

# **AANA Knot Tying Lab Instructions**



**START HERE**

## **Knot Tying Exercises with Each Knot**

- ❶ Use the rope first, tie to hook and then to rubber tubing. Pull apart to check knot.
- ❷ Repeat #1 using fishing line.
- ❸ Tie knot through a cannula using fishing line and knot pusher.

# 10 Golden Rules (Prior to Tying Any Arthroscopic Knot)

## First Understand Nomenclature

- a. ***Post Limb***- The limb farthest from the center of the glenoid- (the dark spot) the limb you slide loops down.
- b. ***Loop Limb***- Used to place loops around the “***Post Limb***”

1. Slide suture back and forth through an anchor (or tissue). Confirm ability of suture to slide. This dictates the type of knot you use (sliding or non-sliding).
2. Place single hole knot pusher and hemostat on the “***initial post limb***” (hold in your left hand)
3. Slide knot pusher down the “***initial post limb***” into the joint before tying (to rule out twists & tangles)
4. “***Initial post limb***” (short limb) should be less than  $\frac{1}{2}$  as long as the “***loop limb***” (long limb)
5. Hold both limbs between thumb & middle finger of left hand to start the knot
6. Index finger is used to organize loops on “***post limb***”
7. All sliding knots are reinforced with Harryman  $\frac{1}{2}$  hitches
8. Cannulas
  - a. Transparent to observe sutures
  - b. Only tie through a cannula
  - c. Only 1 pair of sutures in working cannula at a time
9. Push all knot loops “straight down” the cannula- to reduce friction
10. Learn to “flip” posts and practice, practice, practice!

## To “Flip” a Post

1. The “*initial post limb*” is held under tension and a ½ hitch is placed around it using the “*loop limb*”
2. Relax tension on the “*post limb*”
3. Apply tension on the “*loop limb*”
4. You will feel a “snap or pop”. At that moment – the “*loop limb*” has become the “*post limb*”. Whichever limb you put tension on will become the new “*post limb*”.
5. You can “flip” outside or inside the joint
6. Leave the hemostat and knot pusher on the “*initial post limb*”.
7. Do not shift the instruments to the new post after you flip
8. When you flip posts, the ½ hitch on the “*initial post limb*” changes from “under” to “over” or (“over” to “under” whichever you use).
9. “Flipping” is much more efficient and time saving but it requires remembering which is the post limb and the previous type of hitch (over or under). This will allow you to complete the Harryman ½ hitches properly.

## **Suture Management**

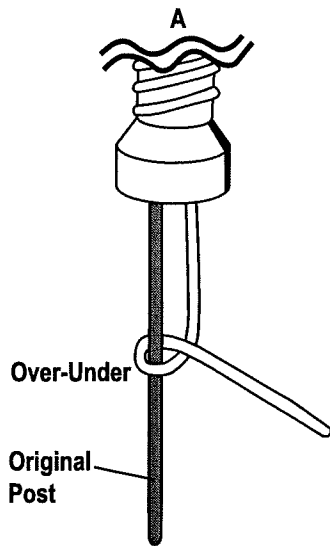
1. First you must have good exposure.
2. Remove excess bursal and synovial tissue.
3. Control bleeding (B.P. ↓ systolic 90-100 mm Hg - if possible based on patient's condition).

### **When doing a Rotator Cuff Repair:**

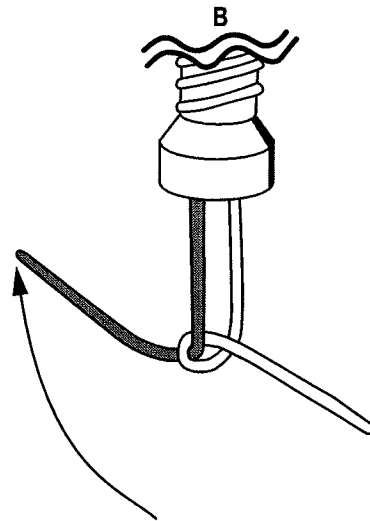
1. Use small separate stab wounds (3mm) for each anchor. Leave sutures in each stab wound until they are used. This separates sutures and identifies them. (Burkhart)
2. After you put an "anchor post" through the cuff tissue, then tie and cut this particular anchor's sutures immediately.
3. If you decide to place multiple stitches first, and then tie them all later, you should identify the sutures as you place them.
4. For identification
  - a. You may use color coded sutures (you can also color code a suture with a marking pen)
  - b. Or use "suture savers" (Linvatec) (colored plastic tubes) (Snyder)
  - c. Consider tying sutures in order (front to back, or back to front)
  - d. You can place two posts of a stitch out different cannulas and identify the corresponding posts with a hemostat on each end. (E.g. straight, curved, short, long, etc.)
  - e. You can move multiple sutures that you placed in one cannula and reposition them outside the cannula using the same port.
    - i. Place a switching stick through the cannula
    - ii. Remove the cannula
    - iii. Replace the cannula over the switching stick and remove switching stick.
    - iv. You now have an empty cannula with all sutures outside the cannula through the same portal.
    - v. Return one pair of posts (at a time) to the cannula with a suture retriever. Tie and cut.
5. When tying, have only one pair of posts in a cannula

**Before Tying Any Given Suture Quickly Review "10 Golden Rules"**

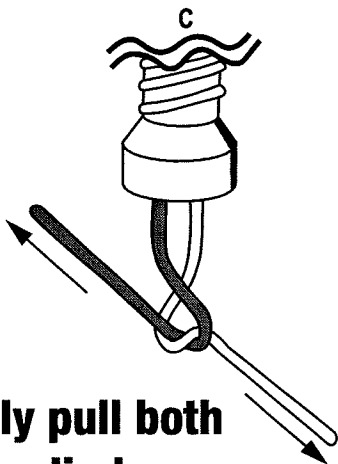
## Switching Posts (Flipping) (Burkhart & Chan)



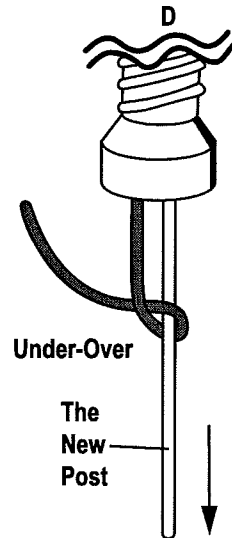
**Over-under Half-hitch**



**Raise post limb up ahead of Half-hitch**



**Gently pull both suture limbs**



**Pull down axially to complete switching of post**

# AANA Knot Tying Lab Instructions

**START HERE**

## Knot Tying Exercises with Each Knot

- 1 Use the rope first, tie to hook and then to rubber tubing. Pull apart to check knot.
- 2 Repeat #1 using fishing line.
- 3 Tie knot through a cannula using fishing line and knot pusher.

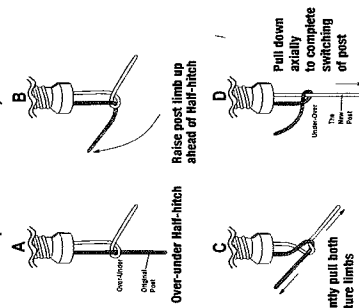
### Ten Golden Rules (Prior to Tying Any Arthroscopic Knot)

1. **First Understand Nomenclature**
  - a. **Post-Limb** – The limb farthest from the center of the glenoid – (the dark spot) the limb around which you make a loop.
  - b. **Loop-Limb** – Used to place loops around the **Post Limb**.
2. Slide suture back & forth through an anchor (or tissue). Confirm ability of suture to slide. This dictates the type of knot you use (sliding or non-sliding).
3. Place single hole knot pusher and hemostat on the **Initial post limb** (hold in your left hand). Slide knot pusher down the **Initial post limb** into the joint before tying (to rule out twists and tangles).
4. **Initial post limb** (short limb) should be less than  $\frac{1}{2}$  as long as the **loop limb** (long limb).
5. Hold both limbs between thumb & middle finger of left hand to start the knot (e.g. Duncan Loop).
6. Index finger is used to organize loops on **post limb**.
7. All sliding knots are reinforced with Harryman  $\frac{1}{2}$  hitches.
8. **Cannulas**
  - a. Transparent to observe sutures
  - b. Only tie through a cannula
  - c. Only 1 pair of sutures in working cannula at a time
9. Push all knot loops "straight down" the cannula – to reduce friction.
10. Learn to "flip posts," and practice, practice, practice!

### To "Flip" a Post

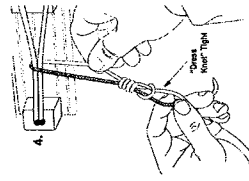
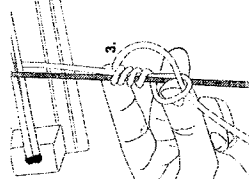
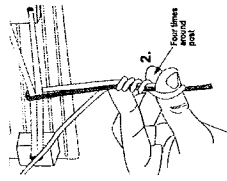
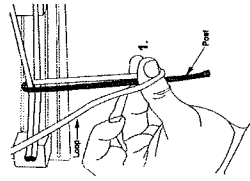
- 1 The **Initial post limb** is held under tension and a  $\frac{1}{2}$  hitch is placed around it using the **loop limb**.
- 2 Relax tension on the **post limb**.
- 3 Apply tension on the **loop limb**.
- 4 You will feel a "snap or pop." At that moment – the **loop limb** has become the **post limb**. Whichever limb you put tension on will become the new **post limb**.
- 5 You can "flip" outside or inside the joint.
- 6 Leave the hemostat and knot pusher on the **initial post limb**.
- 7 Do **not** shift the instruments to the new post after you flip.
- 8 When you flip posts, the  $\frac{1}{2}$  hitch on the **Initial post limb** changes from "under" to "over" (or "over" to "under" whichever you use.) "Flipping" is much more efficient and time saving but requires remembering which is the **post limb** and the previous type of hitch (over or under). This will allow you to complete the Harryman  $\frac{1}{2}$  hitches properly.

### Switching Posts (Flipping) (Burkhardt & Chan)



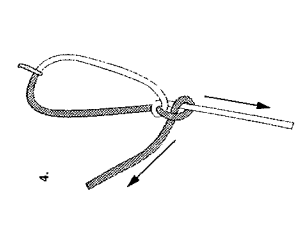
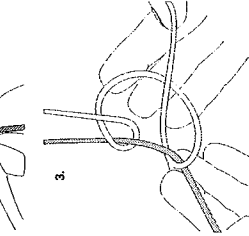
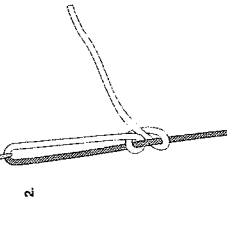
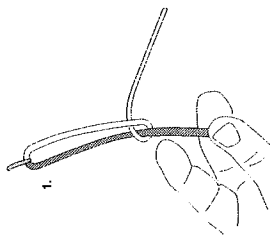
## Sliding Knots

### Duncan Loop Slip Knot

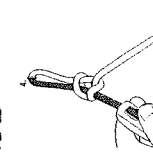
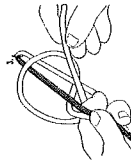
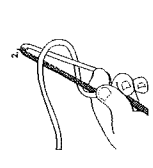
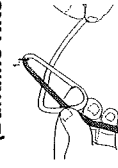


## Sliding Locking Knots

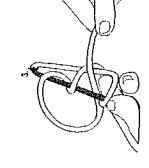
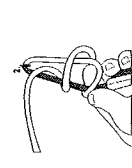
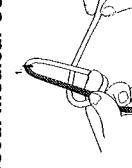
### Simple Slider Knot



### Tennessee Slider (Buntline Hitch)

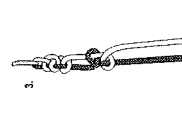
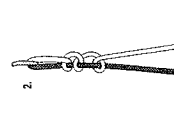
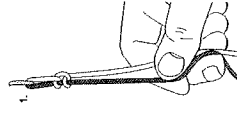


### SMC- Seoul Medical Center



## Non-Sliding Knots

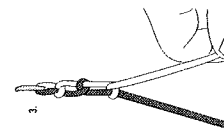
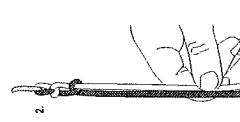
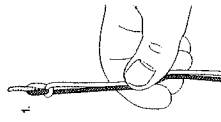
### SCOI Knot



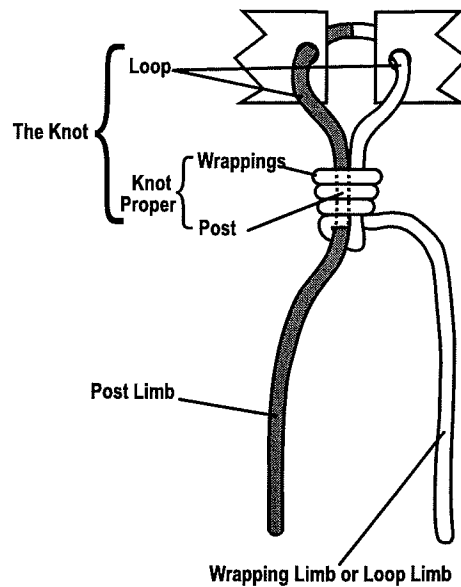
### Square Knot (Not Used in Arthroscopy)

### Harryman Half-Hitches

RHAP – Reverse Half-Hitches on Alternating Posts (100% stronger)  
Apply on Top of all Sliding Knots

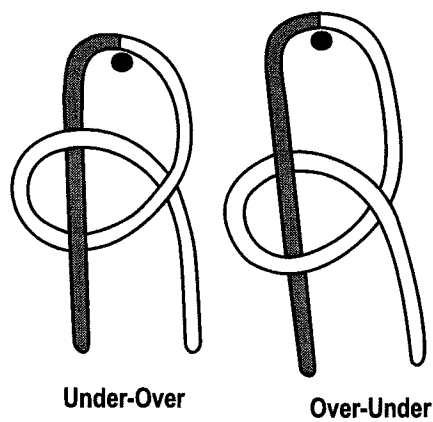


## **Definitions– Generic Sliding Knot**



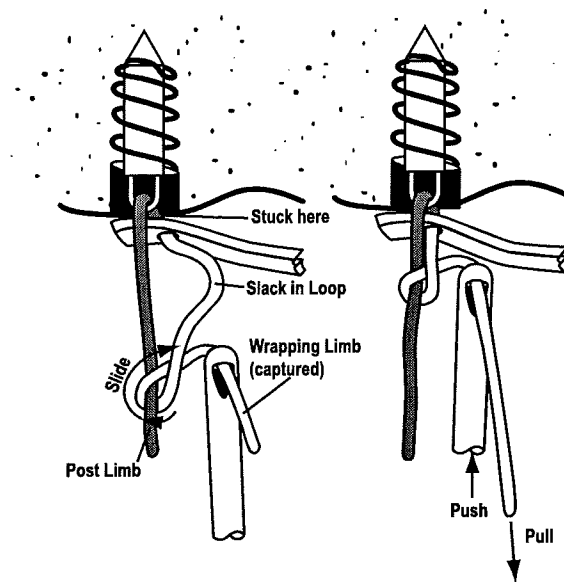
---

## **Types of Half-Hitches**

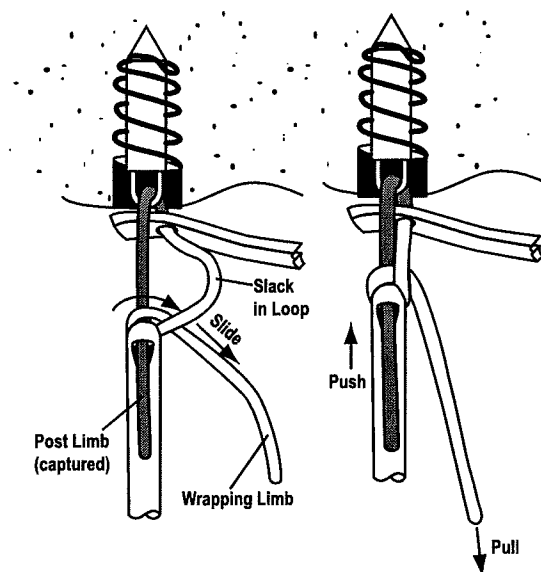


## (Advancing Half-Hitches)

### For Sliding Knots Past Pointing

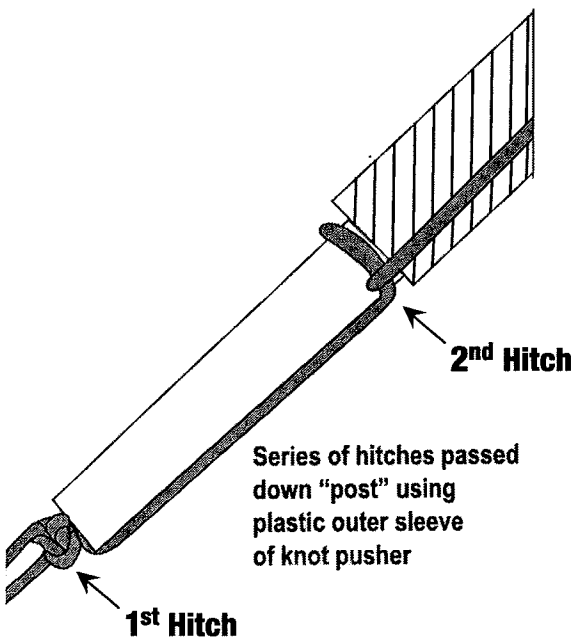
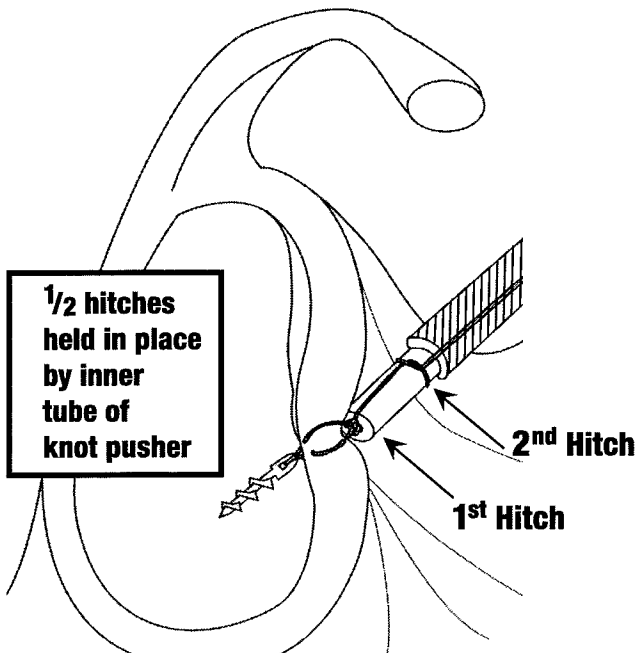
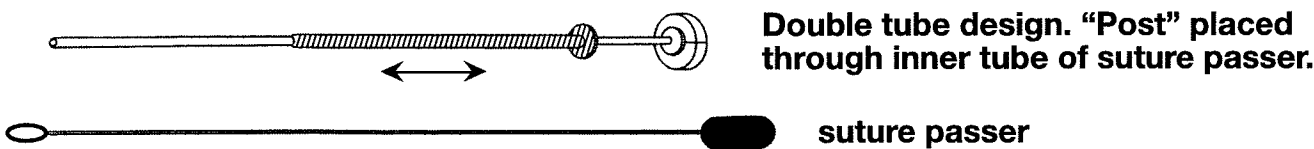


### For Fixed or Sliding Knots Push Down Post



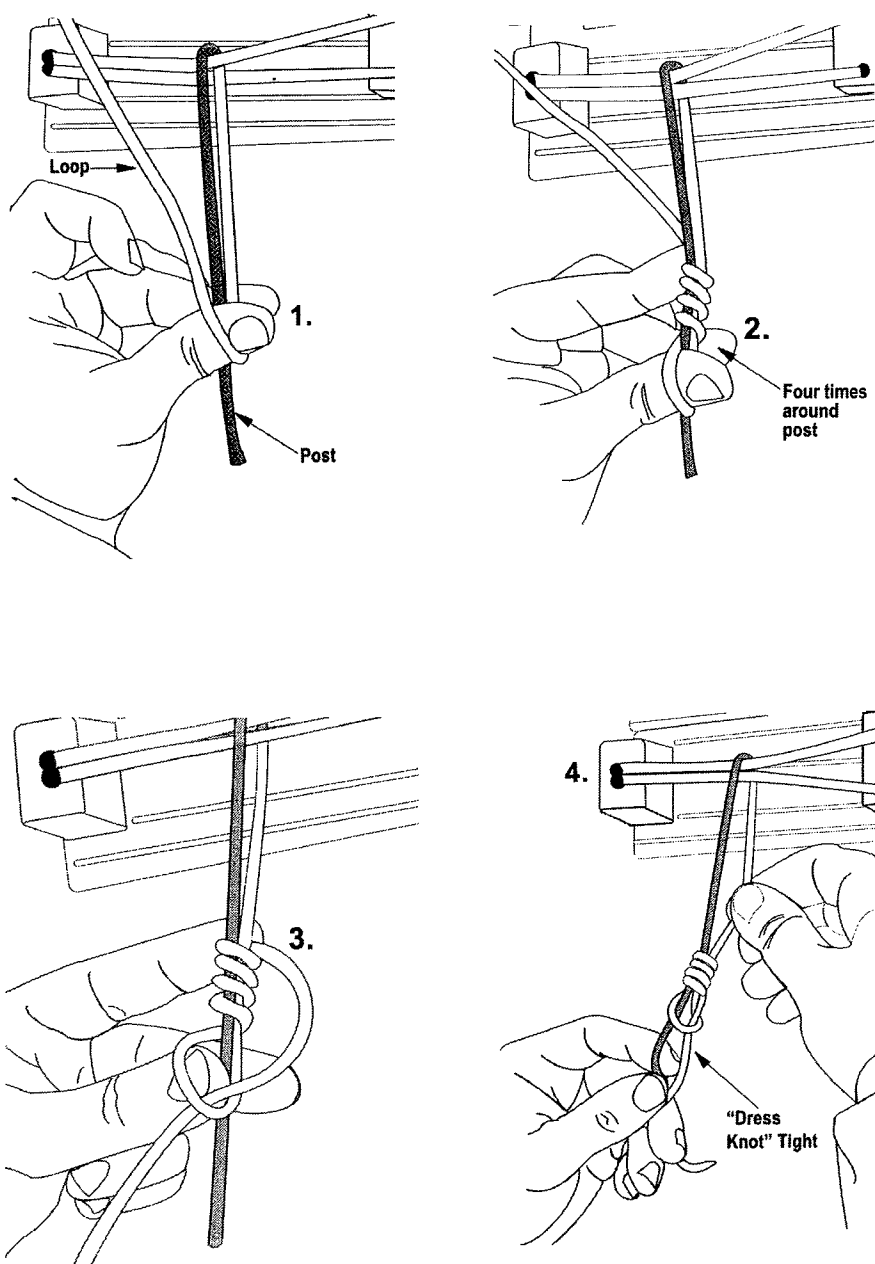


# Sixth Finger Knot Pusher



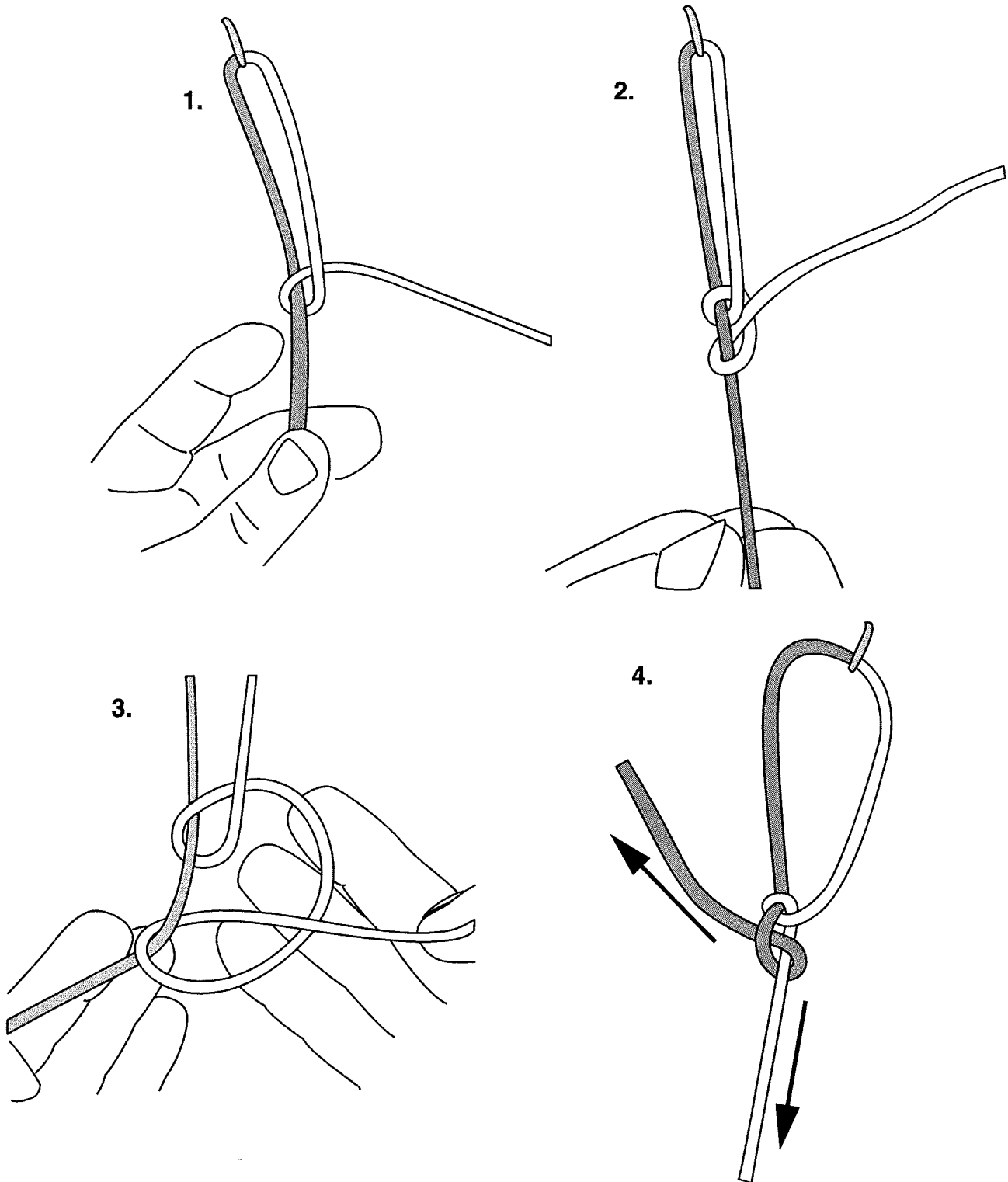
# Sliding Knots

## Duncan Loop Slip Knot



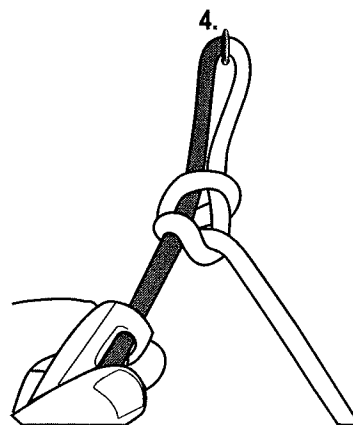
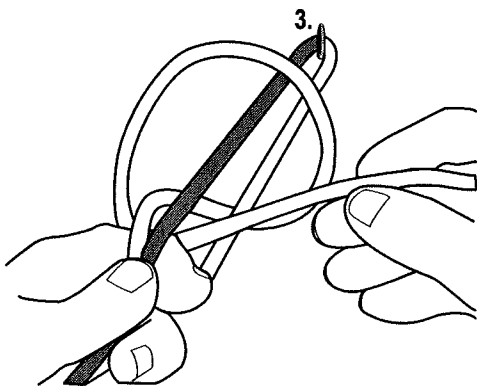
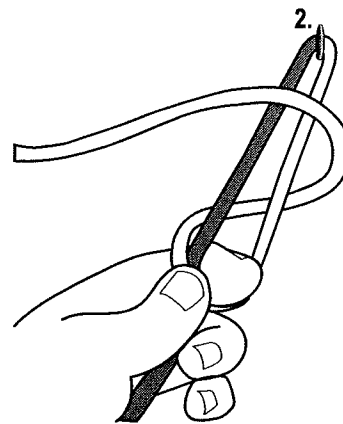
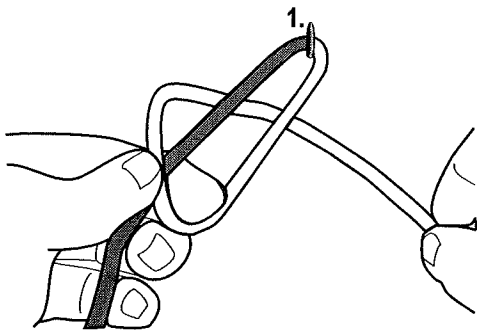
## Sliding Locking Knots

# Simple Slider Knot



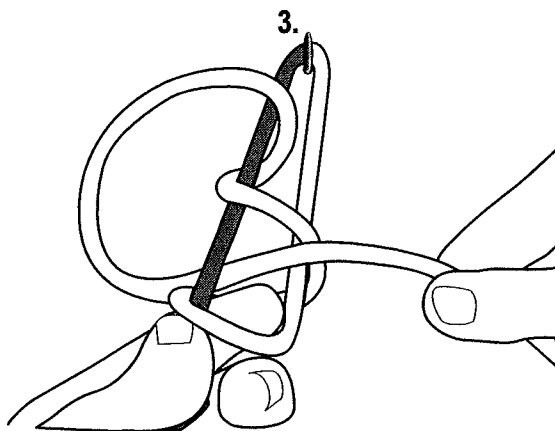
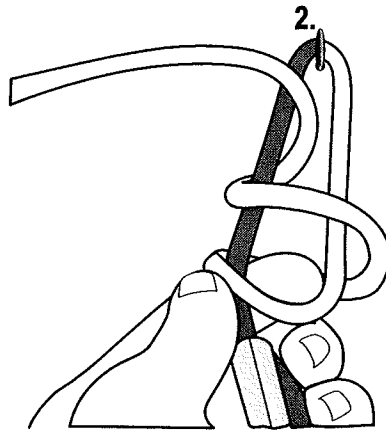
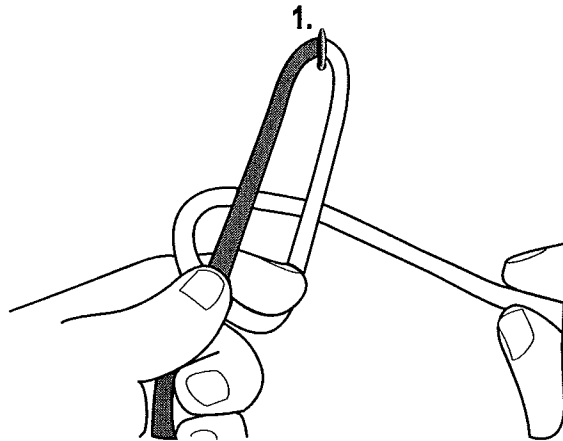
## Sliding Locking Knots

# Tennessee Slider (Buntline Hitch)



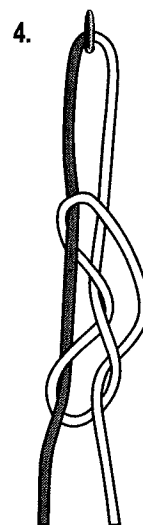
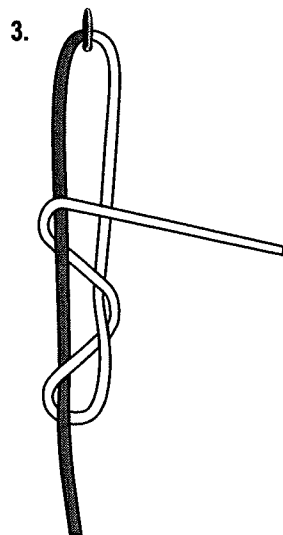
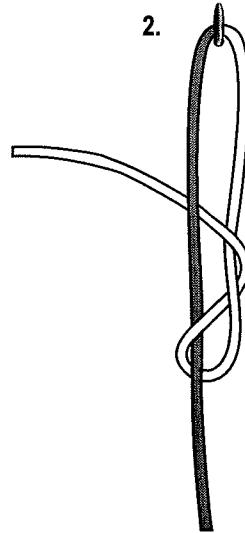
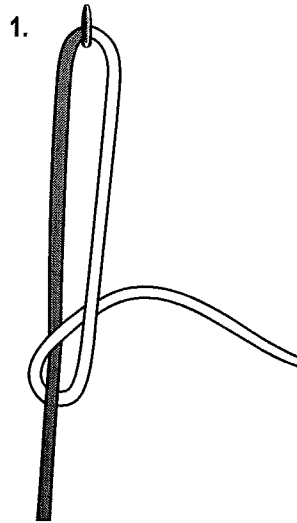
**Sliding Locking Knots**

**SMC–  
Seoul Medical Center**



## **Sliding Locking Knots**

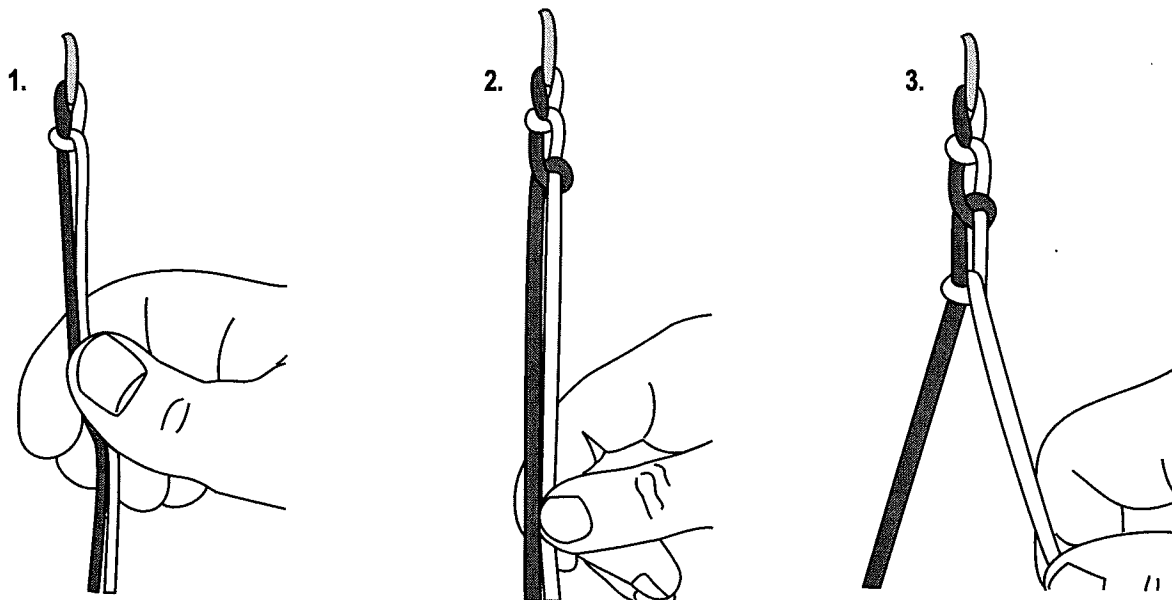
### **Weston Knot**



# **Harryman Half-Hitches**

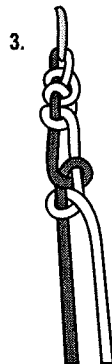
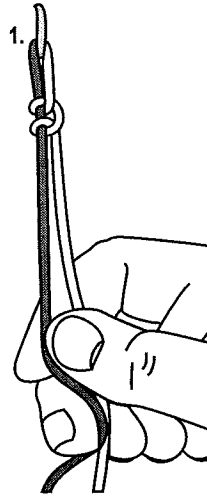
**RHAP-  
Reverse Half-Hitches  
on Alternating Posts  
(100% stronger)**

**Apply on Top of  
all Sliding Knots**



# **Non-Sliding Knots**

## **SCOI Knot**





# **Square Knot (Not Used in Arthroscopy)**

## Arthroscopic Knot Tying

Eric McMillan, MD

### I. INTRODUCTION

#### A. Development

most important historical advance: devices for suture passing and retrieval within joints

initially, knots used in open procedures were tried – not well-suited

slip knots tried for ease of tying and good tension, other knots subsequently added to prevent slipping

devices devised to eliminate need for knot tying – limited application

recently, "locking" slip knots: passed as slip knots then configuration changed once seated to convert to non-sliding configuration – can be tricky

#### B. Indications

a need to secure a suture repair intraarticularly and the technical expertise to tie a secure arthroscopic knot

knot-substitute devices are useful as adjuncts, not substitutes for the ability to tie arthroscopic knots<sup>9</sup>

### II. SURGICAL PRINCIPLES

a significant part of tying knots arthroscopically is appropriate suture management<sup>7</sup> – critically important to understand the path of the sutures

most published information describes configuration of knots and ignores suture management – like debating most efficient way to pack money into duffel bag and overlooking issue of how you're going to get into the bank vault to get the money

### III. SURGICAL TECHNIQUE

some terms

- "limb" – free end of any given suture
- "post" – the limb the loops are being thrown around
- "non-post" – limb not currently acting as post

## A. Preparation for Knot Tying

foundation of learning to tie knots arthroscopically is practice

- short segment of cord
- suture material
- knot pusher
- cannula
- knot-tying board (commercially available or makeshift)

learning in a controlled environment far more productive than on-the-job "training" (ie. experimentation) –  
AANA courses will get you up and running ([www.aana.org](http://www.aana.org))

prior to tying in operating room, ensure necessary equipment is available (Table I)

Table I – Arthroscopic Knot-Tying Equipment

<u>Quantity</u>	<u>Description</u>	<u>Notes</u>
1 or more	water-tight cannula(s)	transparent cannulas helpful <sup>7,9</sup>
1	suture retriever	suture grasper (Linvatec, Arthrex, others) crochet hook (Linvatec, Arthrex, others)
1 or more	knot pusher(s) suture	(see discussion in text) 27" for single or double-hole pusher 36" for modified one-hole pusher

### Which Knot Pusher is Best?

depends on what you're doing

#### checking for suture twisting

two-hole knot pusher is definitely most reliable and easy to use<sup>8</sup>

no way for a suture twist to hide in the cannula when a two-hole knot pusher is used  
twists can occasionally remain undetected with a single-hole pusher

#### tying sliding knots

single-hole knot pusher (Linvatec, Arthrex, and others) is most commonly used and least complicated

- easy passage of knots through cannulas and
- easy application of tension to seated knots (past-pointing)

#### modified one-hole knot pusher (Surgeon's 6<sup>th</sup> Finger, Arthrex)

- bulkier than standard one-hole pusher
- requires use of longer suture
- per-use patient charge since it is disposable
- can slow the inexperienced user
- proponents cite greater "loop security" by virtue of ability to maintain tension in initial knot loop while subsequent throws placed<sup>3</sup>

tying non-sliding knots

modified one-hole pusher is the only good option since it is the only device that can hold tension on initial knot loop while subsequent throws are placed

## B. Selecting the Right Arthroscopic Knot

basic objectives of tying an arthroscopic knot

- provide good tissue loop tension to approximate the desired tissues<sup>3,9</sup>
- maintain this tension as the tissues are loaded postoperatively<sup>9</sup>

ideal knot accomplishes this with the smallest bulk and greatest ease of tying

Sliding vs. Non-Sliding

sliding knots inherently provide better tissue loop tension, and are therefore preferred

Non-Locking vs. Locking

two fundamentally different approaches to prevention of loosening

- throwing additional loops on top of a sliding knot
- changing the sliding knot into a non-sliding knot after it is seated

throwing additional loops on a sliding knot is very effective<sup>6</sup>

- easy to accomplish and very reproducible – as a result, Duncan Loop backed by alternating-post half-hitches has become workhorse of arthroscopic knots
- securing other sliding knots with additional suture throws has been described<sup>11</sup> and been shown to be effective as well<sup>9</sup>

locking sliding knot

- configuration selectively changed by applying tension to suture limbs in the appropriate sequence
- problem is, the knot can be inadvertently locked at any point in the tying process
- can be unforgiving in practice

for the average arthroscopist, best knot to learn is probably Duncan Loop backed by alternating post half-hitches

## C. Suture Management For Arthroscopic Knot Tying

Tips And Tricks: General

eliminate distractions<sup>1,7</sup>

get a good view of the knot tying field<sup>1,7,9,13</sup>

always check for twisting of the sutures limbs prior to tying<sup>5,7</sup> (Fig. 1) – a knot tied on twisted sutures will inevitably untwist after tying, loosening the tissue loop

**IT IS A MISTAKE TO TRY TO TIE A SLIDING KNOT WITH A SUTURE THAT DOES NOT SLIDE FREELY<sup>5,7</sup>**

always have a backup plan<sup>5,7,13</sup>

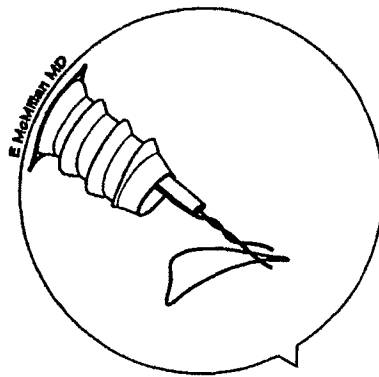


Figure 1 – Knot pusher advanced to knot, revealing twisting.

#### Tips And Tricks: Portals/Cannulas

critical that both sutures limbs being tied exit the joint through the same passage with no soft-tissue bridge – drawing limbs through a cannula prior to tying ensures this<sup>7</sup>

keep the tip of the cannula close to the area where knot is to be seated to minimize soft tissue entanglement during seating<sup>8</sup>

the less soft tissue the knot passes by, the sooner you get home

use a third portal when tying knots arthroscopically<sup>5,7,13</sup>

- allows uninvolved sutures to be passed out of the joint clear of knot tying process (Fig. 2), hence reducing likelihood of uninvolved sutures becoming entangled with knot
- easier to retrieve sutures from a third portal than from around cannula in tying portal<sup>10</sup> (Figs. 3,4)

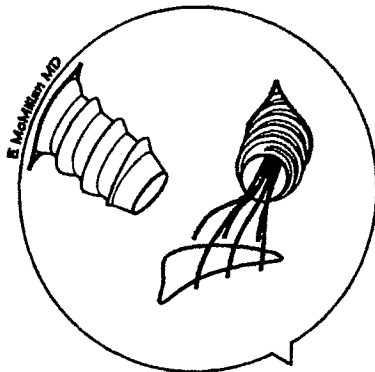


Figure 2 – Uninvolved sutures passing out of accessory cannula, clear of the knot-tying process.

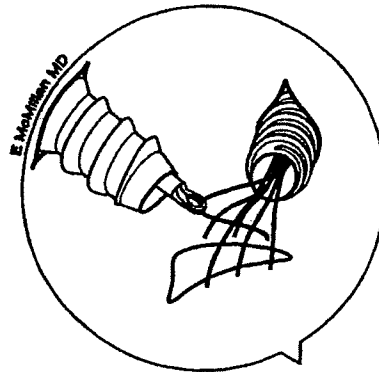


Figure 3 – Suture being easily retrieved from accessory cannula.

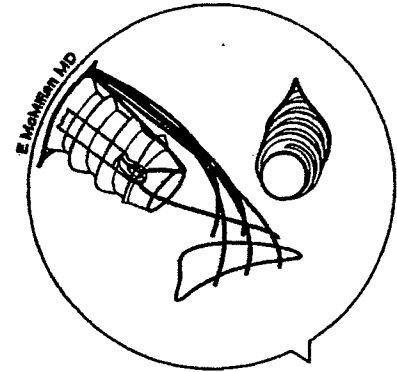


Figure 4 – Suture binding at edge of cannula during retrieval when placed through tying portal adjacent to cannula.

classify the suture limbs into two categories such as "left" and "right", "anterior" and "posterior", or similar to understand the sutures' path

- limbs drawn out of the tying cannula without twisting and laid to appropriate side of cannula
- once limbs separated, assistant or scrub nurse places finger between limbs on top of the cannula<sup>7</sup> (Fig. 5)
- allows surgeon to manipulate the suture limbs while still maintaining original orientation of the sutures within the cannula – prevents suture twisting and provides a clear understanding of which suture limb is which when tightening knot

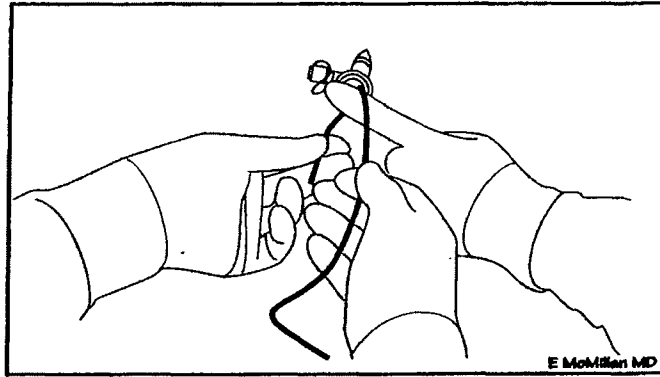


Figure 5 – Assistant's finger placed between exiting suture limbs.

may also tag the post limb with a small hemostat to help remember which limb is currently the post

#### Tips And Tricks: The Anchor

minimize suture friction from anchor

- align anchor to minimize suture twist as suture exits anchor<sup>4</sup> (Fig. 6)
- avoid over-penetrating the anchor to reduce friction between edge of the anchor hole and the suture

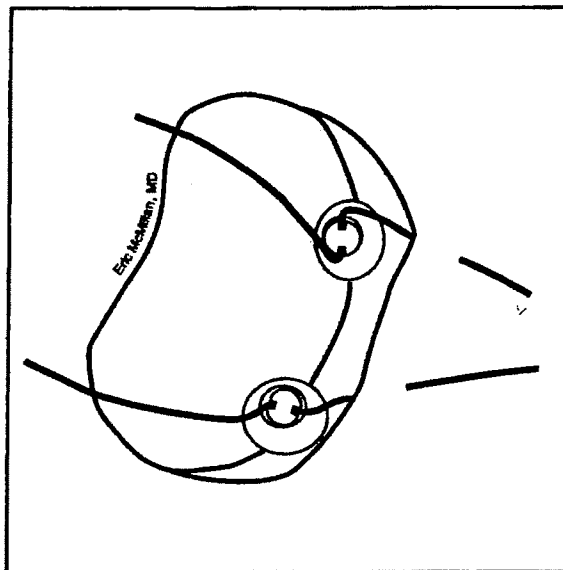


Figure 6 – Top anchor has been placed such that suture must twist just to pass through desired tissue. Bottom anchor shows proper orientation to allow suture to slide freely.

**Tips And Tricks: The Suture**  
**braided or monofilament?**

**handling characteristics**

monofilament sutures generally easier to pass using currently-available suturing instruments  
braided sutures easier to tie and tend to loosen less than monofilament

**initial strength**

non-dissolving braided sutures such as Ethibond (Ethicon) tend to have higher initial failure strength than monofilament dissolving sutures such as PDS II (Ethicon)

**changes in strength over time (Table II)**

Table II – Suture Strength as a Function of Time <sup>9</sup>				
<u>suture</u>	<u>dissolve/non-dissolve</u>	<u>mono/braided</u>	<u>time</u>	<u>% retained strength</u>
Monocryl	dissolving	monofilament	3 wks	0
PDS II	dissolving	monofilament	3 wks	80%
			6 wks	40%
Maxon	dissolving	monofilament	3 wks	67%
			6 wks	9%
Vicryl	dissolving	braided	3 wks	<10%
Panacryl	dissolving	braided	3 wks	95%
			6 wks	90%
			12 wks	80%
Ethibond	non-dissolving	braided	3 wks	100%
			6 wks	100%

(Monocryl, PDS II, Vicryl, Panacryl, and Ethibond are products of Ethicon, Inc)  
(Maxon is a product of the United States Surgical Corporation)

would seem prudent to use either Panacryl or Ethibond where suture was expected to be under greater tension (eg. rotator cuff repair under tension) and suture of surgeon's choice otherwise

**Getting Your Limbs Adjusted**

with sliding knots, a disparity in the length of the limbs can result after the knot is seated if the limbs are not adjusted properly prior to tying

- can make it very difficult to continue the knot tying process
- in extreme cases can leave only one very long suture limb protruding from the cannula

for a sliding knot, leave non-post limb protruding about half overall suture length farther than post limb from the cannula – provides limbs of roughly equal length once initial sliding knot is seated<sup>7</sup> (fig. 7)

for non-sliding knots, post and non-post limbs should be about equal

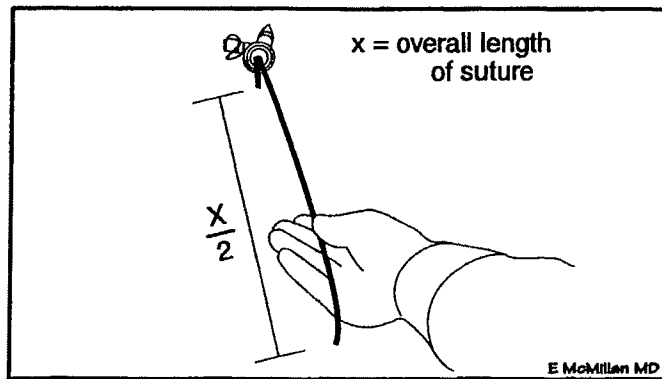


Figure 7 – Non-post limb adjusted so it extends about half of overall suture length farther than post limb from cannula.

#### Tips & Tricks: The Knot Pusher

determining the appropriate suture limb for the knot pusher

sliding knots

- knot pusher placed on the post limb only when seating the initial knot – “pushed” into place, keeping tension on the post to fully seat the knot and prevent loosening once seated
- subsequently, pusher placed on the non-post limb to “pull” additional throws down

non-sliding knots

- knot pusher placed onto the non-post limb for all throws

choosing the limb that will act as the post

choose the limb that passes through tissue in the most out-of-the-way location<sup>4,10</sup> – this will tuck the knot out of the way and minimize the chance of knot interference with joint function

advancing knots with the knot pusher

to pass knots easier

- alternate tension on the two limbs of suture in your hands<sup>5,7,8</sup> (be careful with this technique on the second throw of a sliding knot – pulling on the non-post limb will usually loosen the initial suture loop)
- advance the pusher directly toward the knot – relieves tension on the post limb and allows for easier passage<sup>7,8</sup> (Figs. 8, 9)

seat each knot fully under arthroscopic visualization prior to passing subsequent throws<sup>5,7,12</sup> – knot pusher can be inadvertently passed through the knot within the cannula and can lock with subsequent throws in the cannula

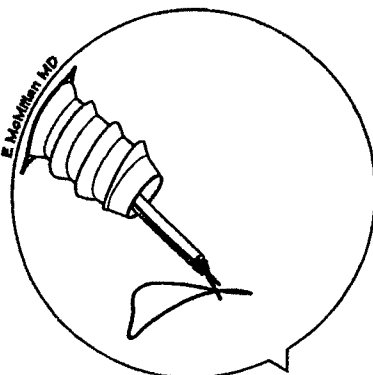


Figure 8 – Knot pusher advanced directly toward knot.

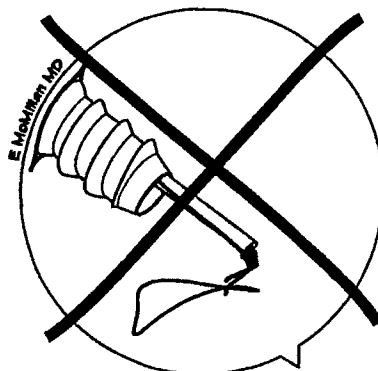


Figure 9 – Knot pusher advanced obliquely, pulling suture.



Once a throw is seated, the knot pusher should be used to “past-point” to gain additional tightness within the knot<sup>1,5,7,8,12</sup> (Fig. 10)

#### Getting Something For (Almost) Nothing

hold the two suture limbs slightly separated between the left thumb and middle finger – this leaves the left index finger free to help pass the non-post limb as it is thrown around the post (Fig. 11)

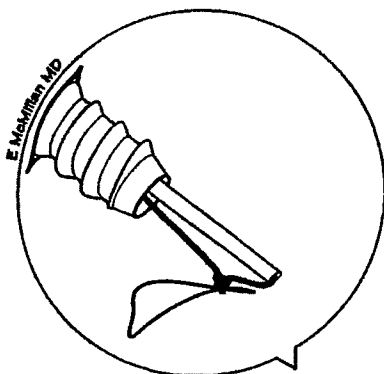


Figure 10 – Past-pointing with the knot pusher to tighten the knot.

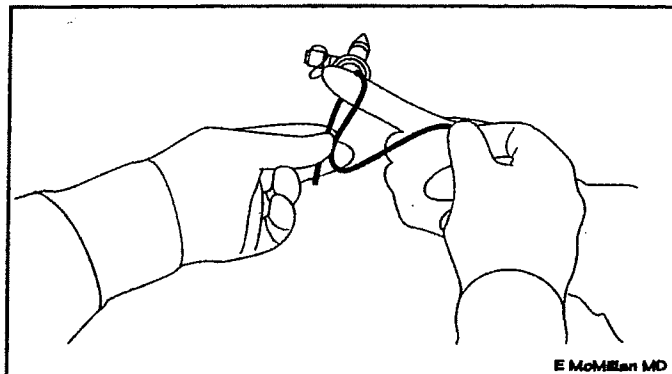


Figure 11 – Suture being held between left thumb and middle finger, leaving the index finger free to help with knot tying.

## REFERENCES

1. Abrams JS. Principles of arthroscopic stabilization. Presented at the 16<sup>th</sup> Fall Course, Arthroscopy Association of North America, Nashville, Tennessee, 1997.
2. Ashley CW. Hitches to spar and rail (right-angle pull). In: *The ashley book of knots*. New York: Doubleday, 1944;296.
3. Burkhart SS, Wirth MA, Simonick M, Salem D, Lanctot D, Athanasiou K. Loop security as a determinant of tissue fixation security. *Arthroscopy* 1998;14:773-776.
4. De Beer JF. Arthroscopic bankart repair: some aspects of suture and knot management. *Arthroscopy* 1999;15:660-662.
5. Fischer SP. Tying good knots arthroscopically. Presented at the Specialty Day Meeting, Arthroscopy Association of North America, San Francisco, California, 1997.
6. Loutzenheiser TD, Harryman DT II, Yung SW, France MP, Sidles JA. Optimizing arthroscopic knots. *Arthroscopy* 1995;11:199-206.
7. McMillan ER. A simplified technique for suture handling during arthroscopic knot tying. *The "Masters Experience" Knot Tying Manual*. Rosemont, IL: Arthroscopy Association of North America, 1999.
8. Nottage WM. Arthroscopic knot tying. Presented at the 15<sup>th</sup> Fall Course, Arthroscopy Association of North America, Palm Desert, California, 1996.
9. Nottage WM. Suture, anchors, and knots. Presented at the 18<sup>th</sup> Annual Meeting, Arthroscopy Association of North America, Vancouver, BC, Canada, April, 1999.
10. Nottage WM, Lieurance RK. Arthroscopic knot tying techniques. *Arthroscopy* 1999;15:515-521.
11. Snyder SJ. Technique of arthroscopic rotator cuff repair using implantable 4mm Revo™ suture anchors, suture shuttle relays and #2 non-absorbable mattress sutures. Presented at the 18<sup>th</sup> Annual Meeting, Arthroscopy Association of North America, Vancouver, BC, Canada, April, 1999.
12. Sweeney HJ. Knot tying. Presented at the 17<sup>th</sup> Fall Course, Arthroscopy Association of North America, Palm Desert, California, November, 1998.
13. Tauro JC. Arthroscopic rotator cuff repair: Analysis of technique and results at 2- and 3-year follow-up. *Arthroscopy* 1998;14:45-51.

*In memory of Dick Caspari, who inspired me to make the most of myself and enjoy life as I go.*

# ***“Make Sense Out of Suture Management and Knot Tying in Arthroscopic Shoulder Surgery”***

**Scott P. Fischer, M.D**

For the Arthroscopy Association of North America

## **I) SUTURE CONSIDERATIONS:**

Choices in suture consist of either braided or monofilament construction. *Braided suture* may tend to “lay down” more nicely as the knot is tied, however the suture can fray with excessive handling causing the suture to weaken. The new “super sutures” are more resistant to this problem than the older polyester sutures. *Monofilament suture* tends to slide through tissue more readily, however, it can be more difficult to tie knots tightly and they may slip more readily. The strength of both suture types (size #1 & #2) should exceed knot failure loads.

## **II) INTRAARTICULAR ACCESS FOR SUTURE DELIVERY:**

Because of *portal placement limitations*, there may be limited access to inferior and superior glenoid anchor insertion sites. There can be difficulty with suture passage or anchor insertion from standard portals because the angle of approach may be too oblique.

**TIPS:** 1) Use *accessory portals*.

Inferiorly- anterior inferior & posterior inferior portals -E. Wolf M.D.  
-anterior-inferior 5 o'clock (trans-subscapularis) portal  
-P. Davidson and J. Tibone M.D.

Superiorly- anterior & posterior para-acromial portals  
-trans-supraspinatus tendon portal (small punctures)

2) Use standard portals and “*sling*” the *capsulo-labral tissue* to more easily placed anchors. To accomplish this, place a suture through the soft tissue to be repaired back to bone at the desired repair site. Next place an anchor at the closest easily accessible glenoid site. Then, as you tie the suture, the soft tissue should be pulled up to and slung over the glenoid rim as desired.

## **III) SUTURE PASSING (AND ANCHOR INSERTION) TECHNIQUES:**

*Option 1)* Insert the anchor (and suture) into bone first, then pass the suture through the soft tissue. This technique can be used with both screw-in and push-in type anchors.

**TIP:** Avoid allowing twists in the suture between the bone and the soft tissue being repaired, if this occurs the twisted suture will prevent

proper knot tightening and will be interposed between the tissue and the repair site's bony surface.

*Option 2)* Pass a suture (without an anchor loaded onto it) through the soft tissue first, then insert the anchor into bone second. This technique is only possible with push-in type anchors. To employ this sequence, you will need to slide the anchor down the suture strand into the joint and then insert it into the bone.

**TIP:** You must slide the anchor down the "inside limb" of suture (that suture limb closest to the repair site) or there will be more difficult suture sliding and soft tissue "inversion" at the repair site.

*Option 3)* Pass the anchor (loaded with suture) through soft tissue and into bone, then pull one limb of the suture back out of the soft tissue. This technique is probably best done with smaller profile anchors to minimize the size of the hole created by the passage of the anchor through the soft tissue.

**TIPS:** 1) Hold the soft tissue in a reduced position with a traction suture or a soft tissue clamp while passing the anchor through the tissue and into bone.

2) Beware of anchors with a profile which may easily become caught in the soft tissue, damage the tendon or disengage from the inserter.

#### IV) CAPSULAR & LABRAL REPAIR CONSIDERATIONS:

A) Optimal restoration of labral anatomy is achieved when labral tissue is pulled back up to it's anatomic attachment site on the glenoid rim. If the ***capsulolabral reattachment site*** is placed onto the medial glenoid neck, normal anatomy is not restored. For suture capsulorrhaphy, we prefer to pass the suture through the labrum directly at the bony attachment of the labrum. When using suture anchors, we prefer anchor placement to be on the articular surface of the glenoid, 1-2 millimeters "central" to the glenoid rim so the most lateral margin of the anchor drill hole does not "breakout" onto the anterior neck of the glenoid. Attempting anchor placement directly onto the edge of the glenoid rim often results in the drill hole's most peripheral margin being somewhat medial to the rim's edge with resulting medialization of the repair.

**TIPS:** (for glenoid anchor placement)

1) Obtain direct visualization of glenoid rim and anterior glenoid neck by using a viewing portal on same side of the joint as the anchor is to be inserted; or if viewing from the opposite side of joint, use a "high" (superior and a bit more medial) viewing portal to see down the glenoid rim better. If this does not give an adequate view, consider using a 70 degree arthroscope.

2) Use a **drill guide** to seat the drill where you desire and to prevent the tip from "wandering" as you drill. When using *drill guides with multiple teeth* at their tip, seat the guide on the glenoid rim with more than 50% of teeth onto the articular surface. When using models with a

*fish mouth tip*, take care not to rock the handle of the guide towards the humerus or the drill can slip off the glenoid rim and down the anterior glenoid neck. Using a *slotted guide* is nice because you can see the drill tip as it approaches the glenoid surface and visualize the point of contact with the glenoid.

3) If using a drill guide is not feasible, make a “starting point” with a small ball tip burr or with an awl, then spin the drill prior to setting it down onto the rim to drill the hole.

- B) When multiple sutures and anchors are used in a repair, regardless of which technique above is selected, place and tie only one suture at a time.

**TIP:** *Placing and tying only one suture at a time* avoids the entanglement of multiple suture strands which often occurs when tying knots with multiple sutures present in the joint at the same time.

#### V) SALVAGE OF SUTURE & ANCHOR COMPLICATIONS:

- A) Suture breakage.

**TIPS:**

- 1) Screw-in type anchors – Use a retriever to remove the anchor, then reload it with a new suture or use a new “over-sized” anchor and reinsert it into the bone.
- 2) Push-in type anchors – Attempt to seat a second anchor into the same hole “on top” of the initial anchor. If this is not possible, then drill a new hole at an alternative site.
- 3) Plastic or bioresorbing anchors – Drill out the initial anchor and insert another device into the hole.

- B) Anchor pull out from bone.

**TIPS:**

- 1) Insert a larger device into the same hole and rigorously check for repeat pull out failure.
- 2) Insert the same device at an alternative insertion site if available.
- 3) If neither option is available, open the shoulder and suture through a trans-osseous bone tunnel.

- C) Loose and ineffective knot.

**TIPS:**

- 1) Attempt to tease the knot apart with a nerve hook or suture clamp.
- 2) Cut the suture out and redo this part of the repair (probably the smartest alternative).
- 3) Attempt to slide the knot down to the tissue by “forcing it” (the worst that can happen is the suture will break... and it probably will!)

- D) Anchor becomes disengaged from the inserter after it is passed through the soft tissue.

**TIP:** Grasp the anchor from an accessory portal. Once it is securely under control, then release it from its inserter and withdraw it through an accessory portal cannula.

- E) The anchor becomes loose within the glenohumeral joint. – Good luck...

**TIPS:**

- 1) Relax and take a deep breath.
- 2) Minimize fluid flow through the joint to decrease the likelihood that the anchor will move about within the joint.
- 3) Check the “favorite hiding places” for loose bodies in the glenohumeral joint (the subscapularis recess and the inferior pouch).
- 4) Call for x ray!

**REFERENCES:**

- Barber FA, Herbert MA, Click JN. The ultimate strength of suture anchors. *Arthroscopy* 1995; 11:21-28.
- Barber FA, Herbert MA, Click JN. Suture anchor strength revisited. *Arthroscopy* 1996; 12:32-38.
- Burkhart SS. The deadman theory of suture anchors: observations along a south Texas fence line. *Arthroscopy* 1995; 11:119-123.
- Davidson PA, Tibone JE. Anterior-inferior (5 o'clock) portal for shoulder arthroscopy. *Arthroscopy* 1995; 11:519-525.
- Saitoh S, Nakatsuchi Y, Lata L, Milne E. Distribution of bone mineral density and bone strength of the proximal humerus. *J Shoulder Elbow Surg* 1994; 3:234-242.
- Wolf EM, Wilk RM, Richmond JC. Arthroscopic Bankart Repair using suture anchors. *Oper Tech Orthop* 1991; 1:184-191.

## How To Make Sense Out of Arthroscopic Knot-Tying

**I) KNOT TYING DEFINITIONS:**

- A) *Post* (or Suture Post)- the suture strand held under tension and around which a loop is tied or wrapped with the other suture strand.
- B) *Wrapping Suture*- the suture which is wrapped around the post to tie a knot.
- C) *Half-Hitch Loop*- a half-hitch knot tied around a post suture, wrapping initially either over or under the post.
- D) *Sliding Knot*- a knot which is tied around the post outside of the joint and then pushed into position within the joint, the suture slides through the tissue as the knot is tightened.

- E) *Lockable Sliding Knot*- a sliding knot in which the post is distorted by pulling on the wrapping limb prior to the placement of locking half-hitches. This produces increased internal friction and resistance to knot slippage (Taut-line hitch, Tennessee slider, Roeder, Weston) [see reference #10].
- F) *Non-Sliding Knot*- a knot which is tied/ constructed inside the joint as half-hitch loops are pushed/ pulled down into the joint to the tissue repair site, the suture does not slide through the tissue as the knot is tightened. Examples include the Revo knot, Alternating half-hitch, square knot, and others.
- G) *Past Pointing*- the action of tightening a half-hitch loop by pushing the tip of the knot pusher past the knot being tied within the joint, followed by tensioning both suture limbs simultaneously to maximally tension the knot.
- H) *Alternating Posts*- the process of alternating the function of "Suture Post" between suture strands as successive loops of the knot are tied.
- I) *Reversed Half-Hitches*- the process of tying successive half-hitch loops in opposite directions, i.e.: overhand loop followed by an underhand loop.

## II) EQUIPMENT:

### A) Knot Pushers

1. These come in a variety of configurations and are used to either push or pull knots into the joint. These most commonly are one of three styles: (1) standard single hole, (2) cannulated double-diameter (also referred to as a "sixth finger" type), (3) standard two hole.
2. Knot pushers may be used to push or pull a half-hitch loop down into the joint and onto the knot being tied. The knot is then tightened either by (a) alternately tensioning the two suture "limbs" or by (b) *past pointing*. This is an alternative method favored by the author in which one "pushes past" the half-hitch loop with a single hole knot pusher and then tightens the knot by simultaneous and symmetric tension in both suture limbs.

## III) REASONS FOR KNOT FAILURE:

### A) **The knot is tied too loose initially.** Reasons include:

- i. *Failure to fully seat the knot onto the tissue at the repair site*; reasons this can occur:
  - Poor visualization of repair site leads the surgeon to mistakenly believe the knot is well seated when in fact it is loose.
  - The suture or sliding knot catches on tissue which prevents the knot from sliding all the way down to the repair site and therefore is not fully seated.
  - Sutures may twist around each other between the knot and tissue preventing the knot from being fully seated onto the tissue.
- ii. *The knot is tied under tension, and it slips* before it can be secured with half-hitches to lock the knot. This may be prevented by (A) decreasing the tension at the

repair site by approximating the tissue with a clamp or traction suture, (B) by using a cannulated double-diameter knot pusher, or (C) by tying a lockable knot.

**B) The knot slips over time.** Reasons include:

- i. *Internal knot looseness.* Inadequate tightening of successive loops as the knot is being tied results in “loose loops” within the knot. These loose loops may compress under strain at a later time and result in overall knot loosening. Past pointing and refined knot tying skills should help prevent this occurrence.
- ii. *The knot is unable to resist applied strain.* Correct this as follows:
  - Decrease the load on each knot in the repair by increasing the number of sutures (and knots) in the repair. This spreads the same load over more sutures/ knots.
  - Tie “stronger knots” ... (see next heading in outline )

**IV) REGARDING “STRONGER KNOTS”:**

**A) Factors which affect knot holding capacity:**

- i. Suture type- Braided suture may hold knots more securely. Loutzenheiser et al (1998) found that with complex knots, Ethibond suture knots had from 10% to 50% greater holding strength than comparable PDS suture knots. The same study also documented at least 50% less slippage with braided suture knots during cyclic loading when compared to PDS knots.
- ii. Knot pusher- For more “slippery sutures” (such as PDS suture) a cannulated double-diameter knot pusher can hold the initial loop more tightly and tie a tighter knot when compared to a standard single hole knot pusher (Burkhart et al, 1998).
- iii. Complex vs. simple knots- Loutzenheiser et al (1998) found that Complex cinching knots (such as the Duncan loop, Tautline Hitch and Revo knot) were 50% stronger than the simple Overhand throw knot when tied with Ethibond suture.
- iv. Tension applied to successive half-hitch loops- This is an unstudied factor. Intuition suggests that increased tensioning may have a significant effect on knot security by decreasing internal knot looseness.
- v. Reversed half-hitches- Loutzenheiser et al (1995 & 1998) found that reversal of half-hitch loop direction by itself had little significance when using PDS suture (1995) and no significance when using Ethibond suture (1998). This contrasts with findings by Burkhart et al (1998) who found a significant improvement in knot holding strength (equivalent to alternating post technique) when tying reversed half-hitches with a cannulated double-diameter knot pusher (with PDS suture).
- vi. Alternating posts- Loutzenheiser et al (1995 & 1998) found that alternating the post suture by itself provided a significant increase in knot holding strength for both PDS and Ethibond suture. Burkhart et al (#9), when testing the cannulated



double-diameter knot pusher, also found this to be present if using Ethibond suture, but observed no additional improvement for PDS.

- vii. Alternating posts and reversed half-hitches combined- Loutzenheiser et al (1995 & 1998) and Burkhart et al (#9) found improved knot holding strength for PDS suture (compared to a knot which only alternated posts) if they used a standard single hole knot pusher. Burkhart et al (#9) found no additional improvement for PDS tied with a cannulated double-diameter knot pusher. Neither group of investigators found significant improvement, above that of only alternating the post, when using Ethibond suture.

B) How much knot holding strength is enough for:

- i. *Cyclic loads* (repetitive low strain loads)- The magnitude and frequency of repeated physiological loading that repairs must withstand is not known. However, prior research (Burkhart et al, 1997) suggests that cyclic loading is more likely to produce failure at the suture-tendon interface than knot failure, so this may not be an important consideration.
- ii. *Sudden muscle contraction*- Burkhart et al (#9) calculate that in an average complete tear of the rotator crescent, a maximal muscle contraction may apply a 60 N load to each suture in the repair (if sutures are spaced one centimeter apart). If twice the number of sutures are used (i.e.: use anchors loaded with two sutures) the load per suture is reduced to approximately 37 N.
  - a. for a 60 N load, the alternating post knots using Ethibond suture (as studied by Loutzenheiser -1998) are sufficiently strong. With PDS (Loutzenheiser 1995) the Duncan loop had sufficient strength but the Overhand loop did not.
  - b. for a 37 N load, most simple knots are sufficient to hold except the knots tied with no loop reversal nor post switching (Burkhart et al 1998).

V) CONCLUSIONS/RECOMMENDATIONS:

- A) Fully seat each loop of your knot down to the tissue being repaired.
- B) If a knot or loop tends to slip backwards after tensioning, relieve the tension in the repair, use a cannulated double-diameter knot pusher, or tie a lockable knot.
- C) Tie knots with sufficient loop tension to remove all internal knot looseness.
- D) Using two sutures per suture anchor will reduce the strain applied to each knot in your repair.
- E) When using PDS suture, the cannulated double-diameter knot pusher may produce a more secure knot than a standard single hole knot pusher.
- F) When using Ethibond suture, resistance to cyclic loading and single pull loading is improved, compared to PDS. Maximum knot strength is accomplished by alternating posts.
- G) The use of complex knots will increase the holding strength of your repair.

H) Do not tie knots with all loops in the same direction around the same post.

### REFERENCES:

1. Burkhart SS, Diaz-Pagan JL, Wirth MA, Athanasiou KA. Cyclic loading of anchor based rotator cuff repairs: Confirmation of the tension overload phenomenon and comparison of suture anchor fixation with transosseous fixation. *Arthroscopy* 1997; 13:720-724.
2. Gunderson PE. The half-hitch knot: A rational alternative to the square knot. *Am J Surg* 1987; 154:538-540.
3. Loutzenheiser TD, Harryman FT II, Yung SW, France MP, Sidles JA. Optimizing arthroscopic knots. *Arthroscopy* 1995; 11: 199-206.
4. Loutzenheiser TD, Harryman DT II, Ziegler DW, Yung SW. Optimizing Arthroscopic knots using braided or monofilament suture. *Arthroscopy* 1998; 14: 57-65.
5. Shimi SM, Lirici M, Vander Velpen G, Cuschieri A. Comparative study of the holding strength of slipknots using absorbable and nonabsorbable ligature materials. *Surg Endoscopy* 1994, 8:1285-1291.
6. Trimbos JB. Security of various knots commonly used in surgical practice. *Obstet Gynecol* 1984; 64: 274-280.
7. Trimbos JB, Van Rijssel EJC, Klopper PJ. Performance of sliding knots in Monofilament suture material. *Obstet Gynecol* 1986; 68:425-430.
8. Burkhart SS, Wirth MA, Simonick M, Salem D, Lanctot D, Athanasiou KA. Loop security as a determinant of tissue fixation security. *Arthroscopy* 1998; 14: 773-776.
9. Burkhart SS, Wirth MA, Simonick M, Salem D, Lanctot D, Athanasiou KA. Knot security and its relationship to rotator cuff repair: How secure must the knot be? *In submission*.
10. Chan KC. Classification of sliding knots for use in arthroscopic surgery. *Presentation at 18<sup>th</sup> Annual Meeting of the Arthroscopy Association of North America, Vancouver, BC, Canada; April 18, 1999.*

## TECHNIQUES OF ARTHROSCOPIC KNOT TYING

### **I) THINGS TO CONSIDER BEFORE "TYING THE KNOT"**

#### **KNOT PUSHERS:**

- knot pushers are commonly used to push a half-hitch loop down to the knot and then tightened by alternately tensioning the two suture "limbs".
- an alternative means (favored by the author) is to "push past" the half-hitch loop with the knot pusher and then tighten the knot by simultaneous and symmetric tension in both suture limbs (this is called *past pointing*).

## TYPES OF KNOTS:

### Sliding Knots (two different types):

#### 1) Non-locking

-Duncan loop



-Overhand loop



#### 2) Lockable sliding knots

-Tautline hitch



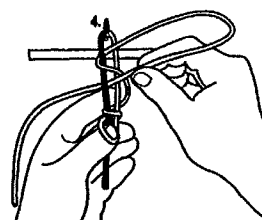
- Modified Tennessee Slider



-SMC Knot



- Roeder Knot



#### Comments:

- It is easier to repair tissue under tension with these knots.
- To utilize these knots, the suture must be able to slide freely through tissue and anchor.
- These knots must be "locked" with additional half-hitches to prevent slippage.
- Lockable knots should also be reinforced with half-hitches for greater security.

#### Nonsliding knots-

-Alternating Half-Hitches



- This knot may be used by itself or to lock a previously placed sliding knot. If used by itself, additional locking half-hitches are required to secure this knot.

-Revo Knot



- This is a good, low profile, and secure knot. It is an excellent choice if the suture doesn't slide.

-Square knot



-This knot is difficult to tie arthroscopically and can be unreliable if improperly tied.

### III) HOW TO TIE THE KNOTS:

DUNCAN LOOP (non-locking sliding knot):



- 1) Slide the suture so the post limb is quite "short" and the wrapping strand is "long". (The "post" is the suture strand further from the center of the joint).
- 2) Hold both sutures between the thumb and long finger. Wrap the long suture over your thumb (creating a loop), and continue by wrapping it over and around both sutures four times. Pass the free end of the wrapping suture through the loop made by your thumb.
- 3) Remove the excess slack from the knot by first tensioning the free end of the wrapping suture; then tension the end of the suture passing from the loop toward the joint.
- 4) Place the knot pusher on the post and advance the Duncan loop into the joint by pushing it down the suture while pulling back on the post. Slide the knot under direct visualization until the tissue and the loop are tight.
- 5) Maintain tension on the post while wrapping a half-hitch loop around it, then push this loop down and tighten it to lock the knot in place.
- 6) Place 2 additional reversing half-hitches on alternating posts to secure the knot.

TAUTLINE HITCH (lockable sliding knot):



- 1) Slide the suture until the post limb is quite "short" and the wrapping strand is quite "long".
- 2) Pass the wrapping suture over the post (this creates a loop) and continue around the post twice, passing the suture through the inside of the loop both times. Wrap the suture over and around the post a third time, but pass it outside and proximal to the loop this time (proximal being closer to you, not closer to the patient). As you make this third wrap, pass the free end of the wrapping suture up through the loop created as the suture was wrapped over the post outside the original loop.
- 3) Take the excess slack out of the knot by first tensioning the free end of the wrapping suture (taking care not to over-tension it and "lock" the knot), then tension the end of the suture passing from the knot toward the joint.

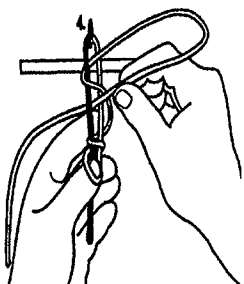
- 4) Place the knot pusher on the post and advance the knot by pushing it down the post while pulling back on the post. Slide the knot under direct visualization until the tissue and the loop are tight.
- 5) Maintain tension on the post while also tensioning the wrapping strand to deform the post and lock the knot in place.
- 6) Place 3 additional reversing half-hitches on alternating posts to secure the knot.

#### MODIFIED TENNESSEEE SLIDER/ BUNTLINE HITCH (lockable sliding knot):



- 1) Slide the suture until the post limb is quite "short" and the wrapping strand quite "long".
- 2) Pass the wrapping suture over the post (this creates a loop) and continue around the post, passing the suture proximal to and outside the loop (proximal being closer to you, not closer to the patient). Wrap the suture over and around the post a second time, but pass it distal to the first wrap and through the loop this time. As you make this second wrap, pass the free end of the wrapping suture up between the wrapping suture and the post.
- 3) Take the excess slack out of the knot by first tensioning the free end of the wrapping suture (taking care not to over-tension it and "lock" the knot), then tension the end of the suture passing from the knot toward the joint.
- 4) Place the knot pusher on the post and advance the knot by pushing it down the post while pulling back on the post. Slide the knot under direct visualization until the tissue and the loop are tight.
- 5) Maintain tension on the post while also tensioning the wrapping strand to deform the post and lock the knot in place.
- 6) Place 3 additional reversing half-hitches on alternating posts to secure the knot.

#### ROEDER KNOT:



- 1) Slide the suture so the post limb is quite "short" and the wrapping strand is "long".
- 2) Hold both sutures between the thumb and long finger. Wrap the long suture over your thumb, and continue by wrapping it around both sutures two times.
- 3) Continue by passing the free end of the wrapping suture around the post suture strand and up between the two suture strands.
- 4) Bring the end of the wrapping strand back over itself (over the top of the last "wrap" made by the wrapping strand as it passed around both sutures) and pass it back down between the two sutures (between the "first" and "second" initial "wraps" made in step 2).

- 5) Remove the excess slack from the knot by first tensioning the free end of the wrapping suture; then tension the end of the suture passing from the loop toward the joint.
- 6) Place the knot pusher on the post and advance the Roeder knot into the joint by pushing it down the suture while pulling back on the post.
- 7) Slide the knot under direct visualization until the tissue and the loop are tight.
- 8) Maintain tension on the post while pulling back on the wrapping strand to "lock" the Roeder knot.
- 9) Place 3 additional reversing half-hitches on alternating posts to secure the knot.

#### ALTERNATING HALF-HITCHES:



- 1) Wrap a half-hitch loop over the post. Push it down into the joint and seat it securely.
- 2) Tension the post, securing the loop in place and remove the knot pusher.
- 3) Transfer the knot pusher to the other suture strand which will become the new post for the next half-hitch loop.
- 4) Wrap a half-hitch loop under the post. Push it down into the joint; tension and seat it securely.
- 5) Continue reversing the half-hitches and alternating the posts as needed.

#### REVO KNOT:



- 1) Wrap a half-hitch loop over the post; push it down to the tissue and tension it to secure the tissue in place.
- 2) Wrap a second identical half-hitch loop; push it down on top of the first loop and tension it to secure the first loop.
- 3) Wrap a third half-hitch loop in the reverse direction around the post (while maintaining tension on the post); push it down to the knot and tension it.
- 4) Withdraw the knot pusher and change it to the opposite suture limb (now the new post)
- 5) Wrap a half-hitch loop over the new post, push it down to the knot and then push the knot pusher past the knot and tension the loop to tighten and secure it in place.
- 6) Withdraw the knot pusher and change it to the opposite suture limb (the original post).
- 5) Wrap a reverse direction half-hitch loop around this post, push it down to the knot and tighten it as before to complete the Revo knot

### SQUARE KNOT:



- 1) Wrap an overhand loop around the post.
- 2) Place the knot pusher on the "loop limb" of the suture (not the post).
- 3) Pull the loop down into the joint and remove the slack in this suture strand.
- 4) Push the end of the knot pusher "beyond" the repair site, and tension the loop (this is called past pointing).
- 5) Inspect the loop to ensure that it lies as an overhand loop and not as a half-hitch loop. (If it is a half-hitch, you may need to wind the knot pusher 180 or 360 degrees around the post until the loop lies as an overhand loop; play with this in the lab and you'll see what I mean).
- 6) Remove the knot pusher, place an underhand loop around the post and pull it down into the joint as before with the knot pusher.
- 7) Gently secure this loop on top of the first loop so it won't slip.
- 8) Remove the knot pusher and place it on the post, then pass it down past the knot, check to ensure this loop lays correctly as an underhand loop (not a half-hitch) and then apply symmetric tension to both suture limbs to tighten and secure the square knot.
- 9) Pass additional alternating loops as above to reinforce your knot.

### IV) KNOT TYING TIPS:

- 1) Always slide a knot pusher down the suture, prior to passing any suture loops, to ensure there are no twists or tangles in it.
- 2) Be sure you see each loop fully seated onto your knot. If a half hitch loop is left behind in the cannula, when the next loop is passed they will lock and tighten inside the cannula and you will have a problem.
- 3) Never tie all loops of your knot in the same direction around the same post, this type of knot will slip at minimal strain.
- 4) Place at least 3 locking loops over your knot, more loops increase knot security.
- 5) To avoid tying knots under tension by rotating the shoulder to relax the tissue being repaired: Internal rotation for anterior capsular repair, abduction for supraspinatus repair, etc.
- 6) If shoulder rotation doesn't reduce tissue tension adequately, consider use of a traction suture, or a clamp.
- 7) If you must tie knots under tension, consider using a locking sliding knot or a cannulated double diameter knot pusher.
- 8) If your suture doesn't slide easily through both the tissue and the anchor device, consider using a non-sliding knot.
- 9) Practice tying knots before you go to the operating room.

- 10) Don't rush yourself; snarled and entangled knots or loose knots may result.
- 11) Have a back-up plan if things don't go as well as you'd hoped.