Open and Arthroscopic Proximal Biceps Tenodesis

Source: Operative Techniques in Sports Medicine

Arthroscopic Biceps Tenodesis in the Beach Chair Position
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Arthroscopic Biceps Tenodesis with Interference Screw Fixation:
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Mini Open and Sub Pectoral Biceps Tenodesis
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ARThROSCOPIC BICEPS TENODESIS IN THE BEACH CHAIR POSITION

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Arthroscopic biceps tenodesis is indicated for the treatment of severe biceps tendinopathy, partial or full thickness biceps tendon tears or biceps instability typically associated with rotator cuff tear. Tenodesis is indicated to establish the appropriate length tension to the muscle avoiding scarring and spasm, allow biceps use for complex elbow motion, and avoidance of cosmetic defects where occasionally deformity can sometimes equal disability. This technical note will provide figures, and detailed descriptions of our arthroscopic tenodesis technique using a Arthrex Bio-Tenodesis system (Arthrex Inc, Naples, FL) in the beach chair position.

KEY WORDS: shoulder, upper extremity, proximal biceps tendon, tenodesis technique, anterior shoulder disorder

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Arthroscopic biceps tenodesis is indicated for the treatment of severe biceps tendinopathy, partial or full thickness biceps tendon tears, or biceps instability typically in association with a rotator cuff tear. There are numerous published methods for tenodesis of the long tendon of the biceps.1-7 Most recently the technique that we have used has been an open subpectoral biceps tenodesis. This approach avoids any injury to the deltoid musculature and provides a cosmetic incision at the anterior medial aspect of the arm below the level of the pectoralis major tendon. The integrity of this repair has been excellent based on clinical examination.

Arthroscopic techniques for biceps tenodesis have been developed to reduce soft tissue trauma. Initially, surgeons used single or multiple bone anchors with suture to secure the biceps tendon. This technique requires arthroscopic knot tying skills. Based on an experience with open biceps tenodesis using interference fit screw fixation, an arthroscopic technique has been developed using interference fit screw fixation.2 This technique uses a guide pin with an eyelet, which passes through the bicipital groove anteriorly, and then out the posterior aspect of the humerus. The angle of the guide pin is placed 1 cm below the rotator cuff insertion in the bicipital groove perpendicular to the axis of the humerus to the axillary nerve and therefore avoids potential neurologic injury. However passage of a guide pin through the posterior aspect of the humerus is a concerning technique and may be responsible for more complications in less experienced hands.

Recently a new instrument, a Bio-Tenodesis driver (Arthrex Inc, Naples, FL), has been designed which will allow a surgeon the ability to place the tendon within a bone tunnel and then hold that tendon in place at the base of the bone tunnel while placing an interference fit screw over the top of the tendon (Fig 1). The key feature is a reverse screw mechanism on the distal segment that allows insertion of the interference screw while holding the tendon in the base of the bone socket to prevent the tendon from displacing from the socket. The expansion of this instrument to allow for large tendon fixation has led to the development of an arthroscopic technique for biceps tenodesis using interference fixed screw fixation. In our opinion, this technique can be easily learned and allows for secure fixation of the tendon using an entirely arthroscopic approach.

SURGICAL TECHNIQUE: BEACH CHAIR POSITION

Patient position is dependent on the technique most familiar to the surgeon for subacromial surgery. The beach chair position can be used for all aspects of subacromial surgery, including acromioplasty, rotator cuff

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1060-1872/03/$10.00 © 2003.35935


Operative Techniques in Sports Medicine, Vol 11, No 1 (January), 2003: pp 6-14

Fig 1. The Bio-Tenodesis screwdriver with tendon measuring device on thumb pad. The bioabsorbable screw is loaded.
repair, and distal clavicle resection. The patient is positioned in the beach position with the arm in 30 to 60° of forward flexion, 30° of abduction, and 20° of internal rotation resting on a padded Mayo stand (Fig 2). A standard 30° arthroscope is used for arthroscopic surgery of the shoulder. A pressure-sensing fluid pump is routinely used with a medium level of fluid flow and the pressure setting at 35 to 40 mm Hg. Standard arthroscopic portals are established for glenohumeral joint arthroscopy. Indications for biceps tenodesis include severe bicipital tendinitis as demonstrated by clinical examination preoperatively or with interoperative findings consistent with tendinitis, as well as biceps instability as demonstrated during the arthroscopic examination of the glenohumeral joint. In particular, an injury to the subscapularis tendon requires a thorough evaluation of the biceps stability. Commonly the disruption of the superior lateral edge of the subscapularis from its insertion point on the lesser tuberosity will result in the loss of the normal restraint of the biceps tendon to medial translation (Fig 3). This restraint, which is primarily provided by the coracohumeral ligament and secondarily supported by the superior glenohumeral ligament and subscapularis, origin cannot be effectively reconstructed. In fact, should the surgeon choose to attempt to perform this reconstruction, the consequence typically is postoperative shoulder stiffness with a loss of external rotation. This occurs because of a tightening of the capsular structures including the coracohumeral ligament and superior glenohumeral ligament in this region, as well as a tethering of the biceps tendon that normally has some excursion through the bicipital groove. With the loss of the medial or lateral restraint to the biceps tendon stability, a biceps tenodesis effectively resolves symptoms related to the biceps. This will allow early range of motion and will not result in any consequences to shoulder function.

After the decision is made to perform a biceps tenotomy, an 18 gauge needle is passed from the anterior lateral corner of the acromion through the rotator cuff and into

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**Fig 2.** Beach chair position with the arm in 30° of forward flexion, 30° of abduction and 20° of internal rotation resting on a padded Mayo stand.

**Fig 3.** Biceps instability secondary to subscapularis injury.

**Fig 4.** (A) A no. 1 monofilament suture is passed through an 18 gauge needle that is placed into the biceps tendon itself. (B) An arthroscopic suture instrument is used to retrieve the suture.
the biceps tendon itself. A no. 1 monofilament suture is then passed through the 18 gauge needle, captured with a grabber from the anterior portal and extracted (Fig 4). After the tendon is marked with a suture, an arthroscopic basket is then used to release the tendon from its origin just lateral to the superior labrum (Fig 5). This completes the preparation for the biceps tenodesis during the glenohumeral joint arthroscopy.

The arthroscopic equipment is transferred to the subacromial space. The lateral portal is commonly placed at the midlateral section of the acromion, which positions the cannula at the posterior aspect of the subacromial bursa. This allows an excellent view of the rotator cuff tendon as well as the subacromial space and also prevents abutment of the instrumentation while an acromioplasty is being performed. However, visualization during the arthroscopic biceps tenodesis can sometimes be compromised, and so a modification in the position of the lateral portal is presented. The modified position of the lateral portal is one-third posterior to the anterior-lateral edge of the acromion. A line can be drawn from the notch created by the posterior aspect of the clavicle and the anterior aspect of the scapular spine. This line goes directly lateral over the top of the humerus and marks the posterior aspect of the

Fig 6. A modification of the standard lateral portal can be placed in a more anterior position. The position is in the center of the anterior third of the acromion.

Fig 7. Illustration of the falciform ligament of the pectoralis major muscle. The biceps tendon is consistently found under this structure.
Fig 8. (A) Using an arthroscopic basket, the sheath of the biceps tendon is identified and opened. (B) Electrocautery ablation device used to clean surrounding transverse humeral ligament tissue. (C) Extraction of the tendon close to the pectoralis major insertion allows for easier identification and withdrawal.

Subacromial bursa. Another line can be drawn along the plane of the anterior aspect of the acromion. By splitting the difference between the two lines, the surgeon has achieved a portal placement at one-third posterior to the anterior edge of the acromion (Fig 6). The portal is typically 2 to 3 cm below the palpable edge of the acromion. This portal can assist in arthroscopic acromioplasty, arthroscopic rotator cuff surgery, and distal clavicle resection. The standard lateral portal or the modified portal can both be used for visualization.

While visualization is maintained through the lateral portal, the anterior portal is the "working" portal. An arthroscopic shaver is placed in the anterior portal and all adventitial tissue is removed. Anatomical landmarks as well as the monofilament suture are used for localization of the tendon in the groove. The falciform ligament of the pectoralis tendon is a reproducible landmark. The biceps tendon is directly under this structure (Fig 7). Using an arthroscopic basket, the sheath of the biceps tendon sheath is identified and opened. An electrocautery can be used to clean surrounding tissue, and a probe can be used to free the tendon (Fig 8). The dissection is extended proximally to the lateral aspect of the rotator interval. Care should be taken to avoid proceeding too far medially or otherwise the dissection to expose the biceps tendon from its biceps sheath may lead to a partial displacement of the superficial attachment of the subscapularis tendon.

Two options exist for retrieving the tendon. Option one involves retrieving the monofilament sutures with a cro-

Fig 9. Option One: A crochet hook retrieves the monofilament suture and tendon out the anterior portal.
Fig 10. Option Two: (A) A spinal needle localizes appropriate placement of accessory low anterolateral portal. (B) A hemostat through the anterolateral portal retrieves the monofilament suture and tendon.

chet hook from the anterior portal and extracting the tendon out through that portal (Fig 9). Option two involves localizing the biceps groove with a spinal needle in the anterolateral quadrant of the shoulder. After a satisfactory angle and position is obtained, a portal incision can be made and a hemostat can be used to retrieve the tendon (Fig 10). The amount of excursion of the biceps tendon is relatively small but can be improved by flexing the arm more than 90°. Excessive distention of the soft tissues with fluid may also make the biceps tendon difficult to extract from the surgical wound. If this event occurs, the surgeon can transfer the arthroscope to the anterior portal and use the modified lateral portal as the position to extract the tendon from the surgical wound.

After the tendon is extracted from the anterolateral portal, a hemostat is placed on the tendon at the level of the skin, preventing the tendon from retracting underneath the skin (Fig 11). The placement and tension of the tenodesis is important for anatomic repair. Anatomical dissection has revealed an average intra-articular biceps tendon distance of 35 mm ± 5 mm with the arm adducted to the side. The tenodesis driver has a 17-mm excursion with a 23-mm screw. To approximate the intra-articular distance, 13 mm of tendon is removed and a "whipstitch" is placed.
Fig 12. (A) Length of biceps tendon to be removed ensuring adequate tension of the tendon. (B) A braided suture is placed on the end of the tendon using a tendon stitch technique as described by Krakow. Our preferred suture is a no. 2 Fiberwire (Arthrex Inc., Naples, FL). 36 inches in overall length.

in 17 mm of tendon (Fig 12A). This will allow the tenodesis driver to "bury" the tendon with all of the suture in it to confirm correct placement in the bone tunnel. A braided suture is placed on the end of the tendon using a tendon stitch technique as described by Krakow (tendon "whip-stitch") (Fig 12B). Our preferred suture is a no. 2 Fiberwire (Arthrex Inc., Naples, FL) that is 36 inches in overall length. After this is completed, a square knot is placed at the end of the suture. This allows the suture to maintain its tension during insertion and allows the tenodesis driver ease in directing its placement. The sutures and tendon are allowed to fall back into the subacromial space. Cannulas are placed into the anterior and anterolateral portal if removed and the sutures can be shuttled into the anterior.

Fig 13. (A) Through the anterolateral portal, instrumented with an 8.25-mm clear cannula, a cannulated reamer guide wire (2.4 mm) is inserted into the center of the bicipital groove 10 to 12 mm distal to the insertion of the supraspinatus, lateral to the subscapularis insertion at the end of the transverse humeral ligament. (B) The calibrated reamer is advanced over the guide pin to the 30-mm mark. Care is taken not to violate the second, or posterior, cortex.
portal so they are out of the way for the bone tunnel preparation.

Visualization is established from the lateral portal. The bicipital groove is identified. The soft tissue is gently débrided so that there is easy visualization of the bicipital groove. The lateral edge of the bicipital groove should be avoided since the ascending branch of the anterior circumflex vessel traverses along this edge. Debridement of the sheath and surrounding tissue avoids soft tissue interposition with the placement of the drill, tendon insertion into the bone tunnel, and placement of the interference screw. The groove should be easily visualized before beginning the bone tunnel procedure.

Instrumentation can be performed through an 8.25-mm clear cannula in the anterolateral portal, enhancing visualization and minimizing soft tissue distension. Through this anterolateral portal, a cannulated reamer guide wire (2.4 mm) is inserted into the center of the bicipital groove.

Fig 14. Sutures retrieved from the anterior (A) to anterolateral (AL) portal after bone tunnel preparation.

Fig 15. The Bio-Tenodesis driver and handle are assembled, and the bioabsorbable screw is placed over the distal end of the driver. One limb of the suture is shuttled through the driver, and the other limb is outside of the assembly.
10 to 15 mm below the insertion of the supraspinatus, lateral to the subscapularis insertion, and at the level of the transverse humeral ligament. The depth of insertion is 30 mm. It is unnecessary to drill beyond the posterior cortex of the humerus, which may increase the risk of complications during this surgical procedure. For most patients, an 8-mm cannulated reamer is of adequate size to allow placement of the tendon into the bone tunnel and secure fixation with a 8-mm bioabsorbable interference screw. The tendon diameter can be measured with sizing holes found on the thumb pad of the Bio-Tenodesis driver. The calibrated reamer is advanced over the guide pin to the 30-mm mark. The standard length of the proximal biceps Bio-Tenodesis screw is 23 mm. After the bone socket has been created, the reamer and the guide pin are removed from the anterolateral portal (Fig 13).

The Bio-Tenodesis driver and handle are assembled, and the bioabsorbable screw is placed over the distal end of the driver. Typically, an 8-mm screw is used for an 8-mm bone tunnel. The sutures are then retrieved through the anterolateral portal (Fig 14). Using a wire loop suture passer through the driver, one limb of the suture is pulled through the driver and the screwdriver handle (Fig 15).

The surgeon holds the other limb loosely. The limb that is passed through the driver is then pulled tightly until the end of the tendon is securely placed against the tip of the driver. It is important to have the thumb pad against the driver handle so that it does not interfere with the insertion of the interference screw.

Visualization is through the lateral portal, and the tenodesis driver is placed through the anterolateral cannula. The tip of the driver and the tendon are visualized as they exit the end of the cannula (Fig 16). The tip of the driver is placed at the superior aspect of the bone socket and manually inserted until the tendon reaches the base of the tunnel (Fig 17). The free suture limb inside of the cannulated driver is held tight against the driver with a hemostat. After the driver and tendon have seated to the bottom of the bone socket, the thumb pad is used to hold the tendon and suture against the base of the bone tunnel. The appropriate insertion of the tendon is confirmed by the observation of the suture disappearing into the bone socket. The bioabsorbable interference screw is placed directly over the top of the tendon until the head of the screw is below the level of the prominence of the medial and lateral intertubercular ridges. The head of the screw

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**Fig 16.** External view of the insertion of the tenodesis driver and tendon through the 8.25-mm cannula. It is important to note that the thumb pad must be against the drive handle.

**Fig 17.** (A and B) The tip of the driver is placed at the superior aspect of the bone socket and inserted until the tendon reaches the base of the tunnel.
can be inserted until it is flush with the base of the bicipital groove. After the screw has been properly seated, the driver is removed from the anterolateral portal. A crochet hook is used to remove both limbs of the suture. One that is through the center of the interference screw as well as the other limb which is now captured between the interference fit screw and the bone tunnel. A knot comprised of multiple half hitches is tied over the top of the interference screw using arthroscopic knot tying techniques (Fig 18). The tendon is now secured with two methods. The primary method is the interference screw, with secondary fixation accomplished by tying the suture to the anchor (suture anchor fixation). The subacromial space is irrigated out, thoroughly removing any remaining soft tissue or debris at this time. The arm is rotated from side to side to ensure that there is no prominence from the interference fit screw head and that there have been no complications related to the surgical procedure. The arthroscopic portals are closed with suture.

**POSTOPERATIVE MANAGEMENT**

Postoperative management is typically dictated by the procedures that have been performed in conjunction with the biceps tenodesis. With a rotator cuff repair, passive range of motion of the shoulder is indicated for the first 6 weeks, followed by a gradual progression from active assisted range of motion to active motion. Elbow range of motion and grip strengthening can progress as tolerated without concern for the biceps tenodesis. If the procedure includes only an acromioplasty, then patients begin with passive range of motion but quickly progress to active assisted and active range of motion without concern of the integrity of the biceps tenodesis. Elbow range of motion and grip strengthening are also included. Strengthening exercises are typically held until 6 weeks after the surgical procedure. If the surgical procedure is only a biceps tenodesis, then the postoperative management is the same as it is for an arthroscopic acromioplasty. Any strengthening activities related to elbow flexion or forward elevation of the arm with the elbow extended should be restricted until after 6 weeks following the biceps tenodesis.

**REFERENCES**

The tenon of the long head of biceps brachii is an important stabilizer within the glenohumeral joint. Biceps tendon pathology commonly occurs in the presence of concomitant shoulder disorders, such as subacromial impingement, and rotator cuff tears. Biceps tenodesis is indicated in the case of a partial tear (>50%), an unstable biceps tendon due to an incompetent medial sling, and in the presence of a torn subscapularis. This article will describe our technique of arthroscopic biceps tenodesis with biodegradable interference screw fixation. This technique uses a uniquely designed Bio-Tenodesis screw system (Arthrex Inc., Naples, FL) and is performed with the patient in the lateral decubitus position.

KEY WORDS: arthroscopic biceps tenodesis, biodegradable implants, interference fixation, shoulder, shoulder arthroscopy

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The long head of biceps brachii (LHBB) tendon is an important stabilizer within the glenohumeral joint. Not only is the LHBB an important anterior shoulder stabilizer, but during biceps brachii contraction the LHBB tendon decreases superior and inferior translation of the proximal humerus as well as alleviating some strain within the inferior glenohumeral ligament. Given the importance of the LHBB as a shoulder stabilizer, it is easy to understand how the potential for LHBB injury exists. Such injury to the LHBB may exist in isolation or it may be associated with other pathology, such as rotator cuff tears, or subacromial impingement. Examination of the LHBB during open surgery and arthroscopic surgery has provide a wealth of information in the understanding and the diagnosis of biceps tendon pathology. Disorders of the LHBB range from a simple case of tendinitis to more complex pathology such as LHBB tendon instability (subluxation or dislocation) and tendon rupture (partial or complete). The treatment of the LHBB is essential in ensuring normal shoulder joint biomechanics. An incompetent biceps tendon may have further adverse effects on the shoulder, thus, increasing the risk for further injury. These pathological entities can be treated either with open surgery or by arthroscopy. The technique for an open biceps tendolisis has been previously described in the literature, and is a more commonly performed procedure in dealing with abnormalities of the LHBB. However, given the recent technological advances, there has been a trend toward arthroscopic treatment of all shoulder maladies. Only two arthroscopic techniques have been described in the literature that address the treatment of LHBB pathology: fixation by suture anchors and fixation by interference screw. The purpose of this article is to describe the indications and technique of arthroscopic biceps tenodesis with interference screw fixation with the patient positioned in the lateral decubitus position.

OPERATIVE INDICATIONS

Failure of the conservative treatment of the signs and symptoms of biceps tendinitis may lead to arthroscopic surgery with subsequent glenohumeral arthroscopy and subacromial decompression. However, since LHBB pathology commonly occurs in the presence of other shoulder disorders, shoulder arthroscopy may be performed after the failure of the nonoperative management of these coexisting shoulder disorders. It is during the arthroscopic examination of the glenohumeral joint that LHBB pathology is commonly encountered and diagnosed. Arthroscopy allows the visualization of the LHBB throughout its entire intra-articular course. On thorough examination of the LHBB the arthroscopist is able to assess the presence of tendinitis, tearing, rupturing, and incompetency of the tendon.

The most common indications for arthroscopic biceps tenodesis are: (1) a tear of the tendon involving >50% of its width, (2) an incompetent medial sling that allows medial subluxation of the LHBB, and (3) biceps subluxation in the presence of a torn subscapularis. In these situations, the biceps tenodesis is done to protect the arthroscopically repaired subscapularis tendon. A biceps tenodesis is rarely indicated in the case of a complete tear of the LHBB. Chronic biceps brachii muscle belly cramping associated with activity is one of the most indications for biceps tenodesis in the case of complete LHBB rupture.
Any retraction of the biceps tendon into the arm necessitates an open tenodesis of the LHBB rather than an arthroscopic tenodesis.

Partial ruptures of the tendon and medial incompetency of the biceps sling are commonly cited indications for biceps tenodesis; however, the third indication is less fully understood. Since LHBB pathology commonly occurs in the presence of a torn subscapularis, it is imperative to deal with the tear of this rotator cuff tendon as well as the biceps tendon (Fig 1). The senior author (S.S.B.) has found that two essential problems exist, with significant associated morbidity, if one fails to address both the subscapularis tear and the incompetency of the LHBB. First, an unstable LHBB that is treated merely with reduction of the tendon back into the bicipital groove by means of sutures or suture anchors, without the security of tenodesis, commonly fails as the tendon redislocates, thus, leading to continued LHBB instability. Second, an unstable LHBB may then jeopardize the repair of the subscapularis leading to persistent symptoms secondary to both the biceps tendon and a recurrent disruption of the subscapularis repair. As a result, an arthroscopic biceps tenodesis is performed in conjunction with a subscapularis repair when there is obvious evidence of LHBB subluxation or dislocation.

We do not adhere to a strict age criteria when determining whether an arthroscopic biceps tenodesis is more ap-
The tenotomized biceps tendon is pulled into the 7-mm clear fishbowl cannula (Arthrex Inc., Naples, FL) to assist in delivering the tendon outside of the joint. However, in sedentary patients who are greater than 65 years of age, we often perform tenotomy rather than tenodesis.

TECHNICAL PRINCIPLES

To ensure a successful arthroscopic biceps tenodesis, one must adhere to four essential technical principles. First, it is necessary to obtain and maintain as much LHBB tendon length as possible. Next, traction sutures must be woven securely within the biceps tendon. Also, it is necessary to ensure adequate visualization within the subacromial space by performing a thorough and complete subacromial bursectomy. This may require the use of multiple viewing portals and possibly the use of both the 30° and 70° arthroscopes. Fourth, it is important to ensure secure fixation of the biceps tendon within the bone by using appropriately strong fixation, such as the Bio-Tenodesis screw system (Arthrex Inc., Naples, FL).

Arthroscopic biceps tenodesis is technically more challenging in the presence of an intact rotator cuff. Although the degree of difficulty is elevated in this situation, a successful biceps tenodesis can be ensured with little variation of the techniques and important principles.

TECHNIQUE

Arthroscopic shoulder surgery is routinely done in either the beach chair position or the lateral decubitus position. It is our preference to perform all of our shoulder arthroscopies in the lateral decubitus position (Figs 2 and 3).
The patient is brought to the operating room and placed supine on the operating table. The patient is then intubated under a general anesthetic. Once anesthetized, the patient is positioned on the operating table. The bony prominences are well padded and pillows are placed between the legs. The patient is then placed in a lateral decubitus position with an axillary roll appropriately positioned. The operative shoulder is allowed to sag posteriorly approximately 15° from the vertical perpendicular line. The patient is secured in position with the use of a Vac Pac bean bag (Olympic Medical, Seattle, WA), which is supplemented with tape at the waist and over the legs (one hand-breath distal to the fibular head). Constant suction is maintained on the bean bag throughout the case. With the patient positioned and secured in the lateral decubitus position, a warming blanket is applied to prevent hypothermia. The operative shoulder is then prepped and draped in the usual sterile fashion. The operative arm is then placed in balanced suspension (5 to 10 lbs) in a position of 20 to 30° of abduction and 20° of forward elevation (Star Sleeve Traction System, Arthrex Inc., Naples FL).

With the patient in the lateral decubitus position, the operation is initiated. A standard posterior portal is created, and the arthroscope is inserted into the glenohumeral joint. Pump pressure is maintained at 60 mm Hg throughout the case. At this point, a thorough diagnostic

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Fig 9. The tendon is passed through the Bio-Tenodesis sizing instrument to calculate both the screw diameter and the diameter of the bone socket.

Fig 10. After the subacromial space is débrided, the biceps tendon and the bicipital groove are well visualized.

Fig 11. The 2.4-mm guide wire is inserted into the greater tuberosity 6 mm posterolateral to the bicipital groove.

Fig 12. The cannulated reamer is passed over the guide wire, and the bone socket is reamed to a depth of 25 mm.
arthroscopic examination is performed. An 18 gauge spinal needle is used to ascertain the precise location of the midlateral anterior portal. This portal is created just superior to the lateral half of the subscapularis tendon. With his portal established the biceps tendon, biceps anchor, and the superior labrum are assessed by palpation, peel-back maneuver, and internal/external rotation. The examination of all three of these structures is necessary to ensure competency of the LHBB, as well as to assess degeneration, and tearing of the tendon. Meticulous assessment of the medial sling, the subscapularis tendon, and the posterior rotator cuff needs to be done as disorders involving these structures are commonly associated with biceps tendon pathology. Inspection of the subscapularis and its insertional footprint is best performed with the arthroscope in the posterior portal and with the arm in an abducted and internally rotated position. A 70° arthroscope may be necessary to visualize the entire subscapularis insertion.

Since concomitant disorders exist in the presence of biceps tendon pathology, it is common to treat these entities surgically at the time of biceps tenodesis. In the presence of a torn rotator cuff, the biceps tendon is secured with traction sutures and then tenotomized before the repair of the rotator cuff or subscapularis. Arthroscopic repair of the subscapularis and the rotator cuff precedes the biceps tenodesis. In the rare situations of a superior labrum anterior posterior (SLAP) repair and biceps tenodesis, the tendon is initially tagged and released and the superior labrum is then reassessed. If the superior labrum provides adequate restraint to superior translation, then the SLAP lesion is repaired before the biceps tenodesis.

Having completed the diagnostic arthroscopy, any degenerative changes of the LHBB are débrided. If the rotator cuff is intact, an anterolateral portal is created approximately 2 to 3 cm anterior and lateral to the anterolateral corner of the acromion. Once again, an 18 gauge spinal needle is used to for localizing the position of the portal. This portal placement allows entrance into the joint through the biceps sheath just above, and parallel with the LHBB. With the portal established, a 7 mm clear fish-bowl cannula (Arthrex Inc., Naples, FL) is inserted into the joint. In the presence of a torn rotator cuff, the anterolateral portal is created directly through the rotator cuff tear.

Two traction sutures are placed through the biceps tendon. This is done by percutaneously inserting an 18 gauge spinal needle near the anterolateral corner of the acromion and piercing the biceps tendon approximately 1 to 1.5 cm distal to its superior labral insertion. A no. 2 nylon suture (Ethilon; Ethicon, Somerville, NJ) is then passed through the needle and retrieved through the anterolateral portal. The traction sutures are inserted at different angles and at different locations to minimize the risk of suture pull-out or further damage to the tendon (Fig 4).

A 90° electrocautery probe (ArthroCare; ArthroCare Corp., Sunnyvale, CA) is introduced through the anterolateral portal, and the biceps tendon is then released close to its insertion. During the tenotomy, the traction sutures are held taut to facilitate the release of the tendon. The residual stump of the LHBB is then débrided to a stable margin.

The tendon is then pulled into the cannula by applying traction to the sutures (Fig 5). The cannula and the sutures are pulled out of the joint allowing the tendon to follow. The LHBB exits out through the biceps sheath, through the subacromial space, through the deltoid, and finally through the skin (Fig 6). In most situations there is an adequate length of tendon to be pulled out through the anterolateral portal. If length is in question, then decreasing the tension on the LHBB can increase the exposed tendon length. This is done by placing the shoulder and elbow in flexion (Fig 7). Another means of increasing the length of exposed tendon is by pushing in on the skin and soft tissues. This creates a dimple around the portal which further exposes the biceps tendon. With the tendon now taut and external to the joint, a whipstitch is woven into the tendon using a no. 2 Fiberwire (Arthrex Inc., Naples,
This suturing is initiated approximately 5 mm from the end of the tendon. Also, the suture is passed in such a way that the suture ends will ultimately assist in pushing the tendon to the base of the bone socket by means of the cannulated Bio-Tenodesis screwdriver tip (Fig 8). The bulbous end of the tendon is then debrided and contoured leaving a nicely tapered end. At this point the tendon is then sized using the Bio-Tenodesis sizing instrument (Fig 9).

The arthroscope is now inserted into the subacromial space through the posterior portal and an arthroscopic examination is performed. A standard lateral portal is created 2 to 3 cm lateral to the acromion and in line with the posterior border of the clavicle. A bursectomy is then performed, clearing the anterior and lateral gutters of the subacromial space. This allows visualization of the biceps tendon within the shoulder. Care is taken during the bursectomy not to damage the biceps tendon or its traction suture. To ensure that the tendon and sutures are not inadvertently cut, a constant tension should be held on the suture ends. Use of the lateral, or anterolateral portals, or changing from the 30° to the 70° arthroscope may be necessary in executing this portion of the procedure.

The biceps tendon is identified, and the overlying rotator interval and bicipital groove are debrided exposing the bicipital groove (Fig 10). An open space, free of any unnecessary soft tissue, is necessary to accommodate the cannulated Bio-Tenodesis reamer. The position in which the bone socket will be reamed is then assessed. The location at which the biceps tendon will be fixed is dependent on the coexisting pathologies. In the case of an intact rotator cuff, the bone socket is placed within the proximal portion of the bicipital groove. When the biceps tenodesis is performed in the presence of a massive rotator cuff tear, the bone socket is placed approximately 6 mm posterolateral to the bicipital groove on the greater tuberosity (Fig 11). This placement allows the tenodesis screw and its sutures to be used as an anchor, thus, providing supplemental fixation to rotator cuff repair. The anterolateral portal is usually ideal for performing the biceps tenodesis. However, if the angle of approach to the proximal humerus is wrong then another portal must be created to ensure an acceptable position of the bone socket. A 2.4-mm guide wire is passed through the portal and placed in the desired location of the bone socket. In younger patients, with hard bone, it may be necessary to gently tap the back of the drill with a hammer to alleviate the chance of the guide wire skiving off of the bone. The guide wire is then inserted perpendicular to the surface of the bone into the desired position. The appropriately sized Bio-Tenodesis cannulated reamer is then passed over the guide wire, and the socket is reamed to a depth of 25 mm (Fig 12). The usual diameter of the bone socket is 7 mm for females or 8 mm for males.

Our technique incorporates the use a specifically designed Bio-Tenodesis screw system. A cannulated biodegradable poly-L-lactic acid (PLLA) interference screw is used in association with a uniquely designed screwdriver. Three sizes of the 23-mm long Bio-Tenodesis screws are available for fixation (7, 8, and 9 mm). The desired screw diameter is 1 mm smaller than the reamed hole if the bone quality is good, or the same diameter as the bone socket if...

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**Fig 14.** (A) The tip of the cannulated screw driver is inserted into the bone socket (H). Manipulation of the biceps tendon (BT) is facilitated by holding the whipstitch sutures (W) taut. Turning the handle while holding the thumb piece allows the screw to be advanced, securing the tendon (BT) within the bone socket (H). (B) This process is continued until the Bio-Tenodesis screw is well seated with in the bone socket.
the bone is osteoporotic. The specifically designed cannulated screwdriver employs a reverse-threaded sleeve and a thumb piece on the shaft of the driver. This system allows the biceps tendon to be held securely under tension within the depths of the bone socket by the tip of the driver shaft as the biodegradable interference screw is inserted into place by the hex driver with the reverse-pitched thumb sleeve.

The ends of the suture that was used to whipstitch the tendon are passed through the suture loop at the end of the cannulated screwdriver (an alternative to this is to pass the suture ends directly through the cannulated screwdriver) (Fig 13). As the suture ends are pulled taut, the tendon is advanced to the end of the screwdriver. This allows the tendon end to be manipulated and controlled by the tip of the cannulated screwdriver. The biceps tendon, controlled by the tip of the screwdriver, is inserted into the shoulder through the anterolateral portal and manipulated into the bone socket. While maintaining the tip of the screwdriver and the biceps tendon at the bottom of the hole, the biodegradable screw is advanced distally into the bone socket. Turning the handle of the screwdriver while holding the reverse-threaded thumb piece causes advancement of the screw while maintaining pressure on the head of the screw. This system allows the tendon to be maintained in a stationary position on the floor of the bone socket as the interference screw is fixed in place, thus, ensuring an adequate screw-tendon-bone in-

Fig 15. (A) The end of the cannulated screwdriver is inserted into the bone socket. (B) The biodegradable interference screw is inserted into the hole. (C) The Bio-Tenodesis screw is well seated in the socket holding the biceps tendon securely against bone.

Fig 16. The transparent Bio-Tenodesis screw allows assessment of the screw-tendon-bone interface.
interface within the bone socket (Figs 14 and 15). After the screw is seated within the bone socket, the screw-tendon-bone interface is assessed by visualizing this construct through the transparent Bio-Tenodesis screw (Fig 16). The traction and loop sutures used in the tenodesis can be cut or incorporated into the rotator cuff repair as was mentioned previously. In the case of an isolated biceps tenodesis the residual defect in the rotator interval is closed with one suture.

POSTOPERATIVE MANAGEMENT

Postoperatively the arm is positioned at the side of the body and placed in a sling with a small abduction pillow. This procedure, as well as all other shoulder arthroscopy cases, is performed as outpatient surgery. The postoperative rehabilitation protocol is dictated by any concomitant disorders.21-27

In general, patients are allowed to perform passive external rotation stretches immediately after surgery. However, this is limited to a maximum of 0° (the straight ahead position) for the first 6 weeks if the Bio-Tenodesis was done in conjunction with a subscapularis repair. If the subscapularis was not repaired, then maximal passive external rotation is allowed as tolerated. Overhead stretching not allowed during the first 6 weeks after surgery. Active elbow flexion and extension is performed with the arm at the side, restricting terminal extension by 20°. It should be noted that full extension of the elbow usually does not cause any discomfort.

After 6 weeks the sling is discontinued, and overhead stretching with a rope and pulley and internal rotation stretching is initiated. Isometric strengthening is not started until the 12th postoperative week. At this point, stretching is continued and rehabilitation of the rotator cuff, deltoid, and scapular stabilizers is started. Progressive activities are incorporated as strength allows, and unrestricted activities are usually resumed 6 months after the biceps tenodesis.

CONCLUSION

With recent technologic advances, there has been an increasing trend toward the use of arthroscopy in the treatment of shoulder disorders. Arthroscopy is used in the treatment of infection, adhesive capsulitis, calcific tendinitis, osteoarthritis, glenohumeral instability, rotator cuff tears, and is even used in the treatment of certain fractures. The technique of arthroscopic biceps tenodesis with interference screw fixation adds another means by which shoulder surgery can be done less invasively. One of the techniques described in the literature uses suture anchors. Our technique employs the use of a biodegradable interference screw. The use of an interference screw provides added security, thus allowing earlier active elbow flexion and extension. The development of the Bio-Tenodesis screw system has simplified the technique of arthroscopic biceps tenodesis. This system allows manipulation of the biceps tendon, ensures the tendon is placed on the floor of the bone socket, allows the insertion of the biodegradable screw while maintaining the appropriate tension and position of the tendon, and ensures adequate screw-tendon-bone interface with excellent fixation strength. We have used this technique for approximately 2½ years. During this period of time, we have noted only failure of fixation. Adherence to the aforementioned arthroscopic principles and surgical techniques will facilitate a strong and reliable arthroscopic biceps tenodesis.

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MINI OPEN AND SUB PECTORAL BICEPS TENODESIS

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The function of the biceps tendon in the shoulder remains controversial. This tendon can be a source of significant anterior shoulder pain that can lead to persistent shoulder dysfunction.

KEY WORDS: biceps, instability tenodesis, subpectoral, subscapularis

Indications for removing the biceps tendon from the glenohumeral joint include biceps tendinosis occurring with or without concurrent rotator cuff problems, biceps tendinosis in association with superior labral pathology (SLAP), and instability of the biceps tendon associated with damage to the coracohumeral and superior glenohumeral ligaments, or supraspinatus and subscapularis tendon tears. Instability of the biceps tendon can occur with disruption of the lateral aspect of the coracohumeral ligament seen with anterior supraspinatus tendon tears, or with the disruption of the medial aspect of the coracohumeral ligament often seen with a subscapularis tear. Recently, there has been recognition that disruption of the coracohumeral ligament without associated rotator cuff tears may also lead to biceps instability. Attempts of stabilizing the biceps tendon have resulted in a secondary rupture of the tendon in at least 25% of the cases in one series and have been associated with stiffness or loss of external rotation due to fixation of the biceps within the bicipital groove. Therefore, instability of the biceps tendon is treated with a biceps tenodesis, not an attempt at reconstructing the coracohumeral ligament.

The diagnosis of proximal biceps tendon disease is a challenge because of the associated pathology, particularly concurrent rotator cuff disease. Physical examination includes an active compression test of the biceps tendon in the bicipital groove, a speed's test (biceps tension test), O'Brien's test, and Yergason's test. Subjectively, the pain is at the anterior medial aspect of the shoulder in the area of the long head of the biceps tendon as opposed to the pain in the anterior lateral aspect of the shoulder, with rotator cuff disease or pathology of the subacromial space. Palpation of the biceps tendon under the proximal aspect of the pectoralis major tendon can also implicate the biceps tendon as part of the pathology. The decision to perform a biceps tenodesis is frequently made preoperatively, but may also be made during diagnostic arthroscopy of the shoulder. Observation of increased effusion on dry arthroscopy or substantial fraying of the tendon itself are all signs of biceps pathology.

Biceps tenodesis is recommended over biceps tenotomy for the following three reasons:

1. Maintenance of the length-tension relationship of the biceps muscle by establishing a new origin to attach the biceps muscle at the appropriate length to prevent muscle atrophy.
3. The cosmetic appearance of biceps tenodesis versus the biceps tenotomy.

SURGICAL TECHNIQUE

The mini open and sub pectoral biceps tenodesis techniques are reported in this article.

MINI OPEN BICEPS TENODESIS

The patient is brought into the operating room and, after either the induction of general anesthesia or successful interscalene block, a complete bilateral examination under anesthesia is performed. The patient is then given preoperative antibiotic prophylaxis and placed in the beach chair position.

A standard posterior portal is made, and the arthroscope is inserted into the posterior aspect of the shoulder; the biceps tendon is then evaluated with no inflow. The intra-articular pressure of the fluid can compress many of the vessels causing the tenosynovitis to be "washed out." A standard anterior portal is made using either inside out or outside in methods. This anterior portal is instrumented with a probe to pull the biceps into the glenohumeral joint to evaluate the tendon's mobility and the tenosynovium surrounding it. The coracohumeral ligament with an ac-
Fig 1. (A and B) Arthroscopic marking of the proximal biceps tendon and excision of tendon. (C and D) Skin incision for the mini open biceps tenodesis. One of the anterior portals is extended at the level of the intratubercular groove. The axillary nerve is can be close to this incision.
Fig 2. (A) A probe is used to withdraw the tendon from the joint and out of the incision. (B) To ensure appropriate tensioning, 20 mm of the diseased portion of the tendon is excised. A Krackow or other type of interrupted tendon or whipstitch is then placed approximately 10 to 15 mm in the tendon.
Fig 3. An Arthrex guide wire is placed in the center of the bicipital groove. This is usually at the junction of the middle and distal thirds of the intratubercular groove between the lesser and greater tuberosities. A 7- or 8-mm acorn reamer is then placed over this and reamed to approximately 25 to 30 mm.

Accurate examination of the leading edge of the supraspinatus and subscapularis should be evaluated for pathology. Fraying of the tendon is a sign of biceps pathology. It is unknown how much biceps fraying is needed for tenodesis but some authors have proposed 30 to 50%.2

A spinal needle is inserted into and in line with the biceps tendon (Fig 1A). A no. 1 monofilament suture is placed through the spinal needle and is used as a marking stitch (Fig 1B). This suture is then captured through an instrumented anterior portal and then secured. The rest of the glenohumeral arthroscopy is then accomplished, and any glenohumeral work is completed.

The arthroscope is then inserted into the subacromial space, and a standard lateral portal is then made. The subacromial bursectomy and/or decompression are then performed. If there is rotator cuff pathology, it is repaired at this time. The arthroscopic approach to rotator cuff repair would involve an accessory anterolateral portal, which will then be placed. The mini open rotator cuff repair would require a small 2- to 3-cm incision in roughly the same position, which is off the anterior lateral edge of the acromion. In either case this would be the incision for the mini open biceps tenodesis repair (Fig 1C). The arm is positioned in approximately 30° of flexion, 30° of abduction with the elbow flexed and neutral or slight external rotation. The axillary nerve can be close to this incision, so care must be taken. Needle tip electrocautery and Metzenbaum scissors are the used to dissect to the fascial layer (Fig 1D). The marking sutures are located, and the biceps sheath is opened. The biceps tendon is then delivered out of the wound (Fig 2A). Anatomical studies have shown that the mean intra-articular length of the biceps tendon is approximately 30 to 40 mm with the arm adducted. The tendon is trimmed 20 mm, and a no. 2 Fiberwire nonabsorbable suture is placed in the proximal 15 mm of tendon (Fig 2B).

The biceps tendon sheath is opened with electrocautery at the level of the greater and lesser tuberosity. This area is then cleared of all debris that can impede the tenodesis procedure.

An Arthrex guide wire and an appropriate size reamer (7 or 8 mm) are then used to make a 30-mm deep bone tunnel (Fig 3). This bone tunnel is then irrigated of all debris. The Arthrex Bio-Tenodesis screwdriver and screw (Arthrex, Inc. Naples, FL) has one loop of the suture threaded through and snapped at the end. The tenodesis screwdriver is then placed into the bone tunnel, and the screw is advanced over the tendon (Fig 4). When the screw is flush with the bone tunnel, the screwdriver is removed and a second knot is tied over the top. This provides both an interference fit as well as a suture anchor stability (Fig 5). Standard wound closure is then used.

SUBPECTORAL OPEN BICEPS TENODESIS

With the arm abducted and internally rotated, the inferior border of the pectoralis major tendon is palpated. The incision is 1 cm superior to the inferior border of the pectoralis tendon to 3 cm below the inferior border on the medial aspect of the arm (Fig 6). The incision site is injected with a local anesthetic plus epinephrine for subcutaneous hemostasis and perioperative analgesia. A scalpel is used to cut down through the subcuticular tissue. An electrocautery is used to control bleeding. A Gelpi or Wheatlander self-retaining retractor can be used for visualization. The fatty tissue is then cleared until the fascia
overlying the pectoralis major, coracobrachialis, and biceps is identified. If these anatomical landmarks are not seen, the dissection could be too lateral. If the cephalic vein is seen in the deltopectoral groove, the dissection is too proximal and too lateral.

Once the inferior border of the pectoralis major has been identified, the fascia overlaying the coracobrachialis and biceps is incised in a proximal to distal manner. A pointed Hohmann retractor is placed under the pectoralis major and on the proximal humerus to retract the muscle proximally and laterally. A blunt Chandler retractor is placed in the medial aspect of the humerus to retract the coracobrachialis and short head of the biceps. Vigorous medial retraction should be avoided to prevent injury to the musculocutaneous nerve. The long head of the biceps musculotendinous junction should be visualized, and it is then withdrawn from the field (Fig 7).

To ensure appropriate tensioning of the biceps tendon, the proximal portion of the tendon is resected to leave 20 to 25 mm of tendon proximal to the musculotendinous portion of the biceps. One centimeter proximal to the pectoralis major tendon, the peristeme in a rectangle roughly 2 x 1 cm is reflected. A no. 2 Fiberwire (Arthrex, Inc., Naples, FL) is placed in the tendon. Enough of the tendon is secured to ensure that adequate fixation is maintained and that the musculotendinous portion of the biceps will sit underneath the inferior border of the pectoralis major tendon (Fig 8). This is critical for the proper tensioning of the muscle tendon unit as well as for cosmesis.

A 4.5-mm drill is used to drill three holes in a horizontal fashion at the top of the area that was cleared of peristeme (Fig 9). These holes are made through the anterior cortex of the humerus and are then connected with a rongeur to allow space for the biceps tendon to pass (Fig 10). An alternative method would be to place a guidewire in this area and then use a 7 to 8 mm cannulated reamer (Fig 11). A 3.2-mm drill is then used to make two holes distally, which will function as the suture shuttle to pull the tendon into the bone tunnel. These holes should be drilled far enough away so that the no. 2 nonabsorbable suture with its corresponding needle can be threaded retrograde (Fig 12). The needles are then retrieved through the bone trough and removed. The no. 2 suture is then tied.
Correct tensioning of the biceps complex is important for both establishing the resting length tension curve of the muscle and for cosmesis. The musculotendinous border of the biceps muscle is directly under the inferior edge to the pectoralis tendon. The proximal biceps tendon is removed to allow approximately 15 to 20 mm of tendon proximal to the musculotendinous junction. This amount of tendon is placed into the bone tunnel, allowing the musculotendinous junction to rest in its exact anatomical location underneath the inferior border of the pectoralis major tendon. (Inset) A Krakow or other type of whipstitch is then placed into the tendon.

Fig 9. A 4.5-mm drill is used to make three horizontal holes at the top of the area that was cleared directly underneath the inferior margin of the pectoralis tendon. This will be the area through which the tendon will slide.

During months 3 to 12 patients may begin elbow strengthening as tolerated with isometrics increasing to elastic bands and then weights. Strengthening of biceps, triceps, rotator cuff, deltoid and scapular stabilizers should be performed three times a week to avoid rotator cuff tendinitis.

POSTOPERATIVE MANAGEMENT

Patients are allowed active assisted elbow flexion for the first four weeks. This gives time for the biceps tendon to heal in its new insertion site in the humerus without being stressed. A sling will be worn during sleep for the first four weeks and only used while the patient is awake if there is difficulty keeping the elbow flexed passively or if the patient is going into a public area.

From weeks 4 to 12 the sling is discontinued totally. Active range of motion of the elbow in pronation, supination, flexion, and extension with passive stretching at end ranges to maintain or increase flexibility is encouraged. Isometrics are begun with the arm at side for rotator cuff and deltoid strengthening and can be advanced to elastic bands as tolerated.

Fig 10. A Rongeur is used to connect the multiple 4.5-mm holes to make an oval hole in the anterior cortex of the humerus. This tunnel is proximal to the inferior edge of the pectoralis tendon to allow for reproducible tensioning.
Fig 11. The second method for making the bone tunnel: an Arthrex guidewire and then a 7- or 8-mm Arthrex cannulated acorn reamer are used to make the appropriate hole in the same position as previously discussed.

COMPLICATIONS
Complications include failure of tenodesis resulting in a functional tenotomy, hematoma, or seroma of the involved area. Reaction to the biodegradable screw, persistent pain, musculocutaneous or axillary nerve damage can also occur. Fracture at the bone tunnel, infection, and potential damage to the brachial artery are other potential complications.

CONCLUSION
The value of any surgical procedure can be evaluated in terms of a benefit/risk ratio. Benefits of tenodesis include pain relief, the maintenance of almost normal biceps function and cosmesis. The risk of tenodesis is minimal with disruption or recalcitrant tenosynovitis as the most com-

Fig 12. Two smaller holes are then drilled inferior to the major bone tunnel and the sizing of this should be done with the needle that will be used as the passing suture. The inferior holes are used for suture shuttling.

Fig 13. The biceps tendon is pulled into the bone tunnel in a retrograde fashion using the inferior holes as a suture shuttle.

Fig 14. The musculotendinous junction lies underneath the inferior edge of the pectoralis tendon. (Inset) The tendon is secured into the bone tunnel.
mon complications. In our practice open and arthroscopic procedures have not been associated with an increased risk of infection, nerve injury, or delayed wound healing. The mini open and subpectoral open approach using a biabsorbable screw or a bone tunnel system had excellent success. These are two reproducible methods for tenodesing the biceps tendon in any age group.

REFERENCES
