a simple square knot or an Aberdeen knot.

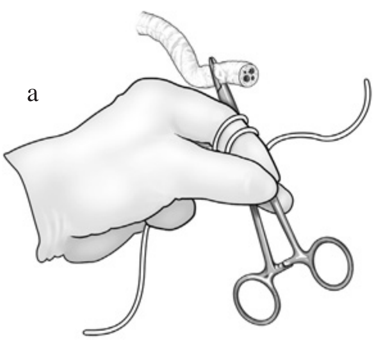
Modified Miller's Knot



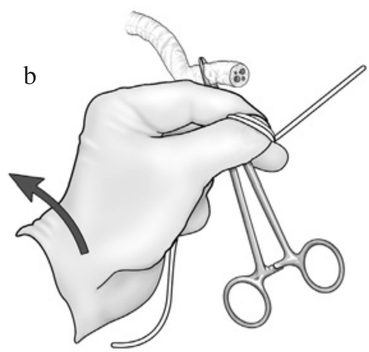
Step 1. Hold the suture strand under the ring and little fingers of the left hand and position the clamp between the index and middle fingers. With the free suture end make two loose counterclockwise wraps around the clamp and fingers.

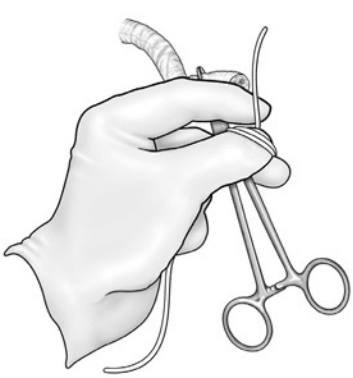
Step 2. (a) Touch the left thumb and index finger. (b) Extend the left wrist to bring the thumb and index finger through the suture wraps.

a

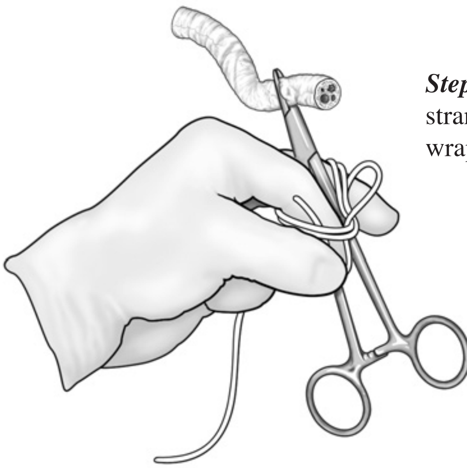


b

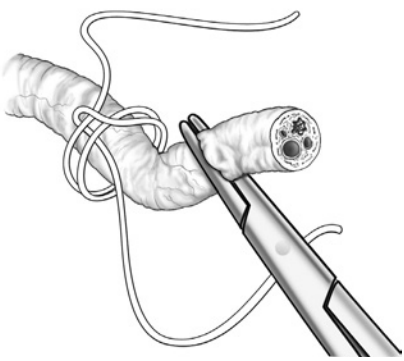




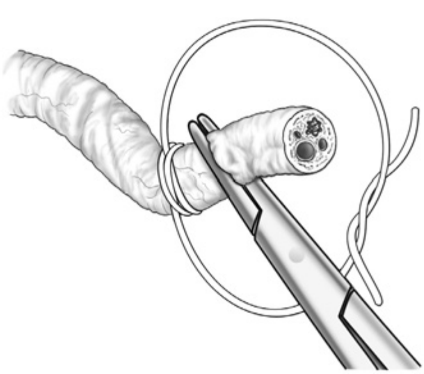
Step 3. Separate the thumb and index finger and place the free suture in their grip.



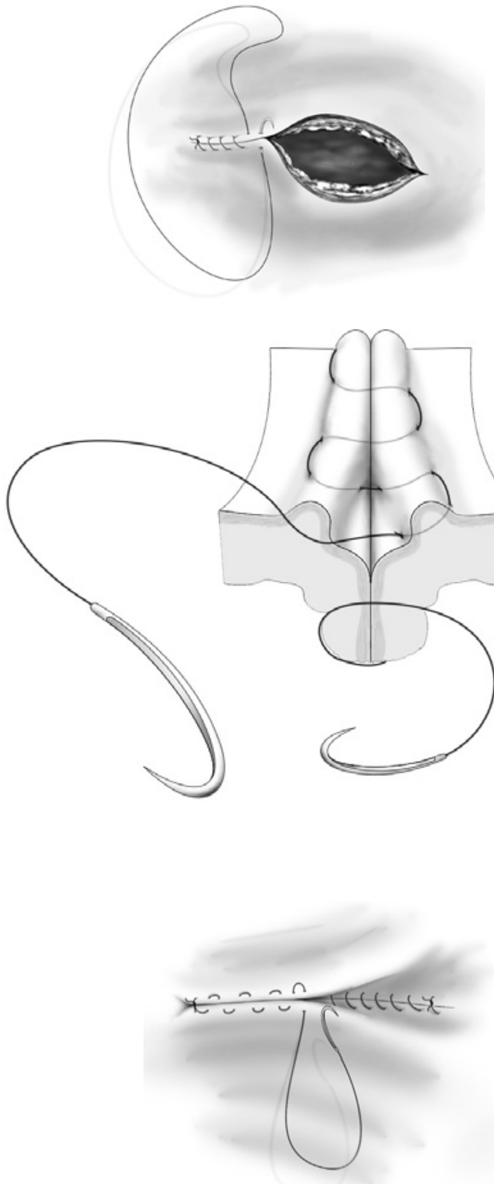
Step 4. Push the free suture strand through the suture wraps with the index finger.



Step 5. Slide the knot off the clamp and over the pedicle before tightening.



Step 6. Both suture ends should be taken 180º around the pedicle and secured with a simple square knot or Aberdeen knot.



Canine cesarian section
Wendy Balzer, DVM, PhD, Diplomate ACVS, Oregon State University
Small Animal Soft Tissue Surgery, Eric Monnet (Editor)
Jan 2013, Wiley-Blackwell,

Section III

Suture Materials, Surgical Needles and Forceps

Suture Materials

Characteristics of absorbable and non-absorbable sutures:

Absorbable sutures are made from the following materials:

- Surgical Gut

  Plain: the intestinal submucosa of sheep intestine or serosa of beef intestine

  Chromic: plain gut soaked in chromic acid salts

- Polyglycolide or polyglycolic acid (PGA)
- Polydioxanone or poly-p-dioxanone (PDO, PDS)

As the name implies, absorbable sutures are absorbed by the body after several weeks. Surgical gut is a common absorbable material but synthetic materials are commonly used. Polyglycolide and polydioxanone handle and tie well. Surgical gut sutures have been banned in Europe and Japan due to concerns regarding Bovine Spongiform Encephalopathy.

Non-absorbable sutures are made from four basic materials:

- Natural fibers of cotton and silk
- Braided synthetics
- Monofilament synthetics
- Stainless steel

Early surgeons used natural fibers of cotton and silk for suturing due to their ease in handling. Cotton holds secure with fewer throws and silk is less likely to cause infection as it lacks the capillarity of cotton and will tie securely with 3 half-knots or throws. Silk is manufactured in twisted and braided forms.[1, 2]

The braided synthetics are less reactive than silk but require more throws for knot security leaving more suture material in the wound.[2]

Monofilament synthetic sutures made of nylon, polybutester and polypropylene are the most inert. Nylon and polypropylene are difficult to handle and tie and the knots are not steadfast. Because synthetics are the most inert, they do not tend to harbor bacteria making them more desirable for infected wounds.[2]

Steel sutures are made of stainless steel available as monofilament and braided suture. Steel wire sutures are not easily placed in tissue and they are extremely difficult to tie but when they are used the knot security is excellent. Large sizes are too cumbersome to tie and must be twisted. Steel wire is advantageous when suturing bone as the desired degree of tension can be regulated by twisting the wire.

Suture material selection:

Absorbable suture material should be used when continued strength is not important or when the possibility of infection from surface sutures makes absorbable subcutaneous sutures desirable. Absorbable sutures are used for subcutaneous tissues and for mucosal layers of the intestine.[2]

Non-absorbable sutures are used for continued strength, when the sutures are to be removed after healing and when minimal tissue reaction is important. Non-absorbable sutures are used for skin and fascial closure, vessel ligation, tendon and bone repair.[2]

Sutures range from a heavy braided #5 suture for orthopedics, to a fine monofilament #11-0 suture for ophthalmic use.

Today, most sutures are made of synthetic polymer fibers. Silk suture is used, mainly to secure surgical drains and is one material still in use from ancient times. Gut suture is another ancient material still in use.

Other methods used to close surgical wounds include staples and metal clips, adhesive dressings, tapes, and glue.

Surgical staples and clips can be used in place of sutures to close skin wounds, hollow viscera and lung tissue. Staples are applied using a disposable stapler and are removed with a specialized staple remover. Clips are used when a less invasive closure is desirable.

Topical cyanoacrylate adhesives, such as super glue, are used with, or as an alternative to sutures. The adhesive remains liquid until it comes in contact with tissue after which it polymerizes forming a bond. The tissue adhesive acts as a barrier to microbial penetration as long as the adhesive film remains intact. Adhesives are unsuitable for oozing or potentially contaminated wounds.[13] For surgical incisions it does not work as well as sutures because the wounds often break open. Cyanoacrylates should not be used near the eyes and there is a learning curve on the correct usage.

The discomfort and complexity of suturing can make patients want to avoid stitches. Small cuts and minor wounds can be managed with wound closing strip bandages. They are not as strong as sutures, however these adhesive bandage strips can be equally effective as long as they are kept dry and affixed to the wound area securely. The strip bandages are also beneficial for wound support after sutures have been removed.

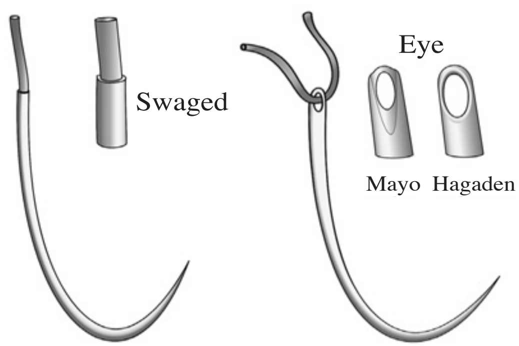
Surgical Needles

Four characteristics of surgical needles:

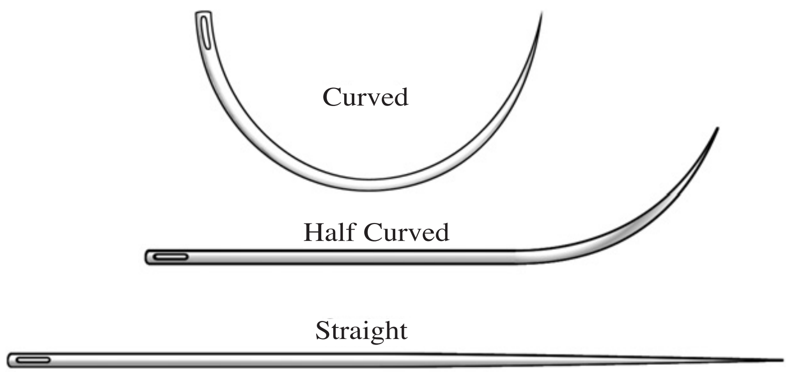
- Needle to suture attachment
- Shaft and shape
- Point and cross section
- Size

Needle to suture attachment is accomplished with an eye or a swaged attachment placed during the manufacturing process. Swaged needles are only slightly larger in diameter than the suture and make smaller holes in the tissue.[1]

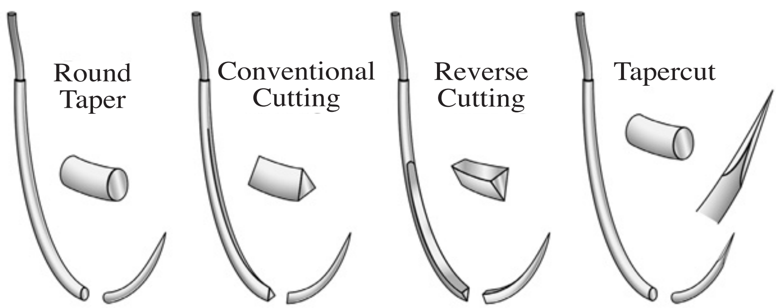
The diameter of needles with eyes is 3x to 4x larger than the suture and will make larger holes in the tissue.



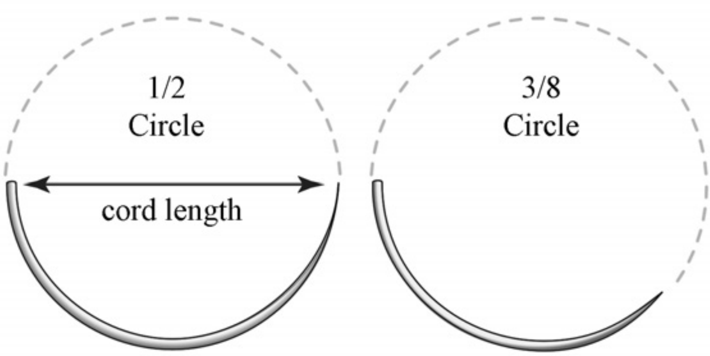
Needle shafts are curved, half curved and straight. Selection of the needle shape is determined by the tissue type, depth and accessibility. Curved needles are held with needle holders and are used for small surface wounds and wounds deep in the body cavity. Straight needles are usually hand held and are used on surface wounds.[2]



Point and cross section are determined by the tissue being sutured. *Round tapered needles* are round in cross section and used for fascia and soft tissue such as urinary bladder and hollow viscera. *Cutting needles* can be curved or straight, have at least two opposing cutting edges and are used for dense tissue like skin and tendon. In addition to the two cutting edges, *conventional cutting needles* have a third cutting edge on the inside concave curvature of the needle and cut in the direction of the suture pull. *Reverse cutting needles* place a cut away from the pull of the suture and are used in the skin. *Tapercut needles* are used in vascular surgery because they are fine needles sharp enough to penetrate synthetic vascular graft material but not so sharp that they damage delicate blood vessel walls.[1]



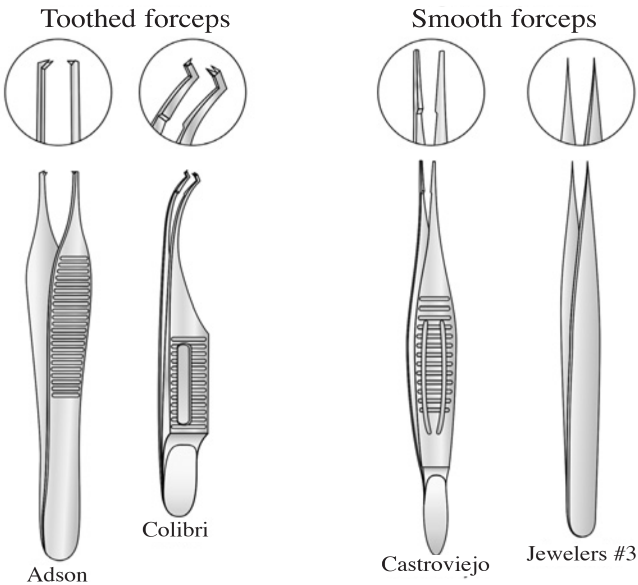
The final characteristic of surgical needles is size. Needle size is equal to the cord length measured across the circle diameter rather than along its curve. The needle should be large enough to permit rapid, accurate and precise suturing.[2]



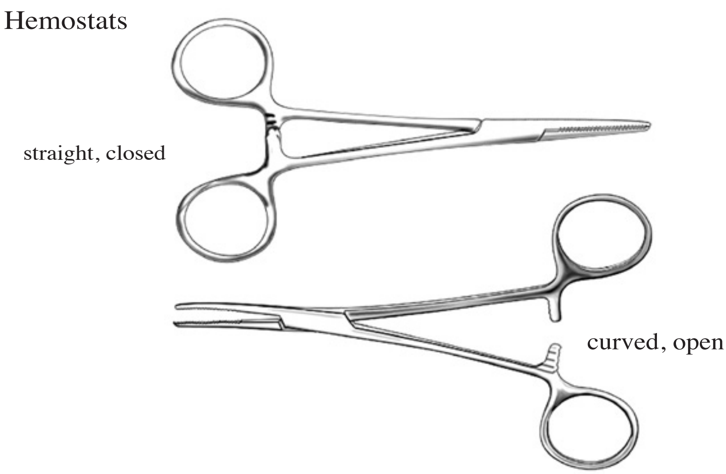
Specific choices in the selection of suture material, needle style and size can only be determined by experience. The scope of this handbook is to teach the basics of suturing. More advanced schooling in the individual specialties along with experience will lead to practical selections.

Tissue Forceps

Tissue forceps, also called thumb forceps, are used to secure tissue during the placement of sutures. *Toothed forceps* are used for grasping subcutaneous tissue, fat, muscle and skin during closure. More delicate tissues of the viscera and blood vessels are held with *smooth forceps*.[1]



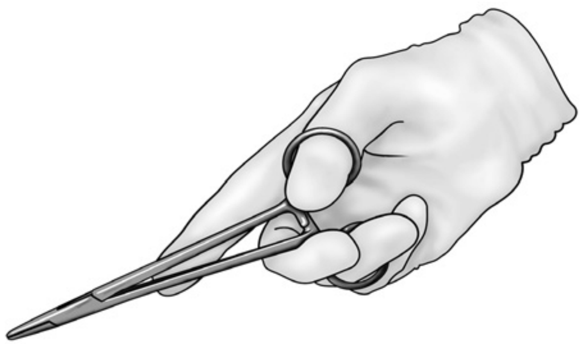
Hemostats belong to a group of instruments that pivot, similar to scissors, and include needle holders, tissue holders and various clamps. The structure of the tip determines the function.



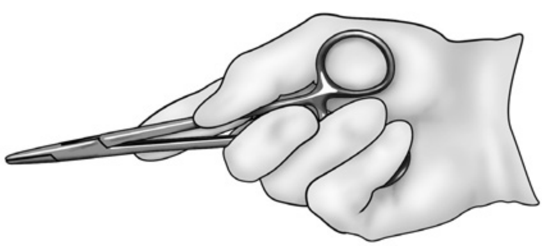
Section IV

Suturing Methods and Suture Removal

Gripping techniques:



Thumb and third finger grip facilitates a rapid grip and release



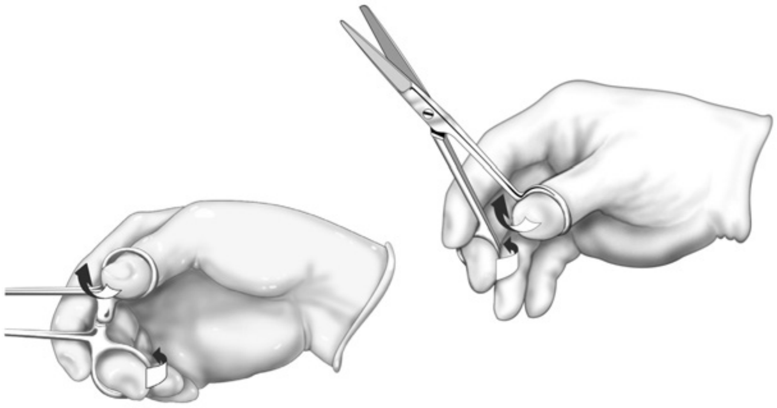
Palm grip allows greater force for insertion of the needle

Pencil grip offers maximum control of fine needles[2]

Right hand grip and release:

All scissors and forceps have been designed for use with the right hand. Used with the right hand, good cutting will occur if the thumb and fingers do not extend through the loops past the first knuckle.

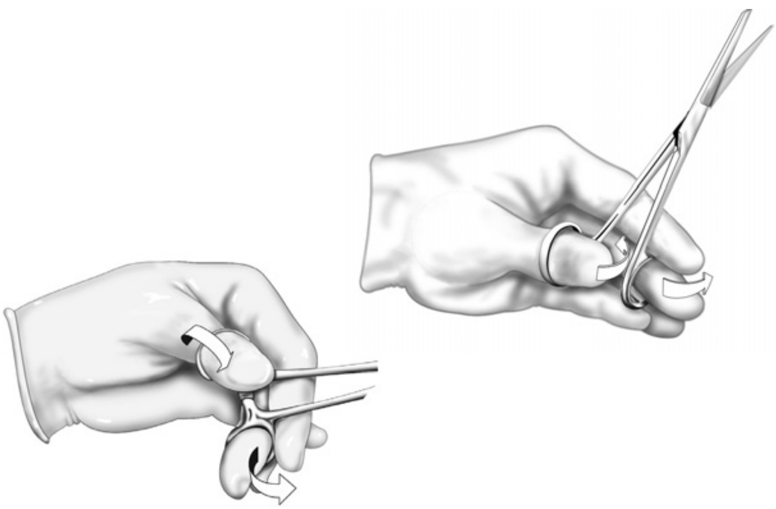
To release the rachet-lock use outward pressure with the thumb accompanied by inward pressure with the finger.



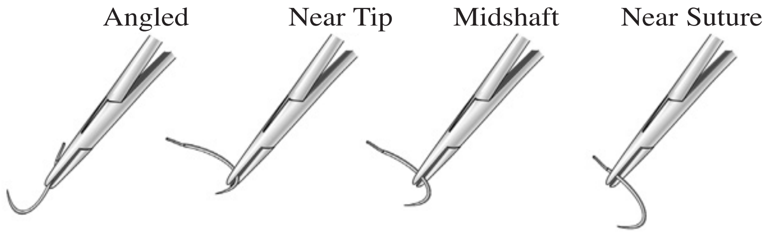
Left hand grip and release:

Used with the left hand, good cutting will occur if the thumb and fingers are extended through the loops past the first knuckle.

To release the rachet-lock use inward pressure with the thumb accompanied by outward pressure with the finger.

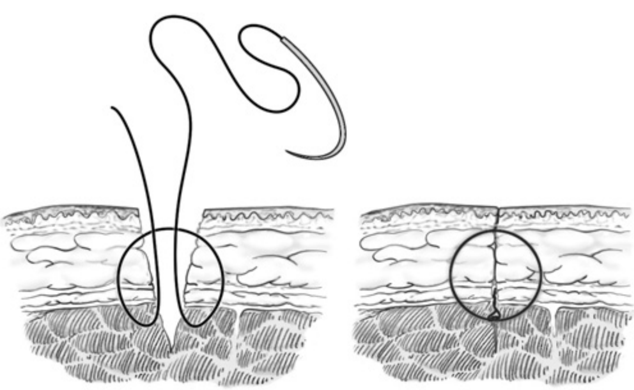


Closing incisions and acute wounds is accomplished, in most cases, with the help of needle holders and tissue forceps. Needle holders, similar to hemostatic forceps, have shorter tips and are heavier with grooved jaws conducive to holding a needle securely.[1] The long axis of the needle holder should be perpendicular to the long axis of the needle, however when a suture must be placed in a deep cavity, the needle is placed in the holder at a steep angle. Grasp the needle near the tip to apply adequate force to penetrate dense tissues. Grasp the needle near the midshaft for general suturing and near the suture end for greater control when suturing delicate tissues.[2]

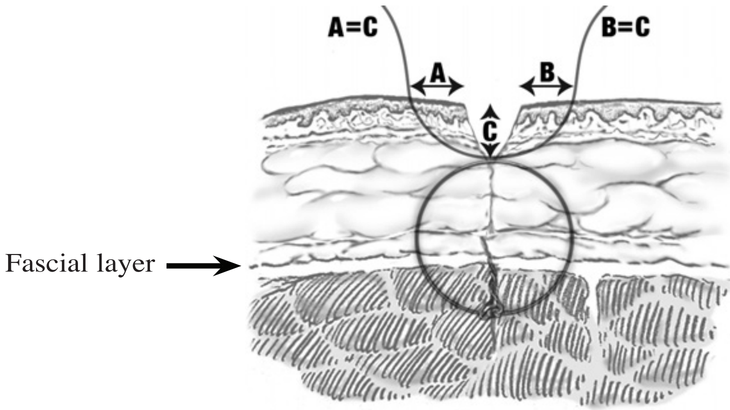


Suturing guidelines

- The suture size should be large enough to provide adequate strength for the tissue being sutured.[3]
- Provide even tension to both strands of each throw to form comfortably secure knots allowing for potential edema.[3]
- For deep wounds, approximate tissue layers as the wound is closed to avoid spaces. Spaces increase the likelihood of infection.[3]



- The distance of the needle puncture from the edges of the wound should be equal to the depth of the tissue being sutured and include equal amounts of tissue on both sides of the wound



- A distance of one fourth inch (0.635 cm) between sutures is good for strong tissue like skin. Delicate viscera, blood vessels and nerves require finer more closely approximated sutures.[2]

- Skin and other soft tissue can swell significantly causing strain. To accommodate this strain continuous stitches must have an adequate amount of slack.

- Jenkin's Rule: Incisions can increase in size due to postoperative edema. If a suture fails to accommodate this stretch, it will cut through the fascia. For a continuous suture, the length of suture used should be at least four times the length of the wound. Sutures should be placed 1 cm apart using 1 cm bites at the wound edge. Using a 4:1 suture length to wound length ratio will allow for an adequate number of sutures and avoid cutting the fascial sheath. The suggested abdominal suture ratio is 6:1.

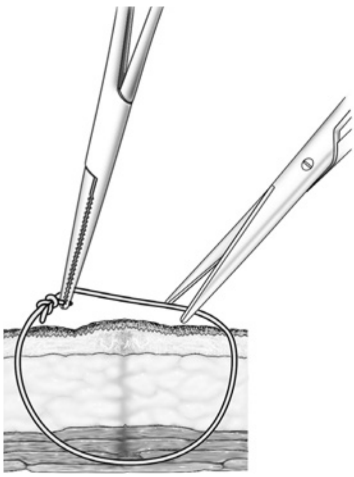
- Carry the throws to the tissue with the tip of the index finger to prevent damaging the suture material. Damaged suture material weakens the knot.[2]

- Tie the minimum number of throws needed because extra throws add bulk which increases foreign material tissue reaction.[2]

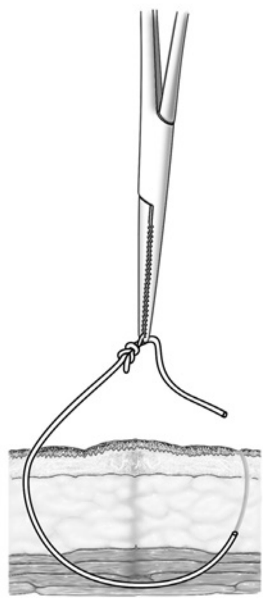
- Trim completed knots to minimize suture material reaction. Free ends of cotton, silk and synthetic materials are trimmed to 3 mm. Trim the ends of absorbable materials to 6 mm.[2]

- Different parts of the body heal at different speeds. Common time to remove stitches will vary. Facial wounds 3–5 days; scalp wounds 7–10 days; limbs 10–14 days; joints 14 days; trunk of the body 7–10 days.

Suture removal should be a painless procedure. Any dried exudate should be removed and the wound swabbed with an antiseptic solution. The knot or a loose end is grasped with forceps providing elevation of the suture. The forceps hold the knot so it will not be drawn through the suture path causing contamination.[1] The suture is cut with scissors or a number 11 scalpel blade close to where it enters the skin. The suture can then be withdrawn with the forceps.



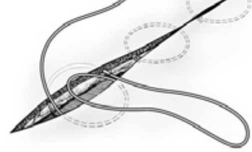
Snip the suture close to where it enters the skin.



Pull the suture with the forceps to complete the removal.

Section V

Suture Patterns



Types of Suture Patterns:

- Interrupted
- Continuous

An *interrupted* suture consists of single stitches placed in a row with each stitch having its own knot. Interrupted suture patterns add security because each stitch has a finishing knot. The tension of each suture along the incision can be adjusted during execution.

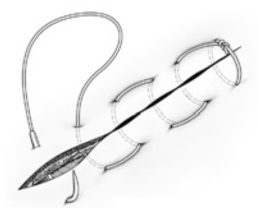
Continuous sutures begin with the initial knot and run continuously to the end of the wound before the finishing knot is tied. Speed is the major advantage of continuous suture patterns because all the stitches required to close a wound can be finished with one knot. If the wound becomes infected, all stitches must be removed. Some continuous patterns allow tension adjustment at multiple points along the wound.[1]

To start a suture pattern, use an approach which permits comfortable use of the surgical needle and instruments. Surgeons can place the needle from right to left or left to right, top to bottom or bottom to top depending on the orientation of the wound.

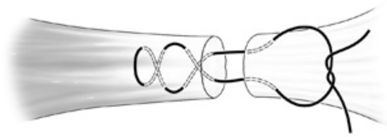
Clamp only the free end of the suture strand during an instrument tie because clamping anywhere along the strand will damage and weaken the material.[5]

Three categories of suture patterns:

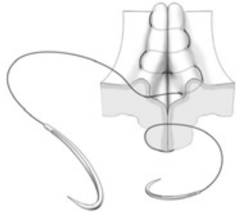
Appositional



Tendon and Ligament

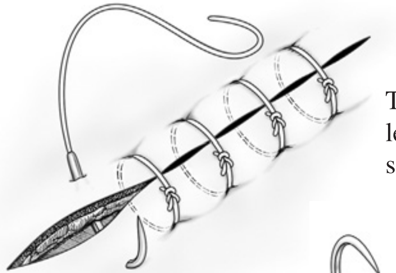


Inverting

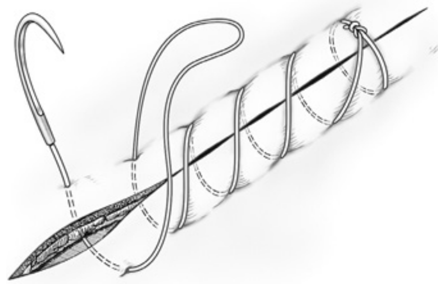


Appositional Suture Patterns

Over-and-Over



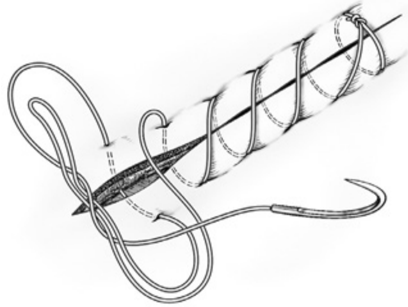
The *over-and-over* pattern on the left is *simple interrupted*. Each stitch is tied with a square knot.



Over-and-over continuous is the pattern on the right. A square knot is used to finish the first stitch. The suture continues as a running stitch until the wound is closed.

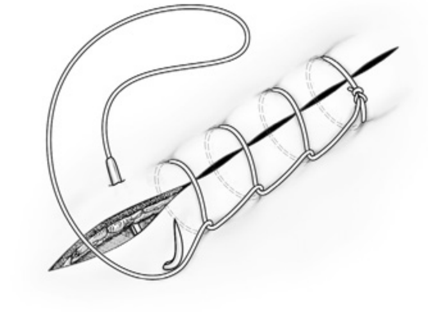
Securing Continuous Suture Patterns

Secure a continuous suture pattern after placement of the last stitch. Leave a length of suture long enough to double back and serve as one tying strand of the final knot. Pull enough suture through the last stitch to make up the second tying strand. When each strand is the proper length, tie a square knot or Aberdeen knot.



The first throw of a final square knot is shown. Finish the knot with as many throws as the suture material and wound require.

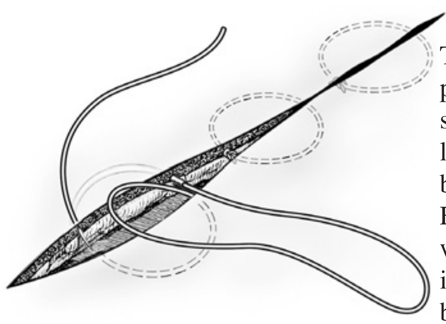
Ford Interlocking



The *locking stitch* is a continuous pattern formed by passing the emerging needle over the suture from the preceding stitch. It is completed using the directions for securing continuous patterns on page 47.

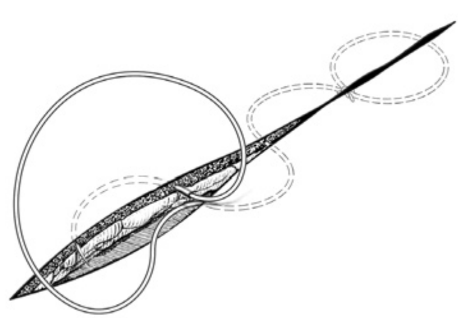
The locking stitch provides greater security than the simple continuous over-and-over pattern and suture tension can be adjusted with each stitch.

Intradermal or Subcuticular

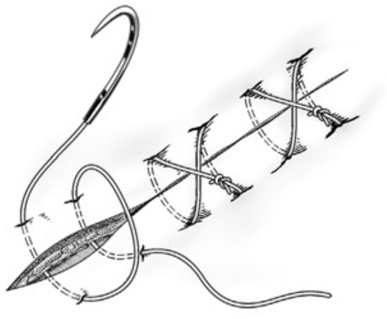


The interrupted *intradermal* pattern, also called a *subcuticular* suture, is the pattern shown on the left. This is a cosmetic closure because it leaves no suture marks. For safety, it should be reinforced with an adhesives bandage. It is shown as a continuous pattern below.

To complete the continuous intradermal suture, carry the needle through the opposing side of the wound and tie off using the directions for securing continuous patterns on page 47.



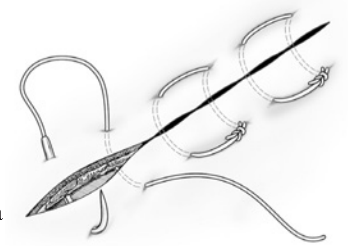
Interrupted Cruciate



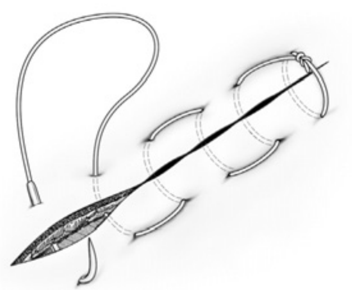
The *interrupted cruciate*, also called the *cross mattress* pattern, is stronger than the simple interrupted pattern. It is the easiest mattress suture pattern. This pattern resists tissue eversion.

Horizontal Mattress

The *horizontal mattress* patterns are (a) interrupted and (b) continuous. The continuous pattern is completed using the directions on page 47. With the horizontal patterns the sutures lie parallel to the wound edges making each stitch equivalent to two simple interrupted stitches. Minor blood vessels along the wound edges are constrained by the horizontal sutures.



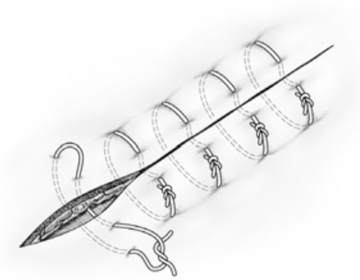
a



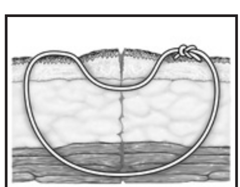
b

Vertical Mattress

The *vertical mattress* takes deep and superficial bites insignificantly constraining minor blood vessels while providing maximum suture strength.

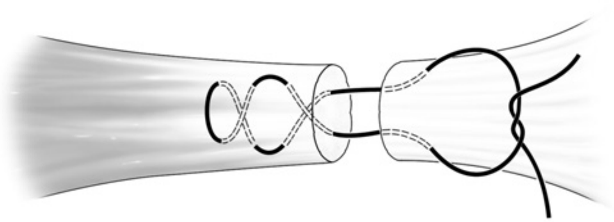


This enlarged view shows superficial and deep suture bites.



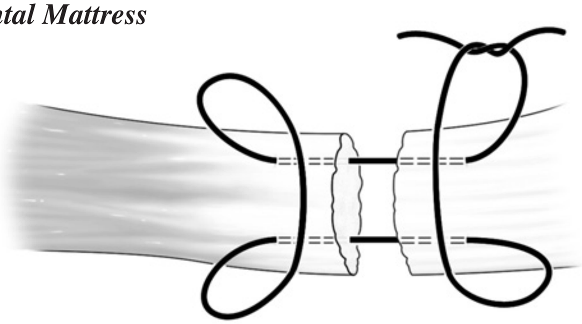
Tendon and Ligament Suture Patterns

Modified Bunnell-Meyer



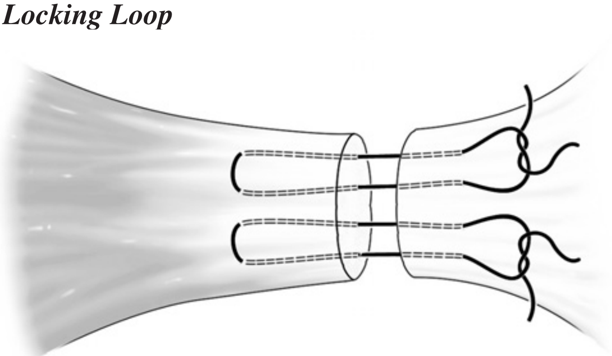
Used for small tendons cut close to the bone

Horizontal Mattress



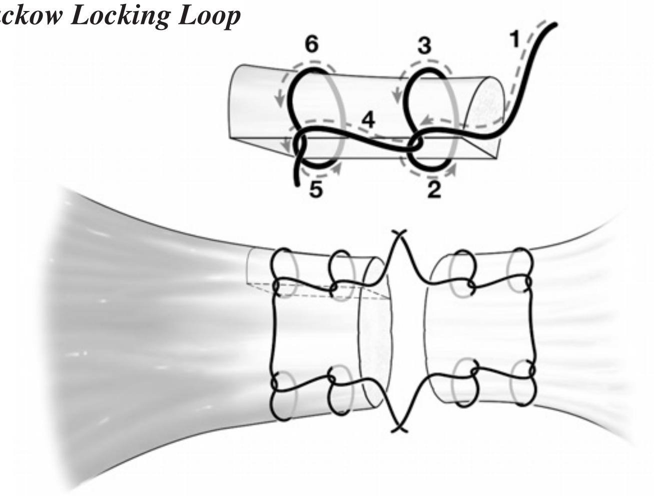
Used for large flat tendons

Kessler Locking Loop



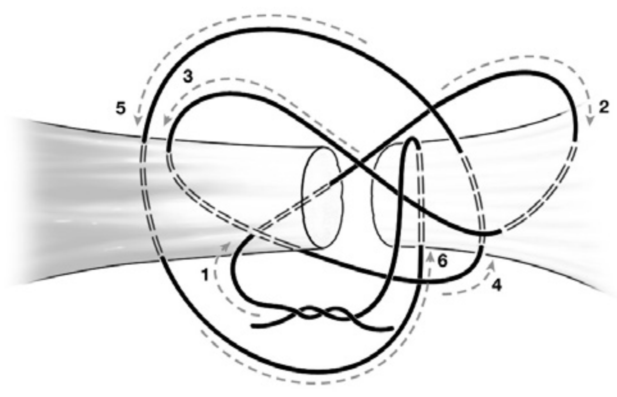
Very secure closure for tendons and ligaments

Krackow Locking Loop



The *Krackow locking loop* suture is used for large tendons and ligaments. Pass 1 pierces the tendon 1 cm from the tendon end. Pass 2 exits the back of the tendon and is brought around the tendon side to the front. Pass 3 is placed beneath pass 1 to form the locking loop. Pass 4 pierces the tendon 5 mm from the first pass. Passes 5 and 6 repeat passes 2 and 3. Use a square knot or Aberdeen knot to appose the cut tendon ends.

Pulley Suture



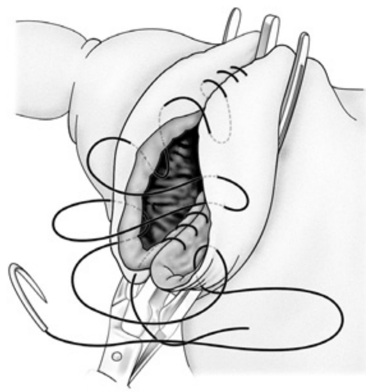
The *pulley suture* is used for small tendons and ligaments. Initial passes 1 and 2 are placed near then far from the tendon end. Passes 3 and 4 are placed 120° from 1 and 2 and midway between the near and far positions. Passes 5 and 6 are placed 120° from 3 and 4 in a far and near pattern. Finish with a square knot or Aberdeen knot.

Inverting Suture Patterns

Surgeries, like an anastomosis of the stomach require inversion of the wound edges. Simply apposing mucosa to mucosa will not provide a good seal. Serosa sutured to serosa will be secure if the suture material does not penetrate all layers of the stomach wall. Infection can follow needle paths from the interior to the outside of the stomach. A secure anastomosis of the stomach can be accomplished using two layers of sutures, an inverting suture through all stomach layers and an outer suture passing through only the serosa and muscularis.

Cushing Suture

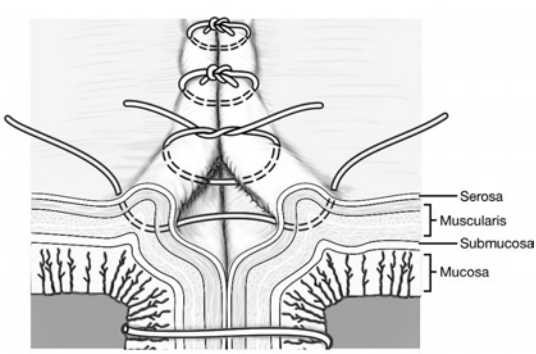
The *Cushing suture*, a primary closure of the stomach, is done by inverting the edges of the wall and apposing the serosal surfaces. The suture is continued completely around the circumference of the anastomosis and tied to the free end of the first stitch. This is shown in progress here. Absorbable sutures are used. A secure anastomosis is accomplished with the Cushing suture but it must be backed up with an outer suture such as the Lembert suture described below.



Lembert Suture

The *Lembert suture* passes through the serosa, muscularis and the submucosa on each side of the previously placed Cushing suture. When tightened, the edges of the serosa are pulled together inverting the Cushing pattern. Lembert sutures can be interrupted or continuous. Complete the Lembert continuous suture pattern with the method described on page 47.

This diagram illustrates a section of anastomosed stomach with interrupted Lembert stitches placed over a Cushing pattern.



Section VI

Basic Sterile Techniques

Infections caused by microorganisms can be minimized or avoided by ensuring that procedures involving interruption of the skin are carried out in a sterile field. The patient's skin, instruments, and the hands of the surgeon must be cleaned and sterilized. Antimicrobial detergent soaps containing iodophor or chlorhexidine gluconate will produce a sterile field. Betadine® is an example of an iodophor and Hibiclens® is a chlorhexidine gluconate. The surgeon's hands should be encased in sterile gloves or the procedure needs to be done without the surgeon's hands touching the sterile field or the active end of the sterile instruments.[1]

Hand Preparation

Even when covered with sterile gloves the surgeon's hands should be scrubbed using iodophor or chlorhexidine gluconate. The standard scrubbing technique requires first cleaning the nails of any visible dirt with a nail file or plastic nail pick followed by a vigorous brush scrubbing. A five minute scrub begins with the fingers and thumbs then the hands and forearms to the elbows. It is important that the hand remain above the elbow to allow washing solutions to flow down and off the elbow and not over previously scrubbed areas.

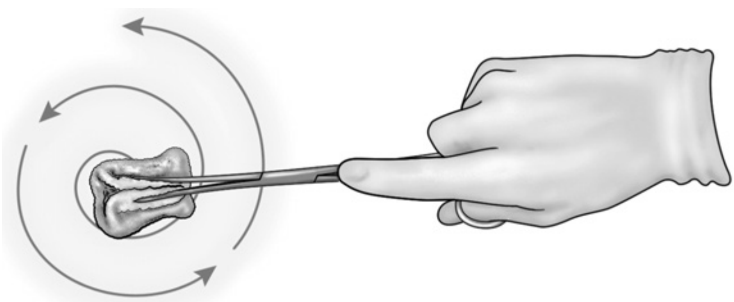
Wound Preparation and Debridement

The first step is to cleanse the wound and the surrounding skin. Use forceps, scissors and an antimicrobial detergent soap to debride the wound of necrotic tissue or gross contaminants. Light scrubbing with a gloved hand can also help remove gross debris. If needed, healthy tissue can be removed from the wound margins for better approximation of tissue layers.[6]

Wound Irrigation

The antimicrobial detergent soaps used for cleaning skin are cytotoxic and should not be used for wound irrigation. Copious irrigation should be done using a sterile saline solution applied with a sterile bulb syringe or a sterile disposable syringe. Care should be taken not to injure tissue.[6] Most wound infections are caused by the patient's endogenous flora. Preventing bacterial contamination is a central role in the prevention of infections. Even with optimal skin preparation true sterilization is not possible.

If the wound area is contaminated cleanse the surrounding skin first and the wound last. The area prepared needs to be much larger than the operative field. Begin sterilization of the operative field and surround area with a microbial detergent soap starting at the center working outward. Betadine® scrub packets can be used for this purpose



Iodine

Iodine is one of the oldest and most effective antiseptics. Tincture of iodine is available in a 7% isopropyl alcohol solution. Tincture of iodine can be mildly toxic and burn the skin. It is best to swab the skin with plain isopropyl alcohol immediately after using iodine solutions.

Iodophor

Iodophors are compounds in which iodine is combined with organic molecules. The iodine is released from the organic compound slowly enough to avoid burning the skin but fast enough to kill bacteria. In the operating room the skin is first cleansed with an iodophor solution. When dry, the skin is again painted with iodophor leaving a thin film on the skin. Iodophor containing detergents will cause the bacterial count to drop markedly in the first minute and after five minutes the count will be minimal.

Alcohol

Alcohol is used to prepare the skin prior to shots and venipuncture but it does not adequately kill bacteria. It is a good cleaning agent however it is not a good antiseptic.

Mercury

Mercury containing solutions have been used in the past in such forms as mercurochrome and merthiolate. Mercurochrome is not effective as an antiseptic. Although merthiolate is more effective, it penetrates the skin poorly and does not kill spores.[1]

Cyanoacrylate Microbial Sealants

Cyanoacrylate microbial sealants mechanically block the migration of pathogens into the wound. They can be applied to the surgical site after preoperative skin preparation, cleansing and draping. The cyanoacrylate microbial sealants improve the effectiveness of Betadine® or Hibiclens® by affixing them on the skin avoiding wash off. Microbial sealants do not affect normal skin transpiration. Sealants are used with a variety of skin preparation solutions and with most wound closure techniques. Sealants can reduce bacterial contamination in clean surgery, i.e. surgery that does not involve the breathing system, gut, genital or urinary tract or any part of the body with an existing infection.[6] Sealants have a good safety profile. Examples of cyanoacrylate microbial sealants are FloraSeal®, Nexcare® and InteguSeal.®.

Sterilizing Instruments

Instruments are sterilized using steam autoclaving, ethylene oxide gas, cold sterilization and irradiation.

Steam autoclaving is used to sterilize instruments and instrument packs. Unwrapped metal instruments require 15 minutes at 120 ºC (250 ºF). Wrapped instrument packs require 30 minutes at 120 ºC (250 ºF). Steam will not penetrate small caliber needles or the jaws of closed clamps.

Ethylene oxide is a gas that sterilizes at temperatures of 50º to 60 ºC (120 ºF to 140 ºF). It is used for instruments that are damaged by heat. This procedure can take up to 2-3 hours.

Cold sterilization involves soaking instruments in a germicidal solution such as iodophor or formalin. Instruments should be soaked for at least 30 minutes and rinsed with sterile water or a saline solution before use.

Irradiation using high dose gamma irradiation from a cobalt source is used by the manufactures of medical devices.

To insure that endogenous flora are excluded from the sterile field, these basic techniques must be followed in all invasive procedures.

1. Van Way, C.W., Buerk, C.A.: *Pocket Manual of Basic Surgical Skills*, C.V. Mosby Company, St. Louis, 1986.
2. Slatter, D.: *Textbook of Small Animal Surgery*, 2nd Ed., W.B. Saunders Company, Philadelphia, 1993.
3. Nealon, T. F.: *Fundamental Skills in Surgery*, W.B. Saunders Company, Philadelphia, 1971.
4. Gray, H.: *Anatomy of the Human Body*, Lea & Febiger, Philadelphia, 1967.
5. Doherty, G.M., et. al.: *The Washington Manual of Surgery,* Little, Brown and Company, 1997.
6. Wilson, S.E.*: University of California, Irvine, CA, USA. wilsonse@uci.edu J Hosp Infect. 2008 Nov; 70 Suppl 2:11-4.*
7. Stott, Philip M., et. al. *The Ultimate Aberdeen Knot; Ann R Coll Surg Engl. 2007 Oct; 89(7): 713–717.*
8. *Gillen, A.M.*, et. al. *Evaluation of the Aberdeen Knot for Continuous Suture Patterns with Large Gauge Suture. Vet Surg. 2016 Oct;45(7):955-961. doi: 10.1111/vsu.12538. Epub 2016 Sep 8. PubMed PMID: 27604910.*
9. *Day, Cyrus Lawrence (1947), The Art of Knotting and Splicing (1st ed.), New York: Dodd, Mead &Co., pp. 114–115*
10. *Singisetti, Kiran K., and George PAshcroft, The Aberdeen 'Continuous Interrupted Surgical Suturing Technique. Volume: 91 Issue: 4, May 2009, pp. 349-349https://doi.org/10.1308/rcsann.2009.91.4.349 Published online: May 14, 2015*
11. *Ashley, Clifford W., (1994). The Ashley Book of Knots, image 31. ISBN 978-0385040259.*
12. *Varshney, S; Manek, P; Johnson, CD (September 1999). "Six-fold suture:wound length ratio for abdominal closure". Annals of the Royal College of Surgeons of England. 81 (5): 333–6. PMC 2503300 Freely accessible. PMID 10645176.*
13. *Dumville, JC; Coulthard, P; Worthington, HV; Riley, P; Patel, N; Darcey, J; Esposito, M; van der Elst, M; van Waes, OJ (28 November 2014). "Tissue adhesives for closure of surgical incisions". The Cochrane database of systematic reviews. 11: CD004287. doi:10.1002/14651858.CD004287.pub4. PMID 25431843.*
14. *https://en.wikipedia.org/wiki/Surgical suture#cite_note-20*