Knot-Tying and Suture-Passing Techniques

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Adam M. Smith
Scott J. Deering
Mary Lloyd Ireland

Chapter Synopsis

- This chapter reviews basic principles and techniques of arthroscopic suture passage and knot tying. The authors also review basics types of instrumentation and different types of arthroscopic knots.

Important Points

- A firm understanding of available technology including different anchor types and available instrumentation is essential for a smooth arthroscopic case.
- Confidence with multiple suture-passing devices makes a case go more smoothly.
- Learn at least one sliding and one nonsliding knot.
- Practice, practice, practice your knot-tying skills.

Clinical and Surgical Pearls and Pitfalls

Suture Passing

- Create accessory portals under direct vision using a spinal needle to assess angle of entry to be able to successfully pass suture through tissue.
- An attempt should be made to place the portal in an adequate position to allow for a reasonable amount of swelling. For example, placement of the lateral portal too close to the lateral aspect of the acromion may lead to difficulty performing adequate acromioplasty and bursectomy.
- Maximize visualization before starting the reparative procedure. Remove obstructing bursa or soft tissue.
- Perform a complete survey of the joint and periarticular structures before beginning the repair. Focusing on only the known pathology may lead to missed diagnoses.
- Make a plan. Make sure all potential equipment and devices are available before the case.
- Work quickly on secondary procedures such as acromioplasty to minimize unnecessary soft tissue extravasation.
- Obtain adequate hemostasis. Failure to do so may ultimately lead to longer operative times with difficulty visualizing the structures. The anesthesia team should maintain blood pressure less than 100 mm Hg systolic to maximize visualization of work in the subacromial space via the arthroscopy.
- Prevent tangling of sutures when multiple anchors are used. We recommend that sutures from each anchor be placed in different portals to prevent entanglement. Other options include keeping the sutures “outside” of a cannula interposed between the cannula and soft tissue, or using a small stab incision to serve as a suture repository while other suture limbs are being passed.
- Different repairs require different suture passers. Gaining comfort with multiple suture-passing techniques allows for better tissue fixation and a quicker operative procedure.

Suture Tying

- A clear cannula in the working portal allows visualization and prevents soft tissue from interfering with the knot as it slides to the tissue.
- Only one set of suture should be retrieved into the working portal used for tying the knot.
- Use the portal that is best directed over the anchor to allow better suture sliding. Be sure to check that the suture slides easily before attempting to tie a sliding knot.
- If the suture does not slide, a nonsliding knot with reversed half hitches is necessary for maximum fixation to be obtained.
- Before the knot is tied, a knot pusher may be passed down the post suture to untwist the suture.[1]
- For nonsliding knots, we tie at least six half hitches, alternating the post and reversing the throws with each (underhand and overhand).

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- Advanced arthroscopists may choose to forego the use of a cannula. If this method is chosen, we recommend that a ring forceps be placed around both suture limbs inside the working space and retrieved together to avoid soft tissue interposition.
- Select the suture limb that will function as the "post" that allows for best tissue approximation and compression. In a mattress suture configuration, the post can be either limb. In the simple suture configuration, pick the post away from articular cartilage. This suture limb is usually on the tissue side, allowing for maximal compression of the tissue against bone and also directing the knot away from the joint, thus avoiding articular injury from the resultant knot.[1]
- Place a clamp to the end of the suture post limb before tying a knot. This prevents the knot pusher from sliding off the post and provides resistance as the knot is tightened.
- Visualize the knot as it slides to the tissue to ensure that the tissue is compressed to the desired location.
- Maintain tension on the post limb as the knot is seated to avoid loosening.
- "Past pointing" is a technique by which the knot pusher is used to tension the knot by switching the tension to the loop limb and pushing past the knot with the post limb of suture (see Fig. 3-7). This technique allows the knot to fully seat, which increases the knot security provided by the knot's internal friction.
- After an initial sliding knot is tied, reversed half hitches on alternating posts should be thrown and seated with the knot pusher, using past pointing to prevent the knot from coming loose or backing out.
- Be patient. Allow extra time on all arthroscopic cases in the beginning.
- Practice your knot-tying skills. The time to practice is before the case when you are not under pressure. When practicing, use bigger string or rope to view the knot configuration. Dry and wet laboratories are extremely helpful and should be used for training when possible.
- Management of suture requires careful attention. You must practice and visualize your knot tying. Make it as easy and automatic as tying your shoes.

Video

- Video 3-1: Shoulder arthroscopic knot-tying

Arthroscopic surgical techniques have advanced as technology and surgical expertise have expanded. Less invasive soft tissue repair, such as rotator cuff or labral repairs, must focus on an anatomic approach that relies on strong fixation of the tissue to either bone or other soft tissue via a surgeon-tied knot. Suture passage and knot tying remain technically challenging exercises that can frustrate any surgeon regardless of experience level. Revisit your memories of learning to tie your shoes as a child. Arthroscopic knot tying must be practiced and must become as easy as tying your shoes. This chapter reviews the basics of soft tissue suture passage and arthroscopic knot tying via standard arthroscopic instrumentation.

Instrumentation

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Unlike open surgery in which the surgeon has direct access to the tissue being repaired, arthroscopic surgery requires different techniques to tie effective knots that can resist displacement and allow for healing. Arthroscopic knot-tying methods have advanced through the years along with advances in implants and instrumentation. This section focuses on the essential "tools of the trade" to make an arthroscopic procedure go more smoothly.

Suture Anchors

The advent of the suture anchor has dramatically expanded the options for tissue repair. Numerous suture anchor designs are available; anchors come in multiple sizes, allowing maximum fixation strength of tissue to bone.[2] Anchors may be made of metal, absorbable material, or plastic and should allow for sutures to slide easily through the eyelet. The anchor, when inserted into the bone, allows suture to be passed through soft tissue and affixed to the desired anatomic location in a predictable fashion. Multiple sutures may be preloaded into the anchor, allowing for multiple points of soft tissue fixation and decreased load on each suture knot.[3] Although the choice of the best anchor for each surgical procedure is beyond the scope of this chapter, a basic understanding of anchor types is advised.

Cannulas

Arthroscopic cannulas allow for suture passage through tissues, avoiding incorporation of unwanted soft tissue in the repair constructs.[4] Sutures and instruments that are not passed through a cannula can be trapped in soft tissues, causing significant difficulty in knot tying, which may result in increased operative times, less secure fixation, and generalized frustration for the surgeon. Cannulas also allow the surgeon to keep sutures organized, prevent suture entanglement, provide easy access to the joint, and facilitate visualization. The ideal cannula size to allow for passage of typical arthroscopic instruments is 8.5 to 10 mm. Cannulas are important tools that play an integral part in the surgical plan.

Arthroscopic Instruments

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After insertion of the anchor, specialized instruments will be necessary to assist with management of sutures to facilitate a secure repair.[4] Suture retrievers are the workhorse of any arthroscopic procedure (Fig. 3-1). These devices can be locking or ratcheting, and function to grasp the suture. Some devices will securely hold the suture, whereas others secure the suture but allow it to slide in the jaws (suture retrieval forceps, or "loopie"). Suture retrieval forceps can facilitate removal of suture from the joint by allowing it to slide as it is extracted. This prevents the suture limb from sliding through the anchor unintentionally. Another option for suture management is the crochet hook instrument.[4] This device allows the surgeon to place the suture at various places within the joint for retrieval and passage. Some crochet hooks have a modification that allows for sutures to be pushed with the tip in addition to being pulled with the hook ("push-me, pull-me").

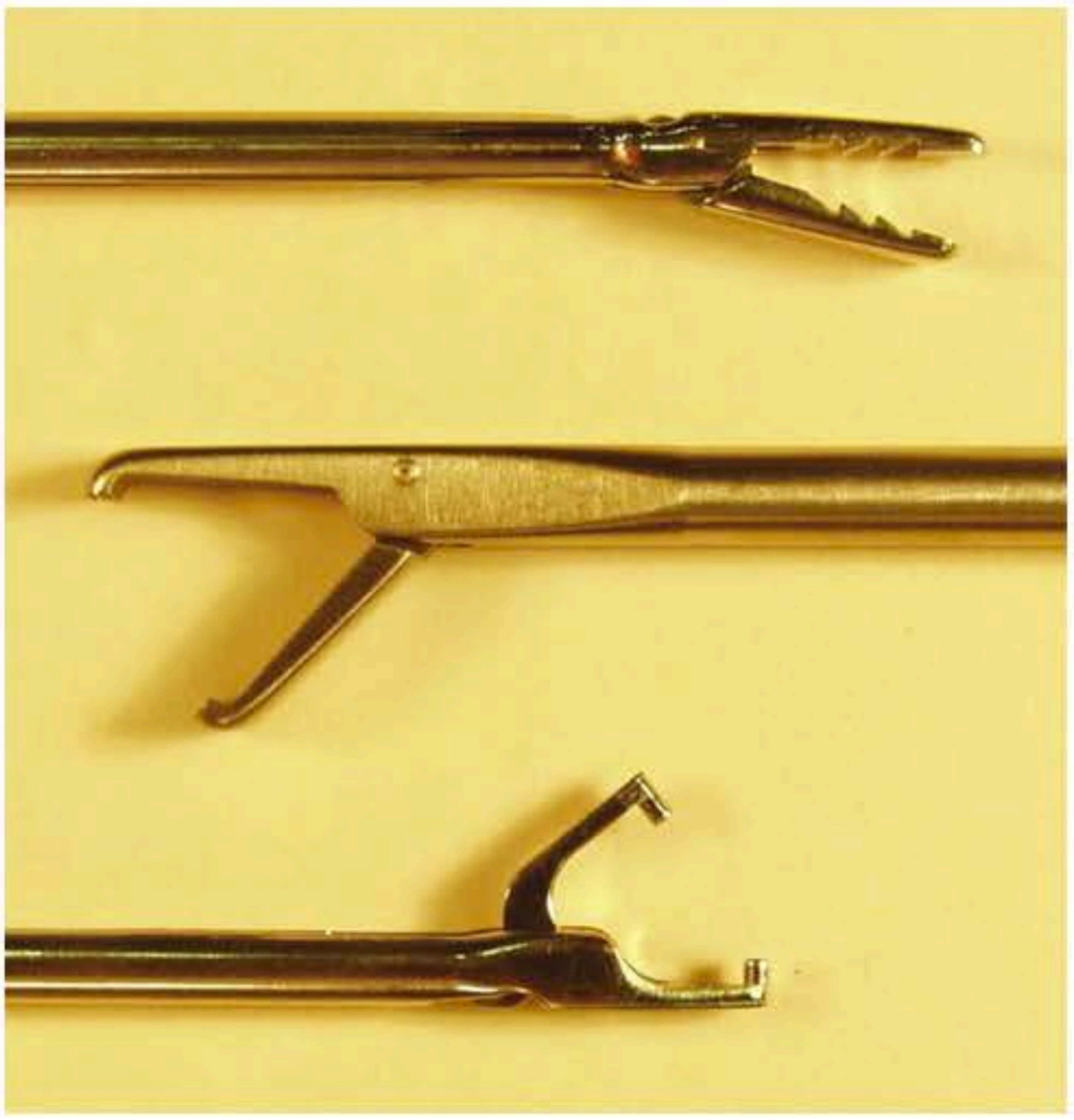


FIGURE 3-1 Several devices are necessary for an efficient arthroscopic repair. Suture g…

Tissue graspers are also important for management during a repair. These devices function to grasp the tissue and apply traction. However, the grasper should not perforate or damage the tissue. This allows the surgeon to manipulate the tissue and both determine the appropriate location and tension of the torn tissue and place the tissue in positions that are amenable to suture passage. Graspers may also lock, allowing the surgeon to work with the tissue in a hands-free manner.

The arthroscopic knot pusher is another critical device used to tension knots and ensure that tissues are tightly apposed. Knot pushers come in various configurations and should be chosen based primarily on surgeon preference.[4,5] Once all knots are completed, there are also a variety of manufacturer-specific cutting devices. Some of these devices are preferentially made to cut the many different high-tensile sutures, including FiberWire (Arthrex, Naples, FL) and Ultrabraid (Smith & Nephew, Andover, MA). However, more generally, there are cutting tools that can be placed into the joint, and then the suture is loaded; other devices allow the surgeon to load the suture external to the joint and follow the suture limbs down before cutting at the knot.

Suture Passage

Proper suture passage allows for precise placement of sutures to maximize secure tissue fixation and to minimize iatrogenic tissue injury. Various techniques have been developed to facilitate the passage of suture through soft tissue. Although a comprehensive review of suture-passing devices is not feasible, it is important for any arthroscopic surgeon to be comfortable with multiple suture-passing techniques. This allows the surgeon to accommodate intraoperative challenges and decrease operative times, as one technique is not always the easiest for any given pathology. Confidence and familiarity with these devices is necessary for an efficient arthroscopic repair.

The ability to manage the soft tissues in a gentle manner is important for avoidance of iatrogenic injury.[6] However, without fail, the key to arthroscopic and minimally invasive surgery is visualization. In our experience and observation, the failure to perform an adequate bursectomy before beginning an all-arthroscopic rotator cuff repair is the most common reason for conversion to an open procedure.[7] Convenience, cost-effectiveness, and tissue quality are deciding factors in use of any suture-passing device.

Suture Relay

Suture relay has been the workhorse of arthroscopists from its inception. Cannulated large-bore needle devices are passed through the soft tissue that is in need of repair (Fig. 3-2). These devices come in numerous shapes and twists to facilitate placement of the suture at the point of maximum fixation. Before the arthroscopic procedure, practice with new devices and use what works best in your hands. Suture relay devices are particularly useful for difficult-to-reach or more delicate tissues such as the labrum.

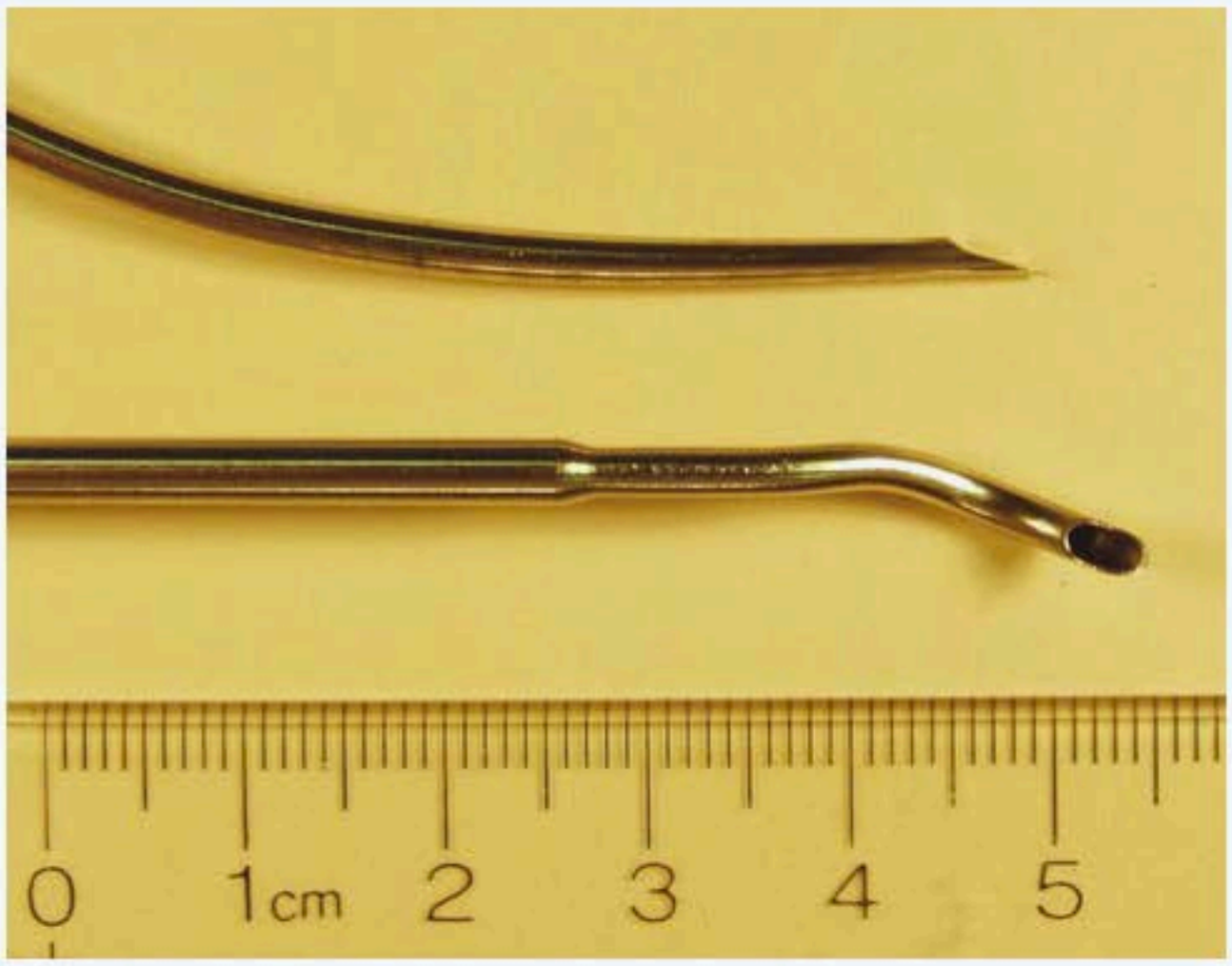


FIGURE 3-2 Suture lassos are the workhorse of arthroscopic shoulder surgery. Cannul…

With these devices the sharp cannulated needle is passed through the tissue; a suture lasso is deployed through the needle into the joint and retrieved with the desired suture to be passed through an accessory working portal. Care should be taken to avoid tangling the suture that is to be passed with the remaining sutures. An easy technique to avoid this is to grasp the lasso and the suture in one pass, retrieving them through the same working portal. Currently we recommend the use of clear plastic cannulas when available to pass sutures to avoid soft tissue interposition in the suture.

The suture end, usually from an anchor, is then passed through the lasso. Only 10 cm or so of suture should be passed, to minimize kinking of the suture or lasso when the lasso is retrieved. The lasso is then pulled through the original portal, allowing retrieval of the desired suture. The process is repeated as necessary until all sutures have been placed.

Tissue Penetrators

Tissue-penetrating devices such as the Birdbeak (Arthrex, Naples, FL) are useful in larger spaces with more robust tissue (Fig. 3-3). These devices have sharp, pointed ends and are used to grasp or pass suture directly through the tissue. These instruments allow for precise placement of sutures through tissues and are usually passed in an antegrade fashion to hand off the suture to other instruments. Alternatively, a retrograde technique can be employed in which the instrument is passed through the tissue and used to grasp a suture, pulling the suture through the tissue on removal of the instrument. Care must be used with these instruments to avoid damage to the tissue through which the device is passing, the articular cartilage, or other structures within the joint.

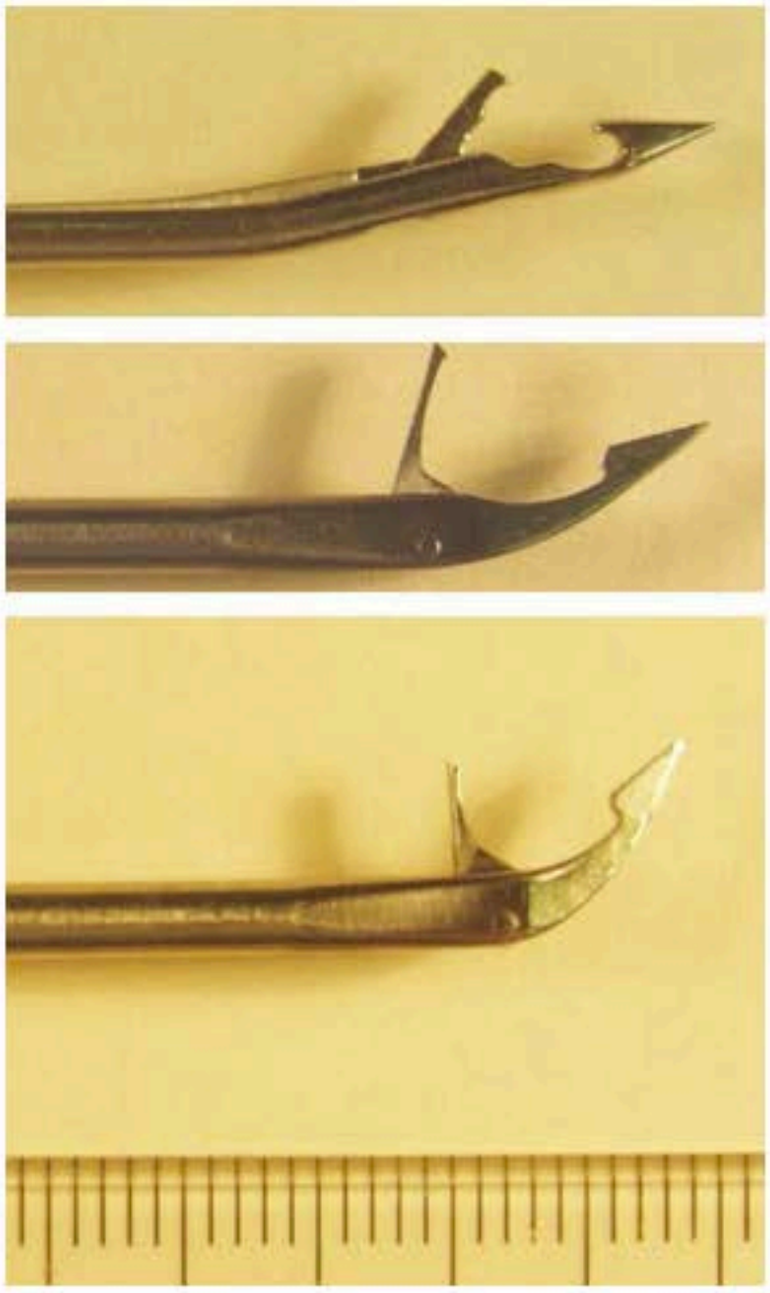


FIGURE 3-3 Tissue-penetrating devices are extremely valuable and can be used in ant…

Obtaining an ideal angle for suture passage can be difficult. Suture punch devices use a needle to shuttle suture through tissue when the device is deployed (Fig. 3-4). Some of these devices allow for a one-step suture passage and retrieval on the opposite side of the tissue with the same instrument. Others require a suture grasper or hook to retrieve the suture. Although several variations on this design are available, suture is passed directly through the tissue and retrieved through the same portal.

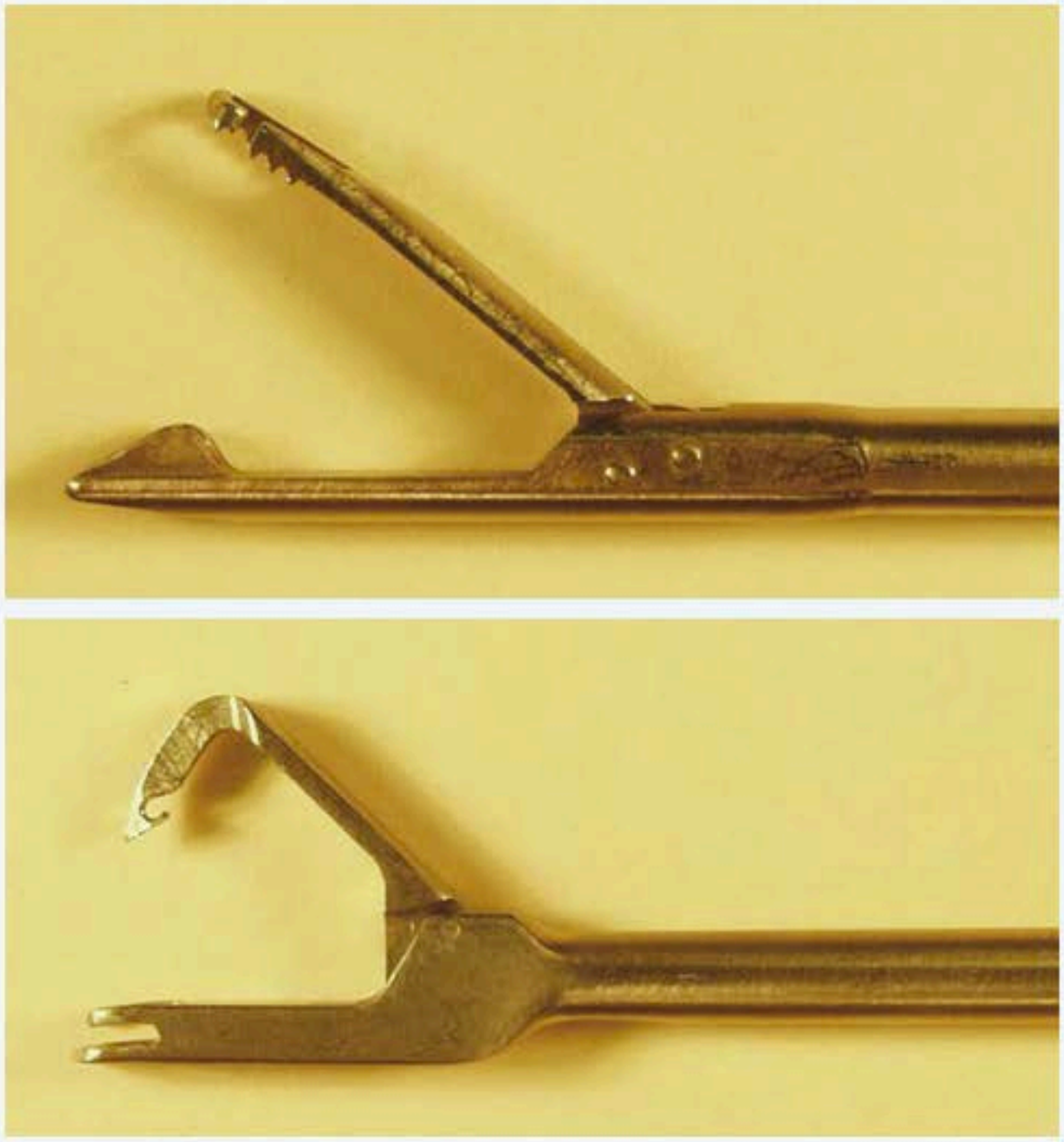


FIGURE 3-4 One-step suture passers were designed to minimize the number of steps i…

Knot Types

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There are many types of arthroscopic knots. The surgeon must be able to tie one of each type of sliding and nonsliding knots. A basic review of terminology is crucial to understand the techniques described for these knots (Box 3-1). Although there are benefits to each knot type, we recommend understanding how to perform a nonsliding and at least one sliding knot.[3,8-10]

Box 3-1

Knot-Tying Terminology

Post: Suture limb around which a loop is made, used to pull knot to tissue
Loop: Suture limb used to make a loop around the post
Half-hitch knot: Single loop around the post
Knot pusher: Mechanical device used to slide a knot or loop down the post limb

Nonsliding Knots

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Nonsliding knots consist of a series of half hitches in which the loop limb is tied around the post. The post and loop limbs can be alternated, and the direction of throws of the suture can also be varied to increase knot security.[10] Each throw of the knot must be guided to the tissue completely to ensure that a tight knot is produced. Examples of nonsliding knots are the Revo knot and alternating half hitches. Nonsliding knots must be used when the suture material does not slide freely through the suture anchor and tissue being repaired. These can be used for any situation in which an arthroscopic knot is tied.

Sliding Knots

Sliding knots consist of a looped suture end that is passed around a shortened post limb. When the post is pulled or the knot is pushed, the knot slides down the post to the tissue. Sliding knots can be further subdivided into locking and nonlocking configurations. Nonlocking configurations do not have internal resistance to knot slippage other than friction between the suture limbs. When these knots are tied, tension must be maintained on the post limb until half hitches are thrown to provide knot security. Examples of nonlocking sliding knots include the Duncan loop and the overhand loop.

Sliding, locking knots have an internal locking mechanism that provides increased loop security while they are tied. These locking knots function by having a wrapping limb that distorts the post limb when tensioned, increasing the internal interference and preventing knot slippage. This locking mechanism is known as the *one-way ratchet effect* or the *self-locking effect*.[11] Locking knots can be further categorized as proximal, middle, or distal locking, depending on the location of the wrapping limb relative to the surgeon. Proximal-locking knots deform closer to the surgeon, whereas distal-locking knots deform closer to the tissue. Nicky's knot is an example of a proximal-locking knot; the Samsung Medical Center (SMC) (Fig. 3-5) and Tennessee slider are examples of middle-locking knots; and the Weston (Fig. 3-6) and Roeder knots are examples of distal-locking knots.[11] Proximal-locking knots can be locked more easily when tension in the knot loop is high; however, distal-locking knots tend to have less enlargement of the suture loop when the locking mechanism is deployed, so each knot has its own advantages and disadvantages.

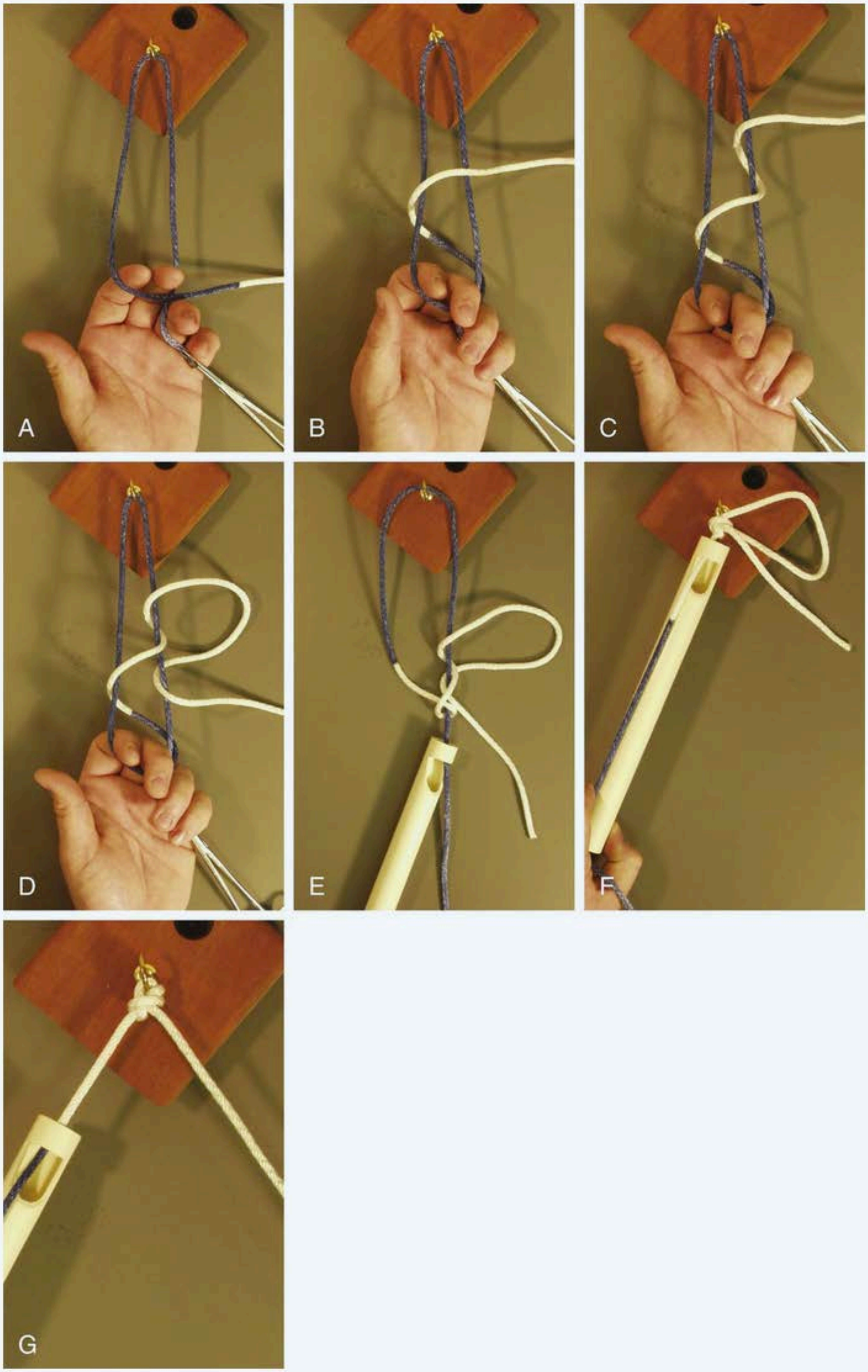


FIGURE 3-5 Samsung Medical Center sliding-locking knot. The post limb is colored dar…

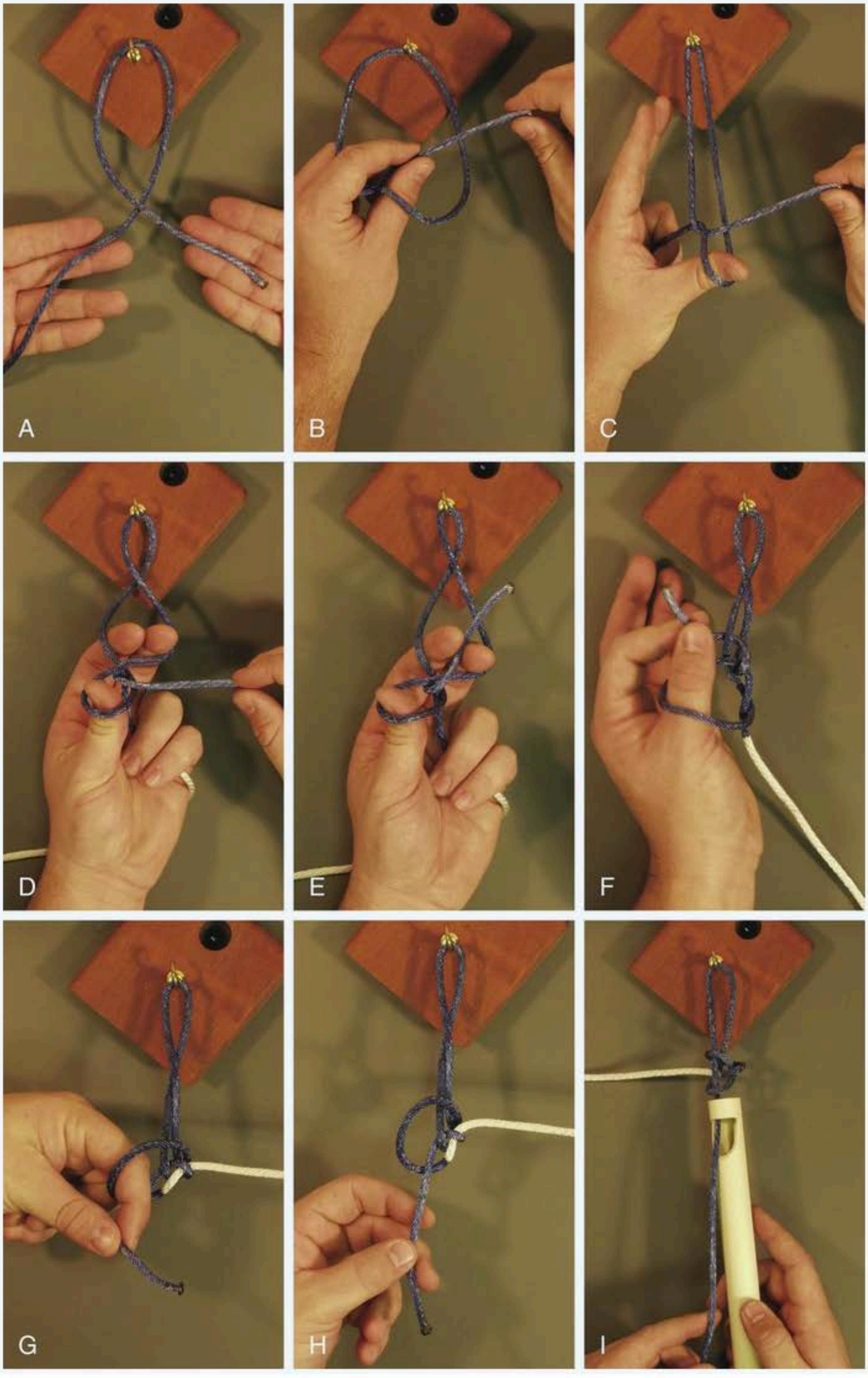


FIGURE 3-6 Weston knot. **A,** The post limb is placed over the loop limb of the suture, ...

Selected Literature Review

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Much has been written on the technique and optimization of arthroscopic knot tying. Burkhart and co-workers did an elegant study in which they evaluated the configuration of sliding knots that would have adequate strength for rotator cuff repair.[3] They found that reversing posts while tying half hitches to secure sliding knots greatly increased the load to failure of the knot. Another recommendation was the use of double-loaded anchors to decrease the amount of stress to which any one knot was subjected by increasing the number of individual knots per repair. The recommendation that they provided was that to withstand maximal muscle contraction in the rotator cuff crescent, anchors should be placed 1 cm apart with two sutures per anchor to allow for adequate healing of the torn tendon.[3]

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Another area of debate is the number of half hitches necessary to secure an arthroscopic sliding knot. A biomechanical study demonstrated that self-locking knots still require half hitches to resist failure in the setting of a dynamic cyclic load.[12] The study also demonstrated that most knots require three half hitches to secure the knot and that security generally plateaus after the third half hitch (Fig. 3-7). We recommend tying three half hitches with alternating posts after a self-locking knot to prevent knot failure and increase security.

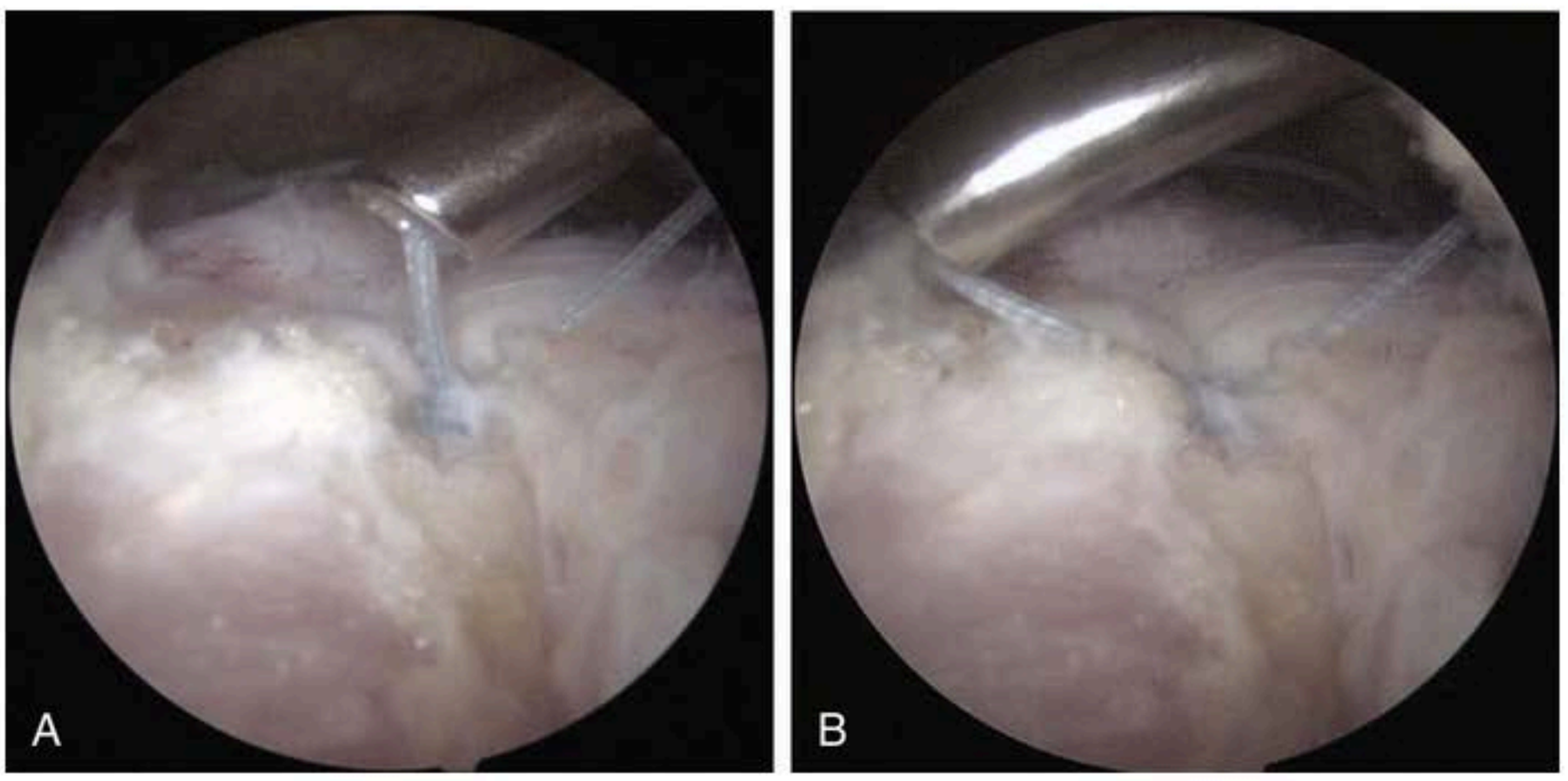


FIGURE 3-7 Past pointing. This technique is used to ensure that the knot is adequately…

The ultimate goal in tying an arthroscopic knot is to achieve a secure knot that stabilizes the tissue and allows for healing in a tension-free environment. The gold standard to which arthroscopic knots have been compared is the open knot. Multiple studies have demonstrated that arthroscopic knots, when tied correctly, resist slippage and elongation, similar to open knots.[13,14] Arthroscopic sliding knots have also been demonstrated to be as secure as square knots tied open when the sliding knots are backed up with three half hitches with alternating posts and throw directions.[13] In addition to sliding knots, studies have demonstrated that arthroscopic square knots have equivalent strength to open square knots in resistance of elongation and ultimate failure in the setting of a cyclic load.[14]

Summary

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Techniques for knot tying and suture passage continue to evolve with the field of arthroscopy. Surgeons who perform arthroscopic techniques for tissue repair need to be comfortable with methods for passing suture through tissue and tying arthroscopic knots. A surgeon should have the ability to throw nonsliding and sliding knots. The best course of action is to practice knot tying before surgery and suture passage in a laboratory, if available. Arthroscopic suture passage and knot tying allow for durable repair of soft tissue injuries in a minimally invasive fashion. Techniques will continue to be developed as the burgeoning field of arthroscopy continues to develop. As with any case, be prepared for any situation in the operating room. Have a plan for problematic situations—loose knot, tangled suture, anchor pull-out. Know how to get out of trouble, and reduce your frustration level.

References

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1 **Mair SD**: Aspects of Arthroscopic Knot Tying, Technique Tips AAOS/ASES Arthroscopic Management of Rotator Cuff Disease and Instability. 2010 Illinois Chicago

2 **Barber FA, Herbert MA, Hapa O, et al.**: Biomechanical analysis of pullout strengths of rotator cuff and glenoid anchors: 2011 update. *Arthroscopy*. 27:895-905 2011 PMID: 21693345

3 **Burkhart SS, Wirth MA, Simonick M, et al.**: Loop security as a determinant of tissue fixation security. *Arthroscopy*. 14:773-776 1998 PMID: 9788379

4 **Nottage WM, Lieurance RK**: Current concepts: arthroscopic knot tying techniques. *Arthroscopy*. 15:515-521 1999 PMID: 10424555

5 **Milia MJ, Peindl RD, Connor PM**: Arthroscopic knot tying: the role of instrumentation in achieving knot security. *Arthroscopy*. 21:69-76 2005 PMID: 15650669

6 **Lo IKY, Burkhart SS, Chan C, et al.**: Arthroscopic knots: determining the optimal balance of loop security and knot security. *Arthroscopy*. 20 (5):489-502 2004 PMID: 15122139

7 **Altchek DW, Warren RF, Wickiewicz TL, et al.**: Arthroscopic acromioplasty: technique and results. *J Bone Joint Surg Am*. 72:1198-1207 1990 PMID: 2398090

8 **Burkhart SS, Wirth MA, Simonich M, et al.**: Knot security in simple sliding knots and its relationship to rotator cuff repair: how secure must the knot be?. *Arthroscopy*. 16:202-207 2000 PMID: 10705334

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9 **Chan KC, Burkhart SS, Thiagarajan P, et al.**: Optimization of stacked half-hitch knots for arthroscopic surgery. *Arthroscopy*. 17:752-759 2001 PMID: 11536096

10 **Chan KC, Burkhart SS**: How to switch posts without rethreading when tying half-hitches. *Arthroscopy*. 15:444-450 1999 PMID: 10355722

11 **Lo IKY, Burkhart SS**: Current concepts in arthroscopic rotator cuff repair. *Am J Sports Med*. 31 (2):308-324 2003 PMID: 12642271

12 **Kim S-H, Yoo JC, Wang JH, et al.**: Arthroscopic sliding knot: how many additional half-hitches are really needed?. *Arthroscopy*. 2:405-411 2005

13 **Elkousy HA, Sekiya JK, Stabile KJ, et al.**: A biomechanical comparison of arthroscopic sliding and sliding-locking knots. *Arthroscopy*. 21:204-210 2005 PMID: 15689871

14 **Elkousy H, Hammerman SM, Edwards TB, et al.**: The arthroscopic square knot: a biomechanical comparison with open and arthroscopic knots. *Arthroscopy*. 22:736-741 2006 PMID: 16843809