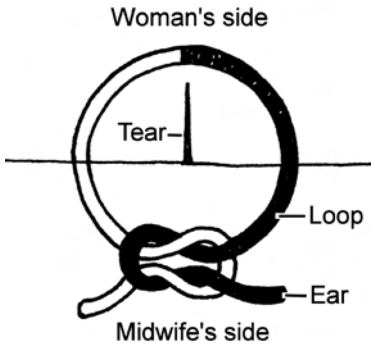
TYING SURGICAL KNOTS FOR THE LEFT-HAND DOMINANT

Surgical knots are used to tie off a single stitch or to anchor a series of continuous or running stitches. Good knot-tying technique is essential to the integrity of your repair. While it is true that you can perform perineal repair using only square knots, each type of knot has its pros and cons, so variations on the square knot as well as the Aberdeen knot are covered in this chapter. Tying well-executed knots needs to become second nature to you. Practice!

Anatomy of a tied stitch

A tied stitch has two parts: the loop and the knot. The suture that passes through the tissue (the woman's side) is called the **loop**. A **knot** closes the loop, holding the ends of the strand, and therefore the torn tissue, together. A knot consists of two or more **throws** (discussed below) that are snugged down to close the loop around the divided tissue. The **ears**, or ends, of the strand are trimmed long enough to allow them to slip slightly without coming untied.



Parts of a knot

The midwife's side of the stitch is the tied part. When considering a simple, interrupted stitch, the segment of the strand that exits the tissue after the loop is created is often referred to as the **fixed end** because it is attached to the needle; I will call this the **needle end**; it is shown in black. The other end of the strand that remains is called the **free end** because, in a simple interrupted (or single) stitch, that end is left sticking out of the tissue with nothing attached; it is shown in white.

A **throw** is the weaving of the two segments together. A **single-wrapped throw** (a wrap is called a **turn** in some sources) is formed by winding one segment around the other one-half (180°) to a full turn or revolution (360°). A **double-wrapped throw** is formed when the free segment is wound around the other twice or two full turns (720°).

After wrapping, the throw is slowly advanced, or **run down**, and snugged against the tissue to bring the wound edges together and keep them approximated. The effort required to advance a throw is called **knot rundown force**. The force required varies among suture materials; some allow rundown and readjustment of knot tension after rundown more easily than others. When the first throw is being snugged down, the amount of tension needed to bring the wound edges together without strangling the tissue is assessed, and the tension is readjusted if necessary. After the first throw is in place, more throws are created until the knot is secure. **Knot configuration** is the number of throws needed to complete a knot.

Knot shorthand: An international code may be used to describe surgical square and granny knots. The number of wraps in each throw is designated by an Arabic numeral. Parallel throws (as in a square knot) are designated by an " = " sign. Crossed throws (as in a granny knot) are designated by an ×. Thus, a square knot formed by using two single parallel throws is coded 1=1. A knot made with two crossed throws is coded 1×1. A slip knot is designated with an S (for example, a single-wrap, double-throw slip granny knot is coded like this: S×S).

Knot integrity

A knot is always the weakest link in a suture loop. The force required to break a knot is always less than that required to break an untied strand of the same material. This is due to the bending, creasing, friction and tension required to form a knot, all of which weaken the strand. The relationship between the tensile strength of an unknotted strand and a knotted strand of the same material is called **knot efficiency** and is expressed as a percentage (the % of knot efficiency = tensile strength of knotted suture ÷ tensile strength of unknotted suture). The amount of force required to break a knotted strand is influenced by the type of knot used, the strand material, the diameter of the strand and the tissue in which it is placed. Once in place, absorbable materials display a progressive decrease in knot-breaking strength. As the suture breaks down in the tissue, it weakens and the knot tends to weaken faster because of the stress to which it has already been subjected during tying.

To a point, knot security is enhanced as the number of throws increases. An ideal configuration uses enough throws to form a secure knot that will fail by breaking rather than by unraveling. The ideal number of throws varies for each type of suture. Once the ideal configuration has been created, however, additional throws do not enhance knot security because they weaken the strand too much, increasing the risk that the knot will break; thus, too many throws only create a bulky knot and provide additional hiding places for bacteria.

Some additional points to keep in mind are as follows:

- Choose the simplest knot for the task and the suture material.
- Nontension ties are used in soft and delicate tissues and to ligate blood vessels and are thus appropriate for most birth-related repairs. Here, the initial throw is snugged down flat to keep it tight, without tugging on the ends. The ends must remain loose, or the throw will loosen by the time the rest of the knot is completed.
- Ideally, the suture material and the knot used allow each completed throw to be easily advanced to the wound edges. During rundown, equal, constant and adequate tension is slowly applied, in opposite directions, to each end of the suture. By applying about 80% of the breaking strength of the knotted material, you avoid breaking the strand while creating a knot that is unlikely to slip. Uniform tension creates a more secure knot; too little tension results in a knot that tends to slip. Jerking the suture or running down a knot too rapidly weakens the strand and produces less secure throws that are more likely to loosen over time.
- Strive to tie a tight knot over a loose loop. Each loop must be tight enough to bring the wound edges together while remaining loose enough to allow for swelling and subsequent tissue shrinkage as edema resolves. Poorly tied stitches will often unravel and those that are tied too tightly may even break if the pressure in edematous tissue encompassed by the loop rises above capillary pressure. Impaired capillary blood flow and a fall in oxygen levels may lead to cell death, with loss of tissue strength and an increased risk of wound dehiscence, infection or necrosis. Overly tight sutures may also cut through healthy tissues. (Unhealthy tissues may shred, however, even when stitches are appropriately tight.) Even when no such clinically obvious problems arise, tight stitches do not make a repair more secure, will not restore an already lax pelvic floor, may cause a repair to heal

unanatomically tight and will, at the very least, be more uncomfortable.

- •Avoid pulling the strand back and forth in the tissue (seesawing) or unnecessarily rubbing the segments together during rundown as either can cause unnecessary tissue trauma and weaken the strand, especially when using gut materials.
- •Avoid pulling on the loop during rundown, as this may tear or avulse the tissue.
- •Be sure the first throw is properly placed and snugged down before beginning the second throw. At first you will need to check the knot both visually and by touch. With more experience, you may be able to check by touch alone.
- •Each knot introduces additional foreign material for the body to break down. Place as few knots with as few throws as possible to minimize tissue irritation.
- •All knots slip to some degree. How much slippage occurs depends upon the suture material, moisture and knot type as well as how well the knot is tied and whether the ears are left long enough to compensate for tissue changes. Ears should be trimmed straight across the strand to a length of approximately 3 to 5 mm, at the most. If the ears are too short, the knot may unravel; if they are too long, they will poke and irritate the tissue. Some practitioners cut the ears of a knot left above the tissue surface, as may occur with a labial repair, nearly flush with the knot to avoid poking. When you plan to trim ears very short, an extra throw should be placed beforehand, but it is best to always leave a short ear as an extra precaution.
- •A poorly tied knot may reduce the strength of the strand by over 50% (Kirk, 2002).
- •Don't leave suture that has been clamped or otherwise damaged in the tissue or the knot, as such insults weaken the strand. (Edlich & Long, 2008; Sanz, 1987; Varney et al., 2004; Zederfeldt & Hunt, 1990; Zikria, 1981)

Suture materials and knot tying

Each suture material requires a specific knot configuration. Chromic gut is somewhat rough; its knot security is considered to be very good to only fair (depending on the source), and its stiffness makes it more awkward to manipulate. In contrast, synthetic monofilament sutures are similar to fishing line, which manipulates easily but the resulting knots also tend to slip after they are tied. Most monofilament synthetics also have more memory than do multifilament synthetics, which have very little. Thus, monofilament synthetics are more difficult to snug down. As a rule, synthetic multifilament sutures are generally easier to handle and to tie than monofilament sutures because they behave more like sewing thread. The braided and twisted construction of multifilament materials provides a high coefficient of friction and, according to the manufacturers, the knots tend to remain snug after they are laid down (although, independent sources report only fair to good knot–security for these products [von Fraunhofer & Chu, 1996]). This also means that the knot is hard to reposition once in place; using coated suture tends to mitigate this tendency to a degree (Ethicon, 2005). More details about how to tie different suture materials can be found on page 383.

Handedness of the tie

When a wound is aligned with your spine (vertically or longitudinally oriented) and the needle holder is manipulated with your dominant hand, the needle passes through the tissue from your dominant to your nondominant side (i.e., from left to right if you are left-handed

and from right to left if you are right-handed). After the suture is in place, the needle end of the strand will have moved to your nondominant side and the free end of the strand will remain on your dominant side. When one end of the strand is fixed (to the needle in this case) and a hand tie is used, surgeon's typically use the nondominant hand to pinch and push the free end through the loop as each throw is wrapped. Confusingly, however, surgeons refer to the hand *opposite* the one wrapping the free end when designating whether a tie is left-handed or right-handed. (The opposite hand will usually be the dominant one manipulating the needle holder, but, it is also possible, for example, for a left-handed surgeon to manipulate the free end with her dominant hand and thus tie "right-handed.") With an instrument tie, the dominant hand uses the needle holder to place the stitch *and* to pull the free end through the loop. Thus, the hand that pulls the free end through the loop, in this case the dominant hand, still denotes the handedness of the tie. In all cases, the free end is wrapped because this avoids having to disengage the needle from the holder and prevents having to pass a swagged needle through the knot loop, an awkward process that greatly increases the risk of needlestick injuries.

All the illustrations in this chapter depict **left-handed ties** and assume a stitch has been taken, thus the needle (black) end is shown on the right. Other knot–tying manuals usually show bicolored cord as well but the handedness of ties is not always explained. Use the rules outlined above to determine the handedness of ties depicted across a vertical incision. If tying is demonstrated across a horizontal incision (or two horizontal layers), the stitch can be formed either forehand (starting with the palm toward the tissue, the needle passes toward oneself, from the far [or upper] side to the near [or lower] side of the wound) or backhand (starting with the palm up, the needle passes away from oneself, from the near [or lower] side to the far [or upper] side of the wound). The segment being manipulated is still the free end, and the hand opposite the one doing the wrapping still determines the handedness of the tie.

Practicing Knot Tying

Practice materials

To learn the basic mechanics of knot construction start by tying to a fat, round object, such as the finger ring of a coffee mug, to get the idea of making a loop in your head, plus a fat object spreads the knot out as it is tied so you can better see how it is constructed. It is also helpful to have on hand a small (4" square) board with a hook attached in the center it to practice hand and instrument ties, although you can use the mug handle for all your practice and it will always be easy to see the knot configuration. Tie the ends of two 10 inch pieces of cotton cord together. Color one side with an indelible marker to represent the needle end; the white half represents the free end. Or, obtain heavy cord in white and a color (or a light color [for white] and another darker color) and sew them together at one end.

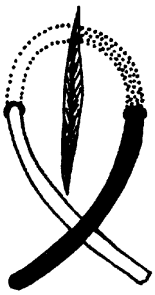
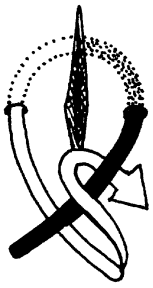
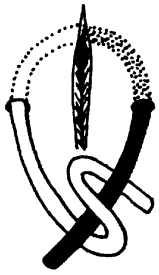
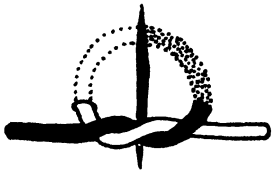
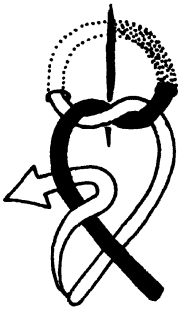
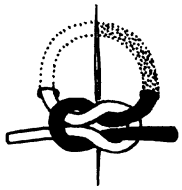
Square knot

The **flat square** or **reef knot** is the most commonly used surgical knot. Depending upon the suture material, it can be up to 10 times stronger than a granny knot (DeLancey, 1987). Ancient peoples ascribed magical powers to this knotting technique.

Place the mug on a table, in front of you. Pass the cord through the handle, with the lighter segment on your dominant side. This positioning mimics that used during suturing when the knot will usually need to be made by stretching the segments away from the loop toward you (i.e., you will be tying knots on the near-side of the loop, rather than above it). Numbers in parentheses in the following text correspond to the drawings on the next page.

A square knot is formed with two throws, also called "half-hitches." First, the loop is placed through the tissue (a vertical tear is shown because the majority of your knots will be tied over a longitudinally oriented wound). The first throw is started by crossing the segments (1), thus closing the loop. In a surgical knot, the free end of the strand is always wrapped around the colored (needle) end (2). The ends of each segment are now on opposite sides from where they started out (3).

After completing (3), the first throw is run down or tightened by steadily applying *equal and opposing tension to each segment at the level of the tissue surface* (4), thus completing the first half-hitch. Equalizing tension during rundown ensures that each segment makes a half turn around the other. The application of unequal tension results in a slip knot by causing the segment to which less tension is applied to wrap completely around the other, more tense and therefore straighter segment.

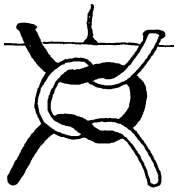
 1. Cross the colored segment over the white to create a loop.	 2. Wrap the white segment toward you, over and around the colored segment.	 3. So it looks like this.	 4. Tighten by pulling segments in opposite directions.
 5. Begin a second throw by crossing the colored segment over the white.	 6. Wrap the white segment toward you, over and around the colored segment.	 7. So it looks like this.	 8. Tighten by pulling segments in opposite directions.

During rundown, the knot must be snugged into place directly over the wound, not off to one side, at an angle. Pulling straight out to either side of the loop at the level of the tissue

transfers all the tension to the knot and also avoids unnecessary tension on the tissue. Examine the completed half-hitch throw (4) and note that the segments are now reversed, with the colored segment now to the left in this example.

A square knot is distinguished by the way the segments are crossed for the second throw and the direction that one segment is wrapped around the other; the crossing and wrapping is alternated with each throw. For example, if the first throw begins with the right segment crossed over the left and the free (white) end is wrapped around the needle (colored) end in a toward-you, over and around direction for the first throw (as illustrated on the last page in steps 1, 2, 3 and 4), the second throw must start with the left segment crossed over the right. The white end *must* then be wrapped around the colored end in the same manner but, because the segments were crossed as in step 5, it is wrapped in the opposite direction (as illustrated in 5, 6 and 7 above; compare steps and 2 and 6). Another way of saying this is that the knot is tied by crossing the right segment over the left to form the first throw and the left segment over the right to form the second throw (or vise versa). In a simple square knot, it does not matter in which direction one segment is crossed or directed in the first throw, as long as the direction is reversed for the second. In a surgical knot, you want to make sure that the free end is always the one being wrapped (as illustrated here). A square knot is constructed using a minimum of two throws that exhibit this mirror-image (so called because the steps are reversed), or "parallel," construction.

The formation of a double-throw square knot can be confirmed by checking for parallel construction, wherein two parts of the needle (colored) segment pass under one side of the knot and two parts of the free (white) segment pass over the other side of the knot (alternating the direction of each throw results in the segments lying parallel with each other; as in the drawing below). The ends of the strand should also lie almost parallel with the segment that forms the loop. To begin learning to tie a square knot, practice using the simple technique illustrated on the previous page. After tying each knot, confirm that it is a square knot by examining its configuration.

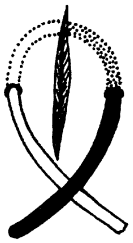
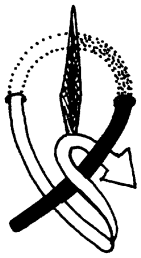
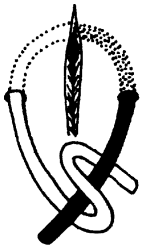
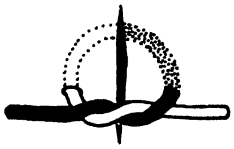
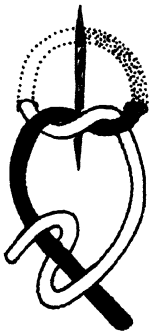
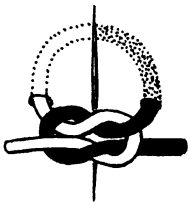
 Square knot with two single-wrapped throws: one side	 Square knot: the other side	 Looking down on the knot to confirm that the ends lie parallel with the loop

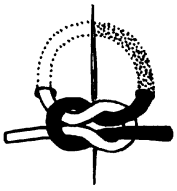
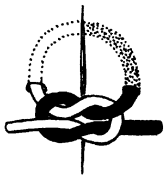
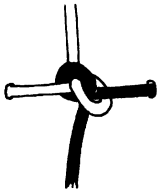
Similar types of knots that should be avoided: There are a few variations on this knot that can cause problems if they are used instead of a classic square knot.

Granny knot: I will now explain granny knots, so you can tell the difference. If you are easily confused by subtle differences, you may want to skip to "friction knots" at the bottom of page 367 and just focus on getting the square knot in your head.

A granny knot is a pseudo–square knot with identical, or crossed, construction. The first half-hitch is formed in the same manner as for a square knot, as illustrated in steps 1, 2, 3 and

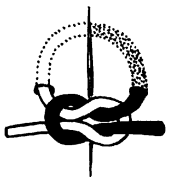
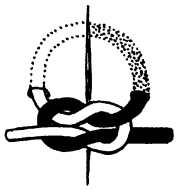
4 below. For the second half-hitch, the movements are repeated: the segment that is now to your nondominant side is also crossed in front of the segment that is now to your dominant side and emerges in front of the dominant-side segment. Thus, a granny knot is formed by crossing and then passing the end that winds up on the nondominant side of the loop in the same direction for each throw (left over right, left over right or vis versa).

 1. Cross the colored segment over the white to create a loop.	 2. Wrap white segment toward you, over and around colored segment.	 3. So it looks like this.	 4. Tighten by pulling segments in opposite directions.
 5. Begin a second throw by crossing the white segment over the colored.	 6. Wrap the white segment away from you, over and around the colored segment.	 7. So it looks like this.	 8. Tighten by pulling segments in opposite directions.

 Square knot	 Granny knot
 Looking down to see that the ends of the segments are parallel with the loop	 Looking down to see that the ends of the segments are at right-angles to the loop

The formation of a granny knot is confirmed when the colored segment passes under and over one side of the knot and the white segment passes under and over the other side and when the ends of the segments project at right angles to the loop (study the two illustrations on the preceding page).

Study and compare the following drawings carefully to see how the segments are crossed and wrapped in each type of knot to create the second throw.

SECOND THROW–SQUARE KNOT			
			
5. Begin a second throw by crossing the colored segment over the white.	6. Wrap the white segment toward you, over and around the colored segment.	7. So it looks like this.	8. Tighten by pulling segments in opposite directions.
SECOND THROW–GRANNY KNOT			
			
5. Begin a second throw by crossing the white segment over the colored.	6. Wrap the white segment away from you, over and around the colored segment.	7. So it looks like this.	8. Tighten by pulling segments in opposite directions.

Surgeon's friction knots: It is also important to understand what creates a friction knot and why they can be problematic in the types of repairs midwives typically perform. A **surgeon's** (**friction** or **tension**) **knot** is a square knot made using one double-wrap throw followed by a single-wrap throw (2=1). Double wrapping the first throw increases the friction on the segments thus temporarily "locking" them, which helps to keep the first throw in place, holding the wound edges together long enough to complete the second throw.

Double–wrapping cannot be relied upon by itself, however, because any tension from the woman's side will cause the throw to slip. A double-wrapped throw is also much more difficult to properly position initially and to readjust later if it is not tied appropriately tight in the first place. Because of the additional friction double-wrapping creates, the strand is more likely to break than slip if an attempt is made to readjust this type of knot.

		
Surgeon's knot	Double-double surgeon's knot	Reversed surgeon's knot

A **double-double surgeon's knot** has two double-wrapped throws (2=2). A single-wrap followed by a double-wrapped throw (1=2) is called a **reversed surgeon's knot**.

Wound orientation and tying square knots: The direction in which the wrapped segments are pulled during rundown is determined by the orientation of the wound and the suture loop. The suture loop is usually at a 90° angle to the orientation of the wound. It is easiest to form a secure square knot when the knot overlies a tear or incision that runs perpendicular to the spine of the practitioner (that is, side-to-side across the tissue), because the suture loops will be vertically oriented. This makes it easy to apply equal tension to each segment in a horizontal plane in relation to the tissue surface, parallel with the orientation of the loop as the knot is snugged down. This always allows the hands to separate as they pull in opposite directions away from the wound, leaving the knot visible at all times.

In contrast, midwives work with tears that almost always are longitudinal or nearly so in relation to their spine (that is, running up and down in the tissue) and that are frequently in small, tight spaces. These factors make proper knot construction considerably more challenging. Your hands must still be kept on either side of the knot, parallel with the suture loop, which is horizontally oriented. This requirement necessitates either reversing the hand positions as each throw is run down or crossing the segments before a half-hitch is begun to avoid forming slip knots. When the hands are crossed, your view of the knot is temporarily obscured. Crossing the hands can also interfere with applying equal tension to the two ends of the suture in a plane parallel with the tissue surface.

Extending your index fingers and pressing the tips against the medial sides of the strands during rundown will help lay the knot flat against the tissue and help equalize the tension applied to each segment, thus increasing the likelihood of forming the throw correctly. Always check that your throw lays flat before proceeding to the next because when you are actually suturing in a small, deep space, your view is likely to be at least partially obscured, which can interfere with visually confirming correct placement (Edlich & Long, 2008).

Different methods of tying a square knot: The following pages illustrate three methods of tying a square knot: one-handed, two-handed and the instrument tie. Although the language used is hand-neutral (dominant and nondominant), left-handed ties are illustrated. Offering three methods of tying allows for individual preference and ensures that you have a sufficient repertoire of skills to place square knots in a variety of clinical situations. It is, nevertheless, perfectly acceptable to master only one of these techniques. If you learn only one, I suggest learning the instrument tie as it is most useful for working in small spaces, although many competent practitioners only use hand ties for all their knots.

Surgical square knots can be tied using either a "one-hand" or "two-hand" technique.

In each method, however, both hands are involved; the tying hand makes the knot and the non-tying hand holds the needle (fixed) end and does some manipulation of the free end as well. If you are going to learn a only one hand-tie technique, the two-hand tie is preferred.

Recall that, in both "left-handed" and "right-handed" tying, the hand to which "handedness" refers merely holds, lets go of and regrasps the free end and is usually the same (dominant) hand that manipulates the needle holder. Many left-handed surgeons, however, tie right-handed, grasping the free end with their right hand. The advantage is that most of the manipulations are done with the dominant hand and the surgeon does not have to put down the needle holder to perform a two-handed tie. Just remember that, once the loop is placed in the tissue, the needle will be on your nondominant side and the free end will be on your dominant side. To help remember this very important detail when practicing with string, attach a hemostat or paper clip to the needle (darker colored) end. This will prevent you from trying to pass the needle end through the knot loop and will help give you more of a feel for what you will be doing during an actual repair.

Lay people tie a square knot by crossing the segments to form a loop and then poking one end of the strand through the loop. Surgeons cross the segments and then poke a finger or fingers through the loop, grasp the free end of the strand and pull or push it through the loop. Keeping hold of the free end during manipulation helps maintain control of the segments.

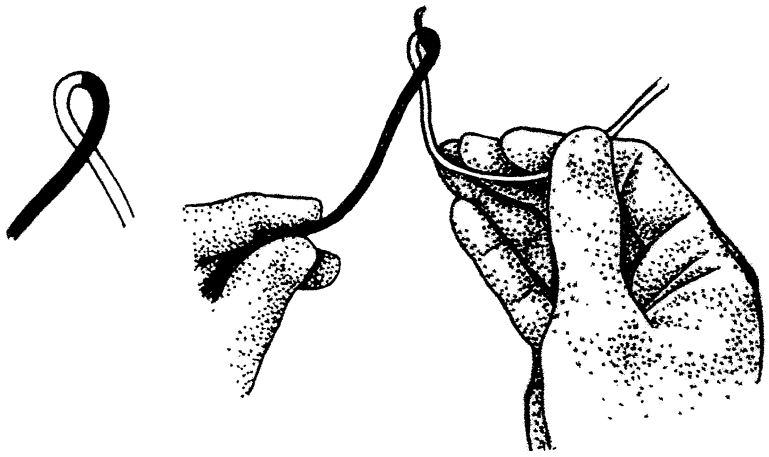
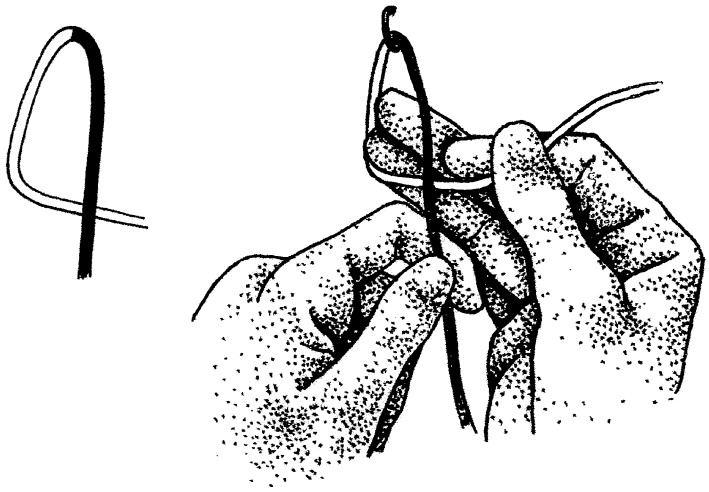
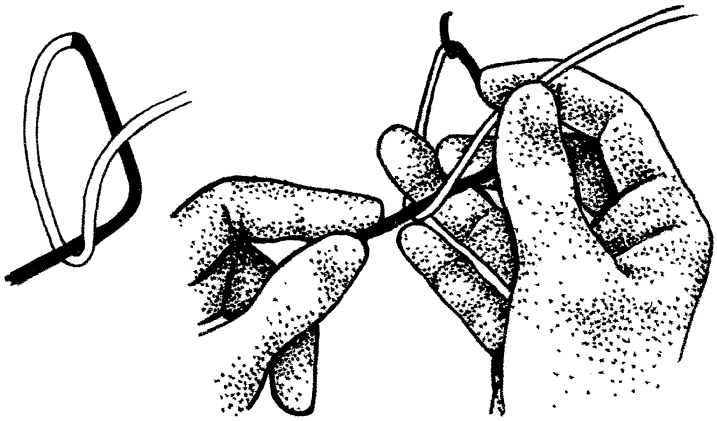
These illustrations assume you are tying over a longitudinal tear. When you begin with the segments uncrossed for the first throw, your hands must cross to keep the knot flat and square as you tighten it down. You can also begin the first throw by first crossing the segments so that the free end is crossed over the needle end toward your nondominant side. This avoids having to cross your hands when tightening the first throw (DeLancey, 1987). To start, become very practiced at executing the knots as illustrated, then you can move on to experimenting with variations that you may like better.

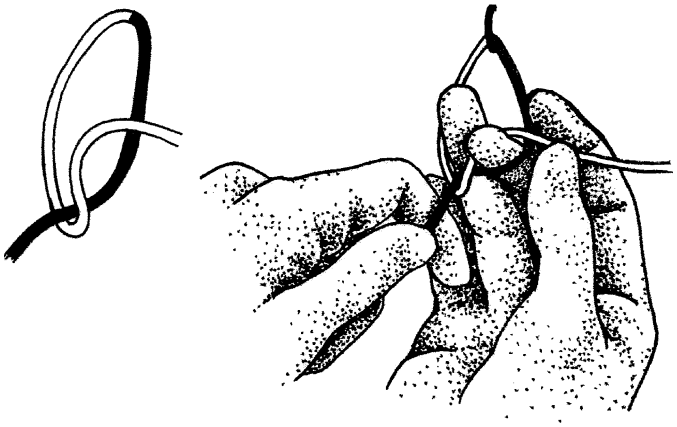
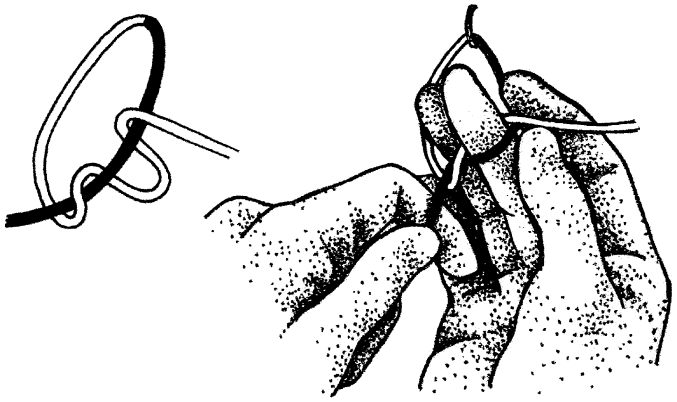
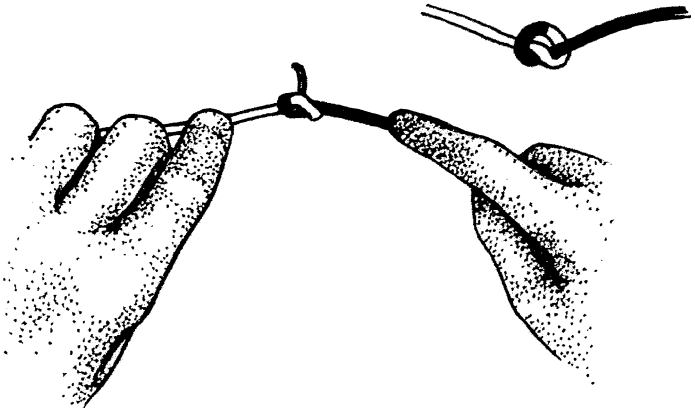
Make sure each throw is properly placed before starting the next. Once finished, check both sides of the knot to make sure it is tied correctly. Rather than using a long piece of string and tying consecutive knots, practice tying individual knots because that is what you must do during an actual repair. It is easy to tie many knots rapidly until you become quite practiced at doing it wrong. Be scrupulous about your technique to start with, even if it means going very slowly. Your speed will naturally increase as you become more proficient.

One-handed square knot: The one-hand technique is so named because one hand does all the maneuvering to tie the knot, including releasing and regrasping the free end of the strand. The other hand merely holds the needle end of the strand taut. The one-handed method is more difficult to learn than the two-handed method because it is harder to maintain tension on the segments as you form the knot. Thus, the first and second throws often slip, especially when you are just learning. Slippage necessitates retightening the knot, which may cause the strand to break, which, in turn, requires placing a new stitch. Nonetheless, the one-handed technique is useful to know; once mastered, it is the faster method of tying. Step-by-step instructions begin on the next page. Note that each step is illustrated with hand positions as well as a closeup of how the segments should look at that point.

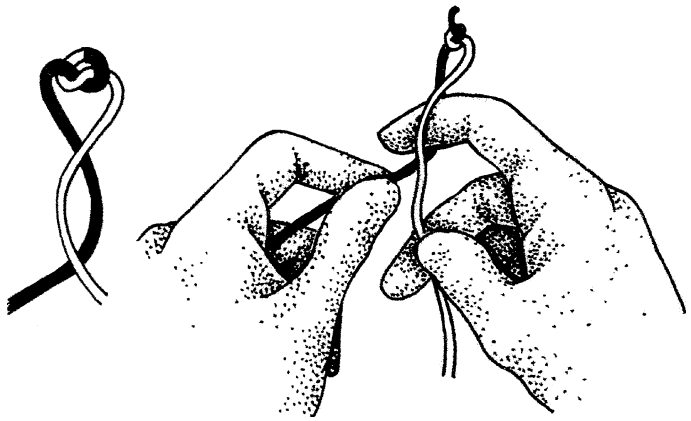
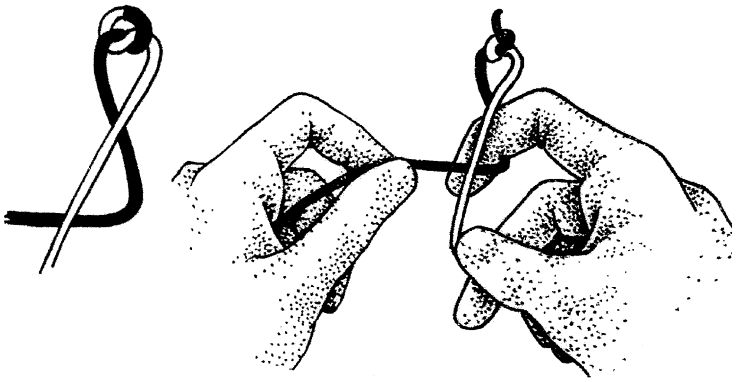
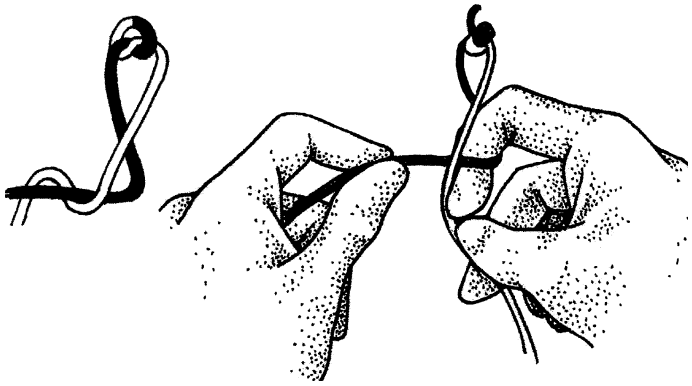
1. One-handed square knot, first throw: Begin with the white segment (free end) on your

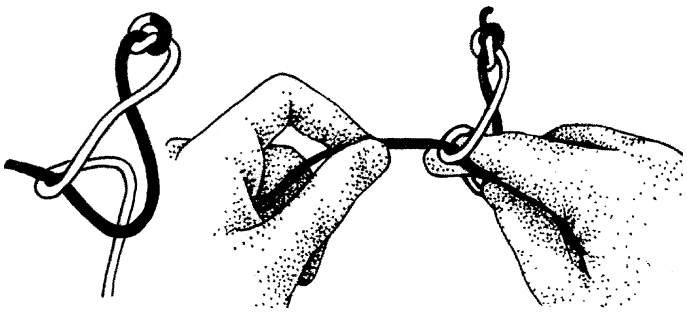
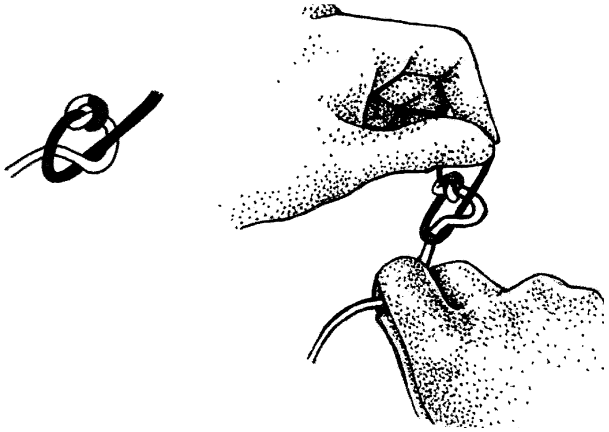
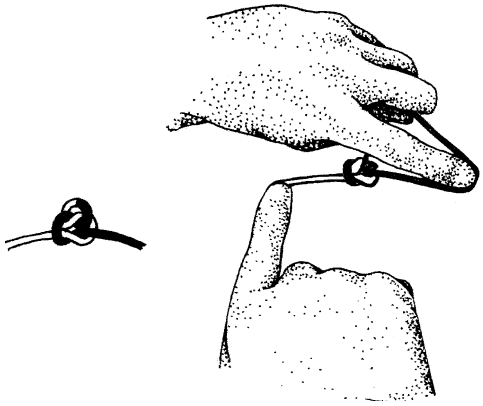
dominant side. Cross the colored segment over the white.

1. Grasp the crossed segments. Pick up the white segment with your nondominant thumb and index finger, stretching it across your other fingers. Hold the colored segment with your dominant thumb and index finger.	
2. Open the crossed segments. Lift the colored segment up and over the middle and ring fingers of your nondominant hand so that the segments form an ×.	
3. Flex your finger. Press your nondominant middle fingerpad against the colored segment as you lift up the white segment with your non-dominant thumb and index finger.	

4. Insert your fingertip between the segments. Insert your nondominant fingertip between the white and colored segments so that the white segment winds up behind the nail of your middle finger.	
5. Flip the white segment through the loop. Release the end of the white segment as you straighten your finger to push the white segment backward through the loop as you release the end from your dominant hand.	
6. Tighten the throw. Press your extended index fingers against the segments to keep the knot as flat and as parallel to the tissue surface as possible as you tighten it down and lay it flat by separating your hands.	

2. One-handed square knot: second throw

1. Grasp the segments. Hold the white segment between your nondominant thumb and index finger and rotate your hand to bring the white segment over your index finger. Pinch the colored segment with your dominant hand.	
2. Cross the segments. Flex your nondominant index finger as you wrap the colored segment under and around it to form an ×.	
3. Insert your fingernail under the white segment. Use your nondominant thumb and index finger to move the white segment over the nondominant index fingernail. Push your nondominant index fingernail under the white segment.	

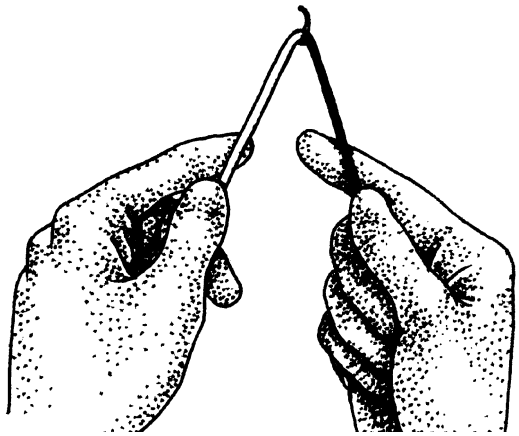
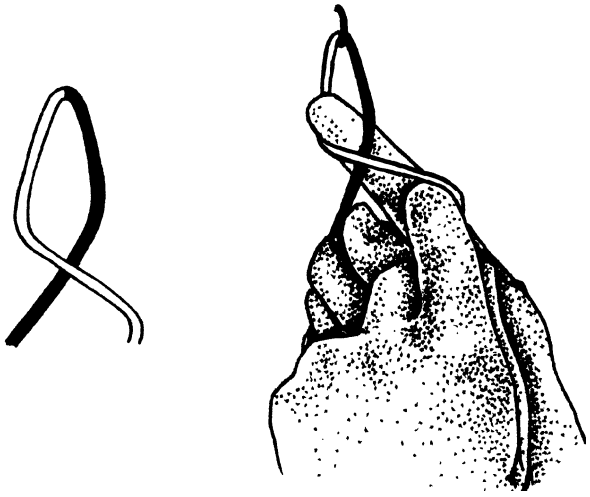
4. Push the white segment through the loop. Let go of the white end and push it up through the loop by straightening your nondominant index finger.	
5. Tighten the knot. Cross your dominant hand past your nondominant hand as each hand pulls the segments in opposite directions.	
6. Lay the knot flat. Extend your index fingertips against the segments as you tighten the knot down and lay it flat. This completes the second throw of a square knot.	

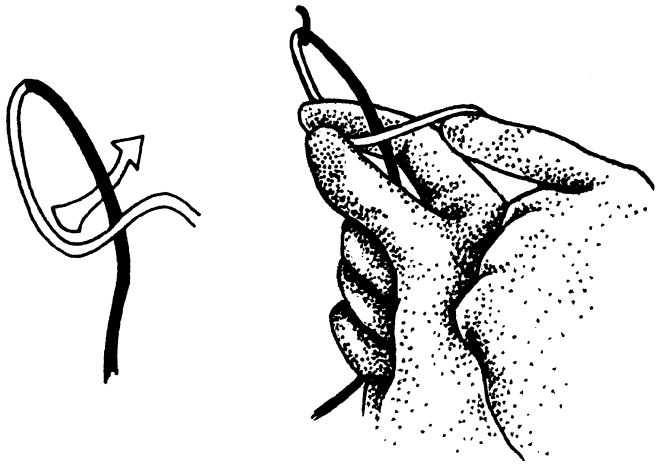
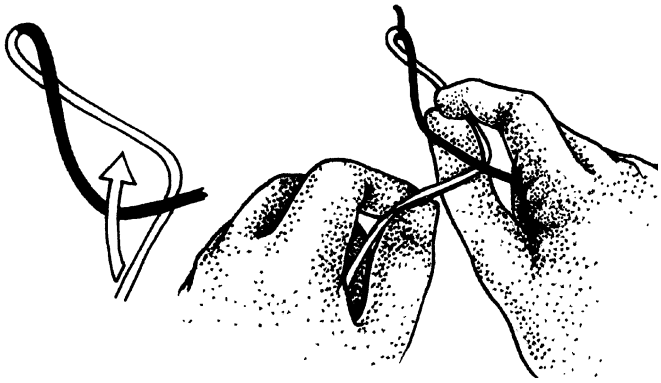
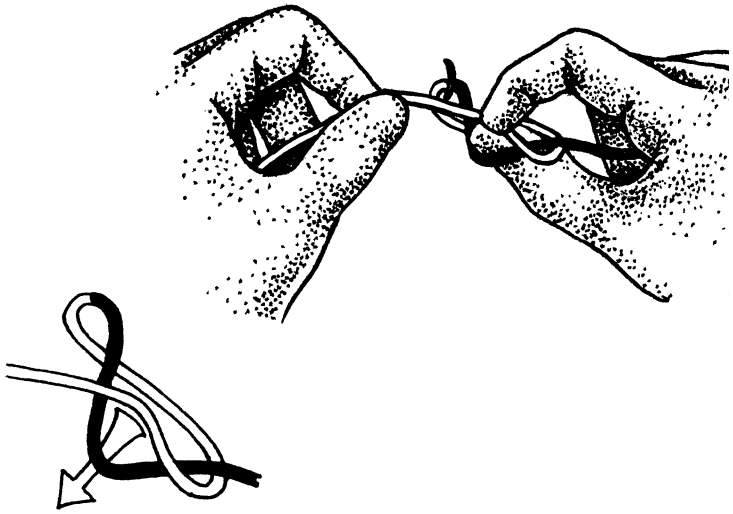
3. One-handed square knot: third throw: To make the third throw, repeat the first throw. This completes three throws (one-and-a-half square knots). Depending upon the suture material, add more throws until an adequately configured knot is formed.

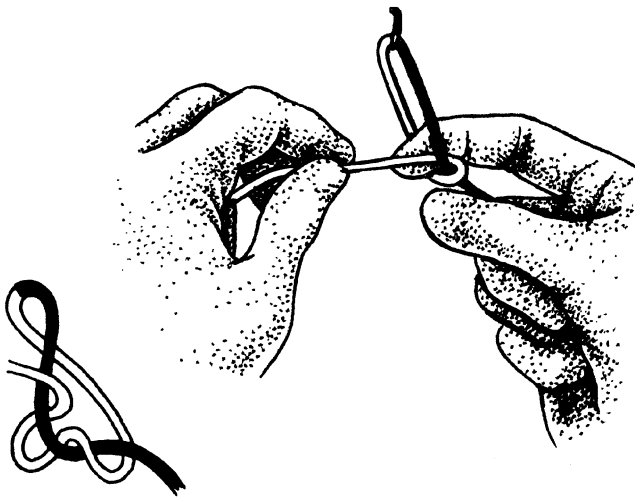
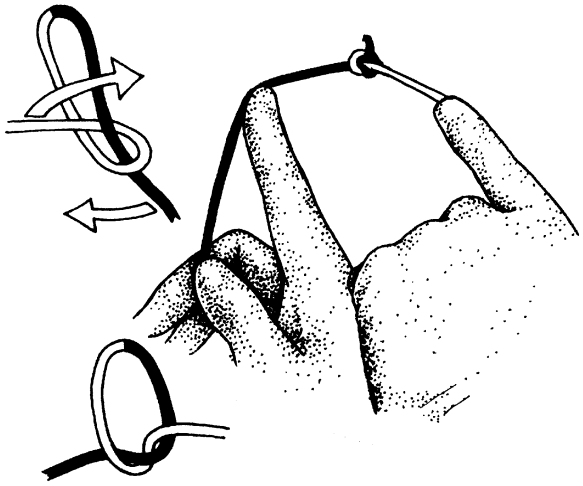
4. Trim the ears: When finished, trim the ends to no less than 3 mm in length.

***Two-handed square knot*:** The two-hand tie is easier to learn than the one-hand method because it relies less on finger action and more on arm and wrist action. It is somewhat slower to perform but gives better control of the knot, allowing you to maintain continuous tension on the segments to form a secure knot.

1. Two-handed tie, first throw: Start with the segments uncrossed (colored end on your nondominant side).

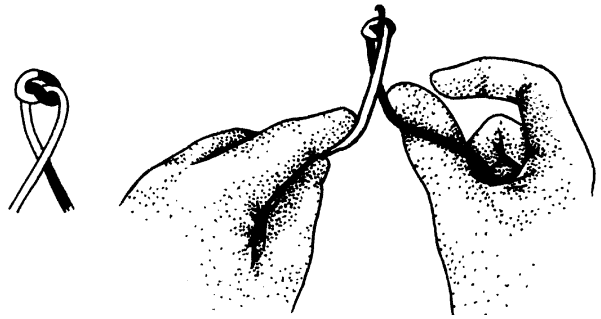
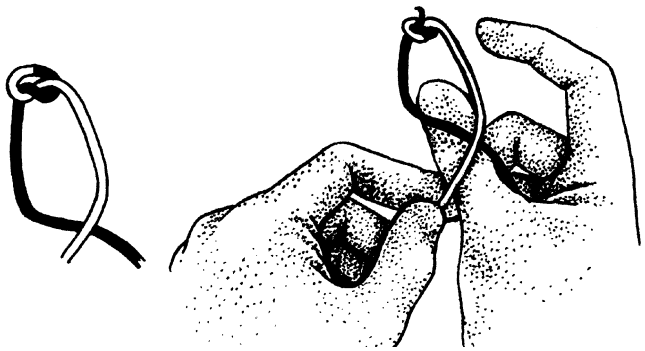
1. Grasp the segments. With palms up and the segments running over the index fingerpads, hold the colored segment in your nondominant hand and the white segment in your dominant hand.	
2. Cross the segments. Wrap the white segment over and around the pad of the nondominant index finger so that the segments form an ×.	

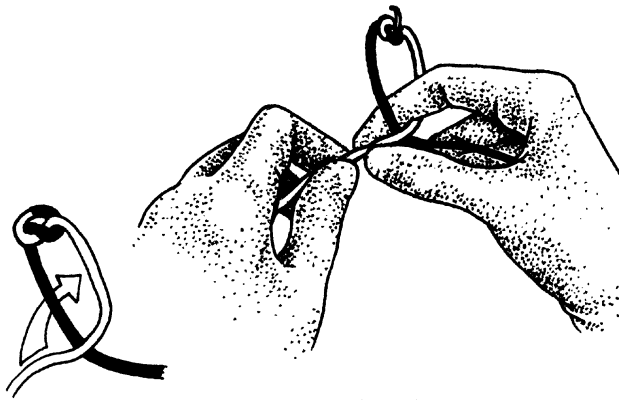
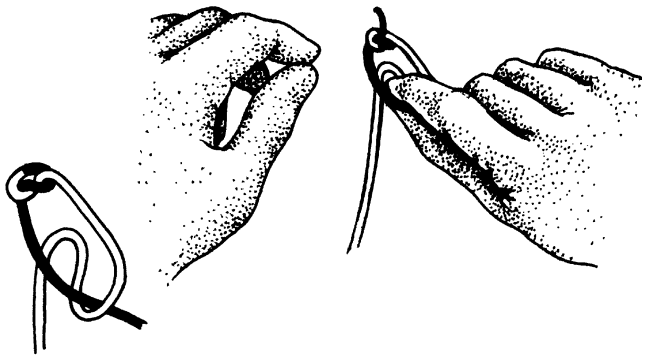
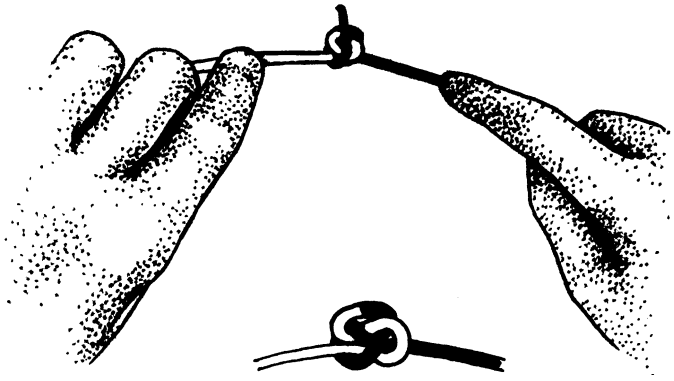
3. Pinch your fingers. Pinch your nondominant thumb and index fingers together inside the loop.	
4. Poke your nondominant thumb through the loop. Rotate your nondominant wrist, palm down, so your pinched fingers pass up through the loop. This causes the colored segment to cross over the white.	
5. Grasp the white segment. Grasp the white segment with your dominant thumb and index finger, bring it around the colored segment and place it between your pinched nondominant fingers.	

6. Push the white segment through the loop. Rotate your nondominant palm toward you, part your pinched fingers and push the white segment down and through the loop; then grasp the white end with your dominant hand.	
7. Tighten the knot. Tighten the knot by crossing your dominant hand over the other. Extend your index fingers to direct the tension as you snug the knot into place.	

As the first throw is wrapped, the ends wind up on opposite sides from where they started because you cross them in step 4. You then cross yours hands as you lay the throw flat to *uncross* the segments, so that the resulting throw does not become bunched.

2. Two-handed square knot, second throw: Upon running down the first throw, proceed with the second.

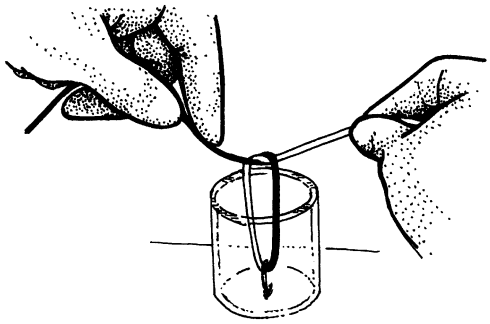
1. Grasp the segments. Continue holding the colored segment with your nondominant hand as you move the white end to your dominant side.	
2. Cross the segments. Wrap the white segment up and around the other side of the nondominant thumbnail so that the segments form an ×.	
3. Pinch your fingers together. Flex your nondominant index finger over the white segment so that you can pinch your thumb and index fingers together inside the loop.	

4. Poke your nondominant pinched fingers down through the loop and grasp the white segment. Rotate your palm toward you to push the pinched fingers down through the loop. Release the white segment and use your dominant hand to insert the white segment between your pinched fingers.	
5. Push the white segment up through the loop. Rotate your wrist to bring the white segment up through the loop. Grasp the white end with your dominant hand and pull it completely through the loop.	
6. Tighten the knot. Extend your index fingers to lay the knot flat and parallel with the tissue surface as you tighten down the knot by separating your hands. (Note that this sequence results in a square knot that is reversed from the rest that are illustrated in this chapter).	

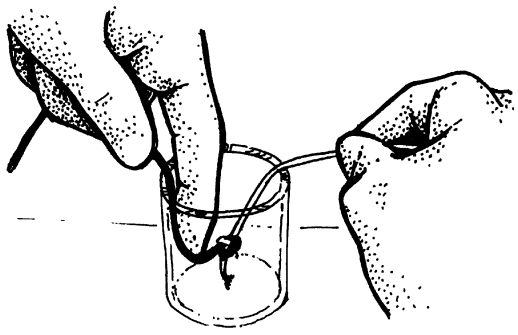
3. Two-handed square knot: third throw: To make the third throw, repeat the first throw. This completes three throws (one-and-a-half square knots). Depending upon the suture material, add more alternating throws until a complete knot is formed.

4. Trim the ears: When finished, trim the ends to no less than 3 mm in length.

***Tying a two-hand square knot in a tight space*:** When forming a two-hand tie in a deep, tight space, you use the same basic technique already described but modified to ensure that you form a well-snugged knot. These considerations are most important when placing a stitch deep within the yoni or the rectum or when tying off a bleeding blood vessel. Before placing the stitch, be sure the ends of the strand will be long enough so that, after you have encircled or sutured the deep structure, both ends will stick up above the cavity. This is important because you will need to hold the segments and form each throw above the wound. Form the first throw outside the cavity using a two-hand tie without applying tension to the segments. Extend a finger or use a closed instrument to push the throw down to the level where the knot is to be placed. Tighten the throw by placing one finger down near the knot location and using it to push down on the strand near the tissue surface, while using the other hand to apply the same amount of force on the other strand from outside of the cavity; this will help the throw lie flat. Alternatively, if there is room in the wound, you can place your extended index fingers against the strands on either side of the narrow space near the knot as you tighten it to ensure that the strands are kept as parallel as possible with the tissue surface.



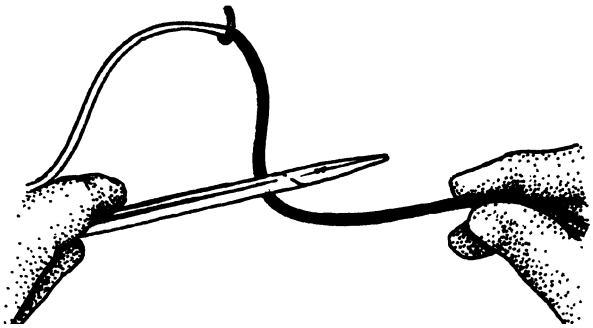
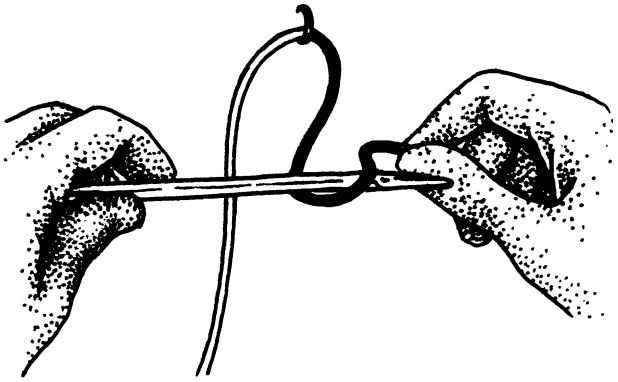
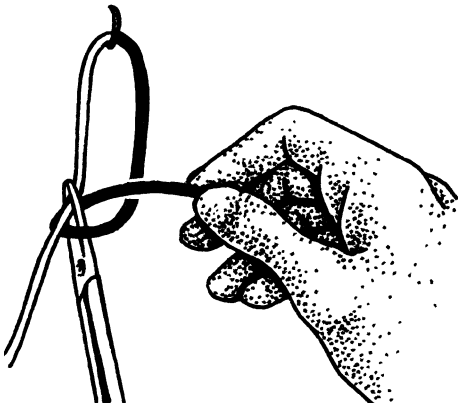
Beginning the throw above the cavity

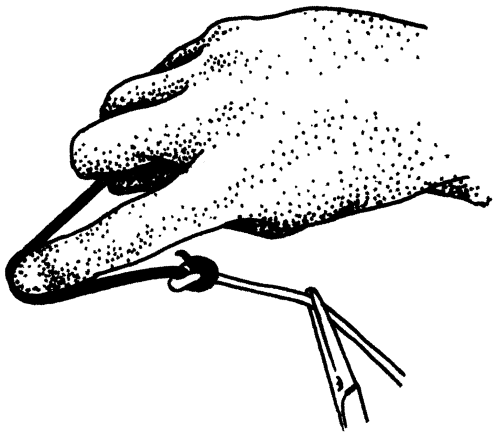


Tightening the throw in the cavity

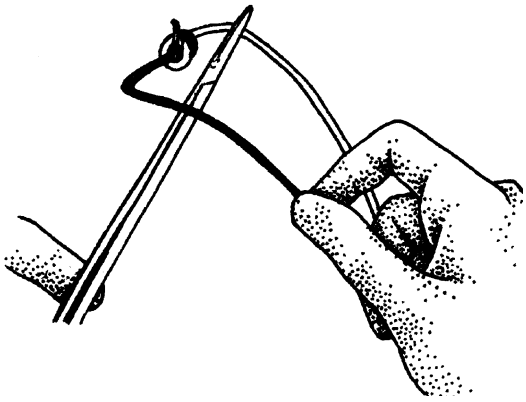
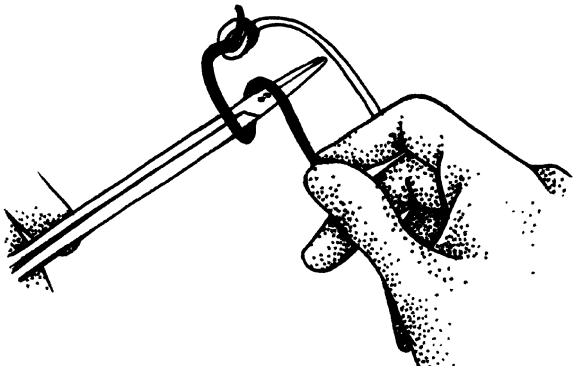
***Instrument-tied square knot*:** The majority of your knots will be in small places, where using an instrument tie will often be easier than hand tying. To begin an instrument tie, place the colored segment on your nondominant side and get out your needle holder.

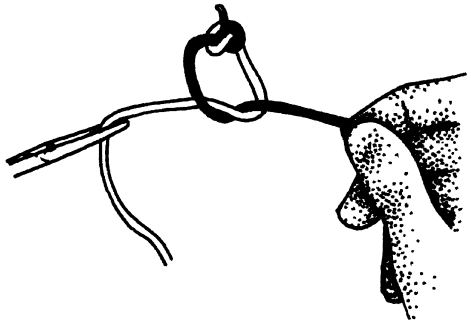
Instrument-tied square knot, first throw:

1. Position your hands. Hold the colored segment in your nondominant hand. Hold the needle holder by its shaft in your dominant hand and lay it over the colored segment.	
2. Loop the colored segment over the needle holder. Form the first loop by wrapping the colored segment over and around the shaft of the needle holder.	
3. Pick up the free end and pull it through the loop. Reposition your dominant hand and place your fingers in the rings. Pick up the white segment with the needle holder and pull it through the loop.	

4. Tighten the knot. Tighten the knot and lay it flat by crossing the nondominant hand over the dominant hand.	

2. Instrument-tied square knot, second throw:

1. Make a loop. Place the needle holder under the colored segment. Wrap the colored segment toward you, around the end of the needle holder.	
2. Grasp the white segment and pull it through. Insert fingers in the rings; pick up the white segment with the needle holder and pull it through the loop.	

3. Tighten the throw. Keep the segments as parallel to the tissue surface as possible as you tighten the knot by pulling in opposite directions as you separate your hands.	

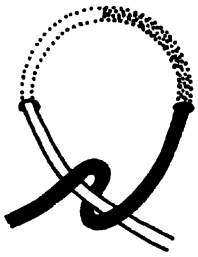
3. Instrument-tied square knot, third throw: To make the third throw, repeat the first throw. This completes three throws (one-and-a-half square knots). Depending upon the suture material, add more throws until a complete knot is formed.

4. Trim the ears: Trim the ends to 3 mm in length. (Anderson & Romfh, 1980; Edlich & Long, 2008; Zikria, 1981)

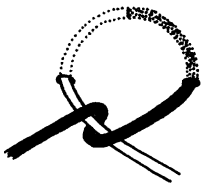
***Slip knots*:** A slip knot consists of two throws, which can be either mirror image or identical. A square knot can be constructed to slip almost as freely as a granny knot. The slip knot has a mechanical advantage in that only the force vector that pulls the tissue edges together is applied to the knot. A slip knot is created when greater tension is applied to one segment than the other during rundown. This is accomplished by not fully snugging down the first throw during rundown, then applying more tension to the needle end than to the free end when tightening the second throw. The knot's ability to slip depends on having one straight segment along which the loops of the other segment can slide. Applying more tension on one side straightens that segment, causing the other, wrapped segment to curl around it.

At times it may be advantageous to temporarily convert a square knot into a slip knot in order to reposition it more accurately or when a square knot has been tied too loosely. The knot, even though snugged down, can be temporarily converted to a slip knot by letting go of one end and gently tugging several times on the other strand to straighten that end out. Slide the knot into place by applying slightly more tension to the straight strand than to the wrapped one, thus the straight strand forms a cable along which the wraps slide into position. Restore the slip knot to a locked configuration by reversing the strength of tension applied to the strands; pull on the free end more strongly than on the needle end and check to make sure that the knot is now flat and square.

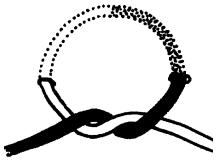
When one end of your suture is very short (a circumstance you will encounter frequently), it is tempting to hold it taut while you tighten the other end. You *must*, however, give the short end slack while taking up the slack in the longer end until the tension is equal or you will wind up with a slipping half-hitch knot. Once the tension is equal, continue to apply equal and opposing tension to both ends to form a true half-hitch.



The half-hitch before rundown



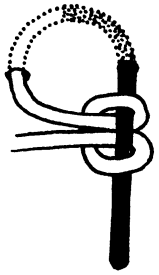
Here, too much tension applied to the white end produces a slip hitch.



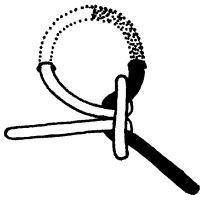
Applying equal tension to each end produces a true half-hitch.

Loose square knot

Tension on the black segment . . .



produces a slipping square knot.



Applying more tension to the white segment. . . .

and then equalizing the tension on both segments converts it back to a square knot.

<u>The influence of suture material on the formation of a knot</u>: Once you are skilled in these basic techniques using thick cord, move on to practicing knot tying using different types of material that are similar to sutures. A thick sewing thread or 3-0 silk suture can substitute for braided synthetic. Fishing line can stand in for synthetic monofilament. There is really no substitute for chromic gut, though. Try to obtain some packets of 3-0 chromic gut for practicing (needle size is not important at this juncture because you are not yet practicing stitches).

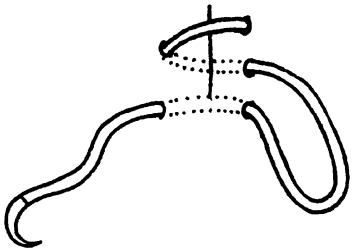
How many throws are optimal to use with each material is still a matter of debate. You'd think, with knot security being so critical, good studies using standardized testing methods would have settled these questions long ago. In fact, there are only a limited number of studies that have addressed knot security, and these have used different testing methods and thus produced results that are not comparable (von Fraunhofer & Chu, 1996b). It is not uncommon for surgeons to try and improve knot security by simply using a larger gauge suture material or adding extra throws. Both approaches increase the amount of foreign material left in the tissues, with the use of a larger diameter strand leaving much more foreign

material in the tissues, greatly increasing the inflammatory zone around the strand, much more so than does an extra throw or two. Therefore, using more throws is the better choice. The following pointers will help form secure knots with different materials.

- **Chromic gut:** Gut exhibits the highest knot security of any suture material and rarely slips regardless of the knot configuration, another good reason to use chromic (von Fraunhofer & Chu, 1996). Each square knot needs at least three alternating throws (i.e., 1½ square knots). Surgical gut is relatively rough and has a moderate amount of memory. It will need to be straightened out frequently during the suturing process to avoid tangles. Even so, experienced midwives report less spontaneous strand knotting when using gut materials.
- **Synthetic materials:** Compared to chromic gut, all coated synthetic materials are smoother and slipperier, and monofilament materials are the smoothest of all. Therefore, synthetic materials require more throws to hold a square knot securely (at least four throws; i.e., two complete square knots). Vicryl, with its thicker coating, behaves more like surgical gut, and some surgeons only use three throws. Dexon II, on the other hand, does not hold knots as securely as Vicryl, which makes it easier to handle during placement. It requires at least four throws, however, or two full square knots, to hold securely. I am recommending that you use a minimum of four throws (two square knots) with all synthetics, although the Colorado Surgical Assistants program recommends 6 throws (3 square knots) for all braided synthetics and 16 throws (8 square knots) for monofilament materials. While a 2=1=1 surgeon's friction knot will usually hold all these materials securely with only three throws, this type of knot is hard to work with and I do not recommend it. Cut the ears on synthetics no less than 3 mm long straight across the strand, even when against the skin; to avoid unraveling, never trim the ears on synthetics flush with the knot.

Practicing breaking knotted suture: You should apply 80% of the knot-breaking strength to the segments when you run down your throws. To get a feel for the breaking strength of various suture materials, experiment with pieces of real suture to see how hard you must pull to break an unknotted strand and then tie two ends in a 1=1=1square knot and pull on each end to determine the knot-breaking strength.

Finishing a continuous row of stitches with a final square knot: At the beginning of a row of stitches or when an interrupted stitch is placed, a "double-strand" square knot is created using the segments of the strand from either side of the stitch. At the end of a continuous row of stitches, however, a **"triple-strand" square knot** is used. It is formed by first creating a loop of suture on the needle-end side. This is done by taking a backwardly directed stitch alongside the one you just created by reinserting the needle on the same side you just exited and bringing it out on



Loop contributes two strands.

the other side of the laceration (your dominant side), beside your original insertion point. The stitch is left loose so that a loop remains open on your nondominant side. Pinch the sides of the loop together, creating a double strand segment, and treat this pinched loop as though it were one thread. Cut the needle off of the dominant-side segment and the pinched loop is then tied to the needle-end.

The triple-strand square knot is markedly different from the double-strand square knot because it has two segments on one side (the pinched loop) that are intertwined with the single segment on the dominant side. Double-strand square knots have two ears that point in opposite directions. A triple strand knot has one ear on one side and two ears (from both ends of the loop) that exit the opposite side of the knot. Triple-strand square knots are thus more likely to slip. Nevertheless, this is a good way to close off a row of stitches and is widely used.

To avoid slippage, additional throws are added to increase knot security. When constructing a double-strand square knot with absorbable synthetic multifilament material, use *at least* four throws. Tying a triple-strand square knot using a synthetic monofiliment material, requires *at least* five or six throws to achieve knot security, leaving a big bunch of suture on the surface of the tissue. Because of this, there is really no advantage in attempting any techniques to bury such a bulky knot. When working with chromic gut, one and a half square knots (three throws) may be used to form either a double- or a triple-strand square knot.

The Aberdeen knot

The **Aberdeen knot** is a variation of a **highwayman's hitch** or **high post hitch knot**. These knots were originally developed to temporarily secure an object to a post and are therefore designed to release easily. The knot has been modified for surgical applications so that it will not come untied and thus lacks a built-in mechanism to unravel it. This knot has gained wide popularity in the United Kingdom, Australia and New Zealand. It was named by James Learmonth (Professor of Surgery, Aberdeen University, Scotland, from 1952 to 1958), who noted that it used less suture than a standard surgeon's knot and therefore must have been invented by a Scot.

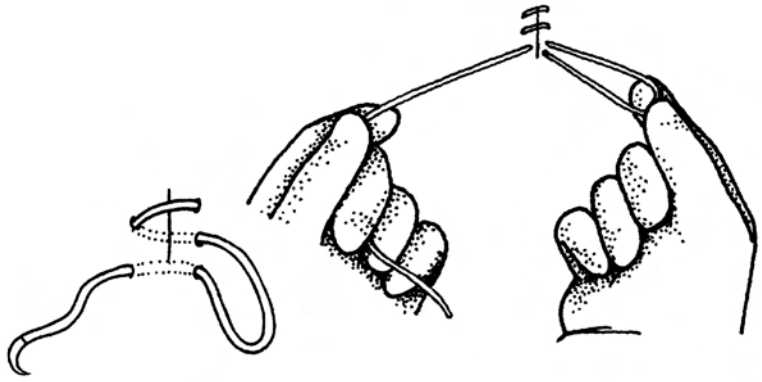
This knot can be used as the final knot to tie off continuous stitches and is a good alternative to the triple-strand square knot for this purpose. It is very easy to construct and, if done correctly, offers the best security of all surgeon's knots when used appropriately. After running the strand through the tissue, a knot is formed by creating a loop of thread with the free end and passing another loop created on the needle end through it; each such configuration equals one throw. A wrap is created when the needle end is passed around one side of the final loop one or more times prior to running down the last throw.

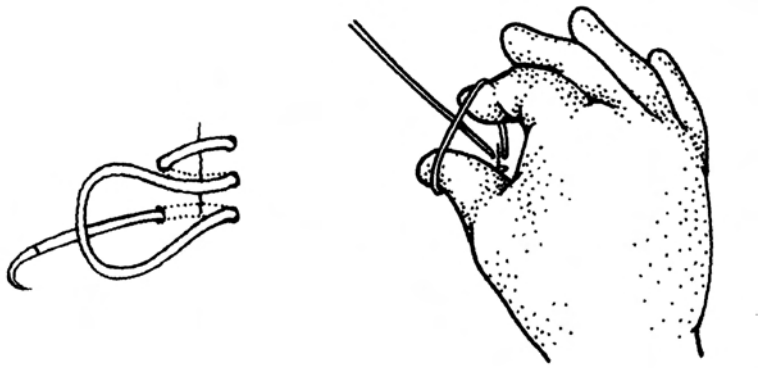
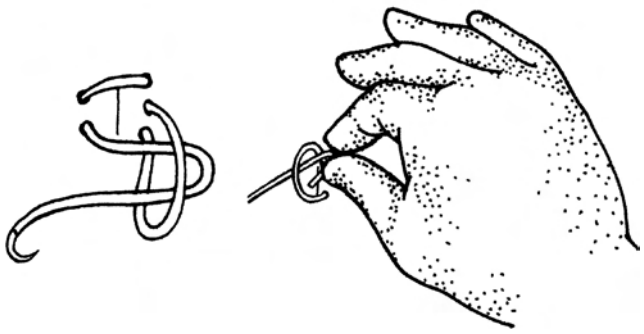
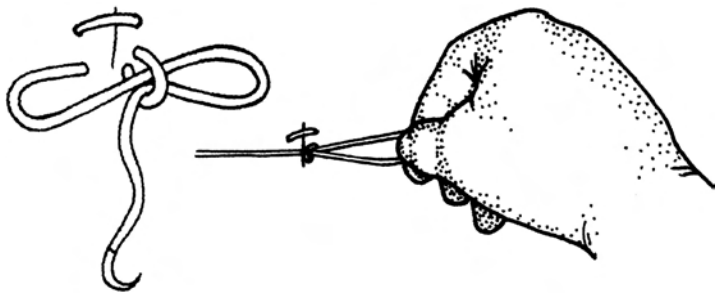
Stott and colleagues (2007) found that a maximally strong and slip-free knot could be created using three throws, with two wraps incorporated on the final throw. They used Polydioxanone monofilament (PDS II, Ethicon), size 0, for these tests, which is not recommended for perineal repair. Nevertheless, synthetic monofilament materials are widely regarded as the most difficult materials with which to create a secure knot. PDS-II is considered quite pliable compared to other synthetic materials, but the use of such a thick strand stiffens the material somewhat. Based on this understanding, the three-throw, two-

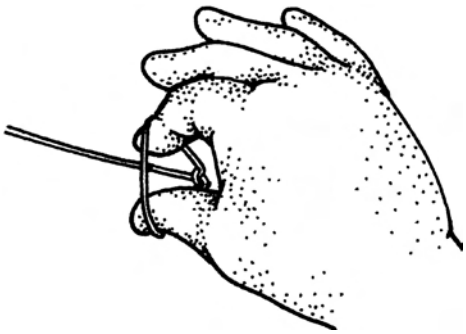
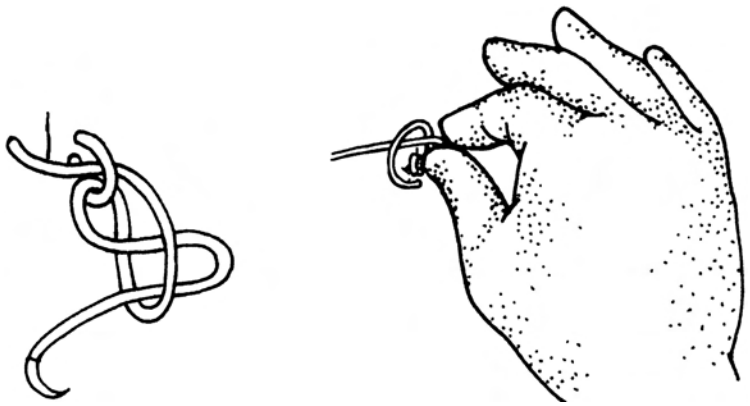
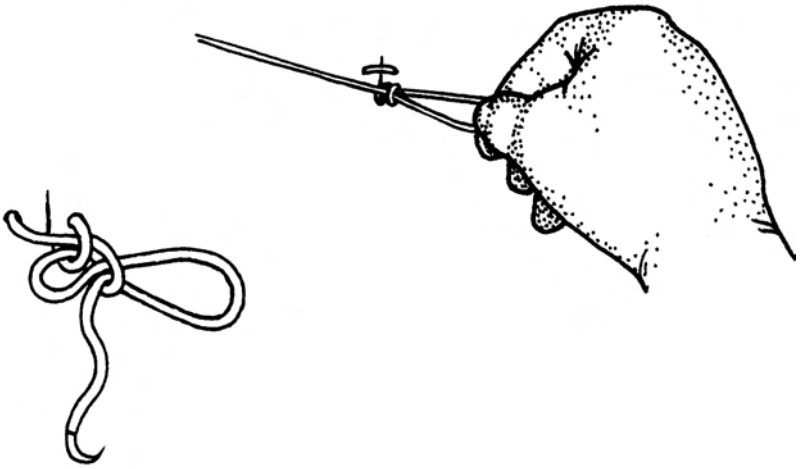
wrap configuration they found to be most secure in this material is likely to be entirely adequate for use in the thinner materials that midwives commonly use. If you are in doubt about this, you could add one more throw before wrapping the last loop.

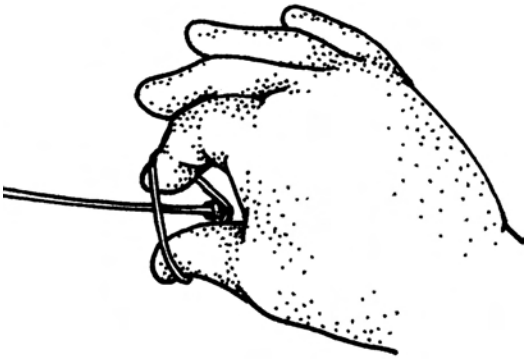
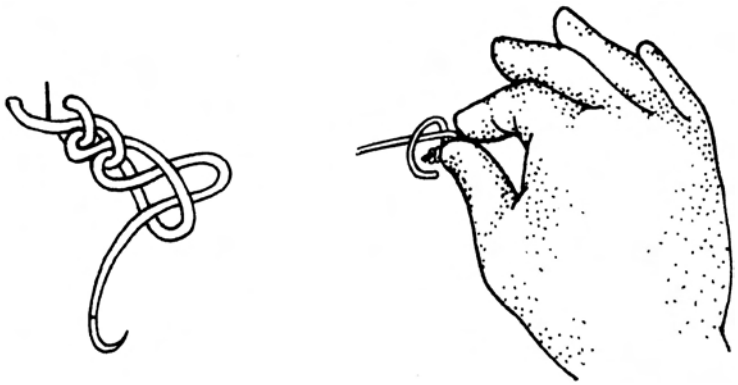
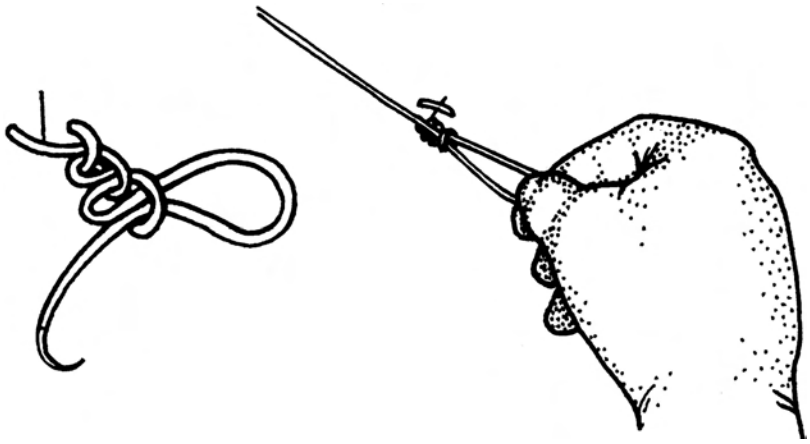
The Aberdeen knot is self-tightening. As it tightens, the stitch becomes slack. Thus, it is important to snug down the first throw securely before beginning the next.

Practicing the Aberdeen knot: Begin this knot by forming a loop. This can be done by not completing your last stitch or by completing the final stitch and then reentering the tissue on the same side you just exited and coming out on the opposite side, as for a triple-strand square knot, thus creating a loop on your nondominant side and moving the needle end back to your dominant side. Based on my experience, completing your last stitch before creating a separate loop is the best option because I believe it places less tension on the tissues, although it does require leaving more suture in the tissue. A left-handed knot is illustrated here, where the loop will be formed on the nondominant side.

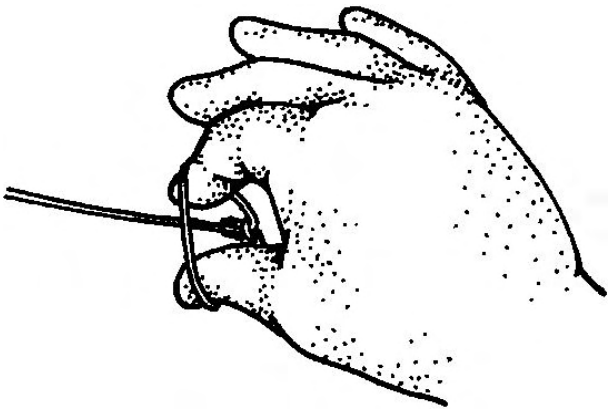
1. Create a loop. Reinsert the needle on the same side you just exited and come up on your dominant side. This leaves a loop on your nondominant side. Whenever needed, reduce the size of the loop by pulling on the needle end with your dominant hand. (You can trim off the needle at this point, here the needle is shown in the closeups to clarify which end you are manipulating.)	

2. Lift the loop toward your dominant side and insert your non-dominant thumb and index finger into it.	
3. Grasp the needle segment between your nondominant thumb and index fingers and pull it through the loop.	
4. Finish the first throw. Continue pulling to snug down the first throw. This process also creates your second loop. Whenever necessary, adjust the loop's size by pulling on the needle segment with your dominant hand.	

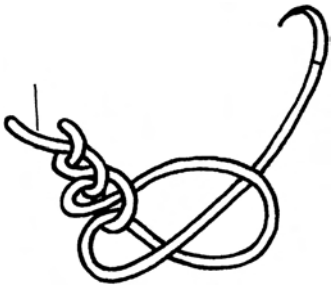
5. Begin a second throw. Lift the second loop toward your dominant side and insert your non-dominant thumb and index fingers into it.	
6. Pinch the needle-segment and pull it through the loop.	
7. Finish the second throw. Continue pulling to snug down the second throw. This process creates a third loop.	

8. Begin a third throw. Lift the loop toward your dominant side and insert your nondominant thumb and index finger through the loop. Reduce the size of the loop by pulling on the needle end with your dominant hand.	
9. Now pinch the needle segment with your nondominant thumb and index fingers and pull it through the loop.	
10. Finish the third throw. Continue pulling to snug down the third throw. This process creates a fourth loop.	

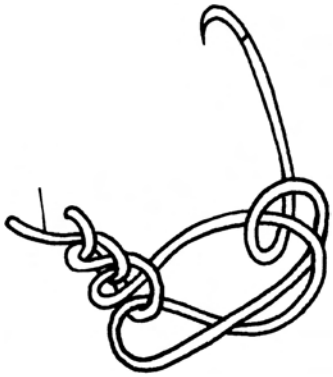
11. Finishing the knot. Start by inserting your nondominant thumb and index fingers into the fourth loop and spread them to open the loop.



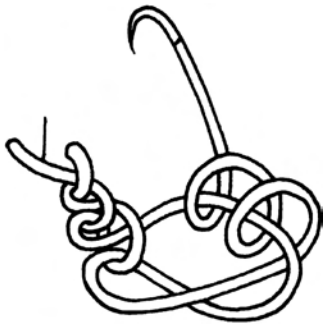
12. Begin to lock the stitch. Pass the needle end of the strand through the loop.



13. Create the first wrap. Wrap the needle end around one side of the loop.

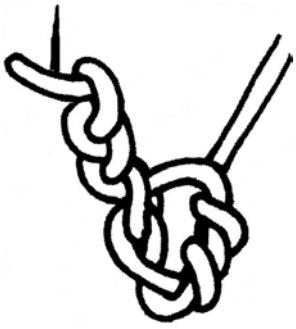


14. Create the second wrap by passing the needle end around the side of the loop a second time.



15. Now the knot looks like this.

16. As you rundown the knot for the last time, it starts to twist and look like this.



To bury an Aberdeen knot: If desired, you can bury the knot. To do so, you must leave the needle attached. Arm your needle holder and insert the needle tip between the edges of the perineal tear, just below the uppermost perineal stitch. Bring the needle up between the edges of the tear, behind the last stitch in the yoni floor (which will, in most women, also be behind the hymenal ring). Pull up on the needle end, which will drag the knot between the edges of the perineal tear, thus burying it under the tissue surface. The disadvantage to this is that it leaves an additional wad of suture in the tissue. The disadvantage to not doing this is that a longish knot is left on the tissue surface that could become entangled in a sanitary pad and that may be otherwise irritating to the woman.

Trim the ears: Trim the needle-end, leaving a short ear.