

The Proximal Biceps as a Pain Generator and Results of Tenotomy

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Abstract: Many palliative interventions have been proposed for patients in whom rotator cuff repair is not feasible as a result of advanced fatty infiltration, definitive loss of tendons, and proximal humeral migration. The long head of the biceps tendon has been proposed as a source of pain in patients with rotator cuff tears. This article presents a review of current concepts on the rationale for arthroscopic biceps tenotomy or tenodesis, and evaluates the objective, subjective, and radiographic results of these palliative procedures. On the basis of different studies, it seems that isolated arthroscopic biceps tenotomy or tenodesis is a valuable option for the treatment of rotator cuff tears in selected patients. Although it does not improve shoulder strength, tenotomy or tenodesis reduces pain and improves the functional range of motion with a high degree of patient satisfaction. However, the progressive radiographic changes that occur with long standing rotator cuff tears are not altered.

Key Words: biceps tendon, tenotomy, tenodesis, arthroscopy, rotator cuff tear

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RATIONALE OF BICEPS TENOTOMY

Full thickness tears of the rotator cuff tendon are common and a frequent cause of dysfunction of the shoulder. Treatment options depend on patient age, comorbidities, activity level, and extent of the disability. Conservative treatment is initially attempted, with modalities such as nonsteroidal anti-inflammatory medications, corticosteroid injections, gentle physical therapy with strengthening of the intact components of the rotator cuff and deltoid, and periods of rest.^{1–3} Nonoperative management has a satisfactory outcome in 40%

to 82% of cases. However, a narrowing of the acromio-humeral interval occurs in nearly three-fourths of patients within 5 years with nonoperative treatment of full thickness rotator cuff tears.^{1–3} Additionally, Hamada et al⁴ showed that 5 of 7 full thickness rotator cuff tears that were treated nonoperatively and followed for a minimum of 8 years had progression of glenohumeral arthritis of at least 1 radiographic stage.

Persistence of symptoms despite adequate conservative therapy may warrant operative treatment. The results of rotator cuff repair are generally recognized to be better than isolated acromioplasty.^{5–7} Although rotator cuff repair has been reported to be a highly successful procedure, the outcome for patients undergoing repair of large or massive rotator cuff tears is distinctly less satisfactory with a retear rate of 36% to 70%.^{8,9} Additionally, attempts at repair of massive rotator cuff tears with static superior subluxation of the humeral head or massive rotator cuff tears involving the subscapularis or the teres minor may have a detrimental effect resulting in postoperative loss of active elevation or even development of a pseudoparalytic shoulder.^{9–11} Some authors have stated that age at the time of repair and sex does not appreciably affect the outcome, whereas others have reported poorer outcomes in individuals above the age of 65 years and in females.^{12,13} Finally, fatty infiltration of the rotator cuff musculature has been reported to be the most important predictor of clinical results after rotator cuff repair.^{9,14,15} Although muscular atrophy may be arrested or reversed after repair of supraspinatus tears, fatty infiltration is irreversible.^{9,14,15}

Many palliative interventions have been proposed for patients in whom rotator cuff repair is not feasible as a result of advanced fatty infiltration of the rotator cuff muscles, definitive loss of tendons, and proximal humeral migration. Open treatments such as simple debridement and acromioplasty have been adapted to be performed arthroscopically.^{5,7,16–19} Arthroscopic acromioplasty has yielded good early objective and subjective results in 70% to 90% of cases of rotator cuff tears especially in small and medium size tears.^{17,20,21} Gartsman²² found less satisfactory outcomes in massive tears, and Zvijac et al¹⁹ showed that the promising early results of arthroscopic acromioplasty deteriorated with longer follow-up.

Lesions of the long head of the biceps tendon are often associated with massive rotator cuff tears and may be responsible for shoulder pain and dysfunction.^{23–25}

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The lesions vary in degree, from tendinitis, delamination, and subluxation on the medial rim of the bicipital groove to frank dislocation or even joint entrapment because of hypertrophy. Spontaneous rupture of the long head of the biceps is common during the evolution of rotator cuff tears.²⁶ Surgery is rarely required as this event is commonly associated with pain relief after the acute episode subsides. The very small number of published articles reporting the results of repair of a ruptured long head of the biceps tendon attests that this condition is well tolerated.²⁷⁻²⁹

After observing multiple patients with chronic rotator cuff tear developing long head of biceps rupture and getting subsequent pain relief, the next logical step was to accelerate the natural history by performing biceps tenotomy in selected cases. Walch began performing arthroscopic biceps tenotomy in 1988. Early-term and long-term results with the procedure have been promising.³⁰⁻³² To reduce the possible cosmetic deformity and associated muscle belly discomfort, different authors have proposed arthroscopic biceps tenodesis as an alternative to arthroscopic biceps tenotomy. Boileau et al^{33,34} developed a technique of arthroscopic biceps tenodesis with interference screw fixation.

INDICATIONS AND CONTRAINDICATIONS OF BICEPS TENOTOMY AND TENODESIS

Indications for biceps tenotomy or tenodesis include painful shoulder with rotator cuff tear if appropriate conservative treatment including rest, rehabilitation, anti-inflammatory medications, and/or corticosteroid injections failed. Passive range of motion must be symmetric with the unaffected shoulder except in the case of an "hourglass" biceps deformity.²⁴

Our indications for performing biceps tenotomy in lieu of rotator cuff repair were based on technical reparability of the rotator cuff and patient motivation and willingness to undergo postoperative rehabilitation required after rotator cuff repair. The concept of what constitutes a technically repairable rotator cuff tear has been extensively discussed by Gartsman et al^{5,22} and Gerber et al,⁹ who have noted that this concept differs among authors and has been based on clinical, radiographic, and intraoperative criteria. At the beginning of our experience with arthroscopic biceps tenotomy in the treatment of rotator cuff tears, we judged reparability based on the acromiohumeral interval (< 7 mm contraindicated repair).^{10,11,20,30} More recently, fatty infiltration of the rotator cuff has been found to be an important prognosticator in rotator cuff surgery and a major contributor to superior humeral migration.^{14,15,35} Therefore, in our practice, rotator cuff reparability is largely determined by the presence of superior migration of the humeral head on radiographs and/or the presence of fatty infiltration of the rotator cuff musculature on secondary imaging studies.

The decision not to repair the rotator cuff is based on the presence of one or more of the following criteria:

substantial tendon retraction precluding direct repair to the bone (grade 3),^{16,18} advanced rotator cuff muscle atrophy or fatty infiltration (Goutallier stages 3 and 4),^{14,35} and proximal humeral migration with an acromiohumeral interval of < 7 mm seen on a true anteroposterior radiograph made in neutral rotation.^{10,11,30,35}

Another criteria required for successful rotator cuff repair is to have sufficient patient motivation to perform the necessary postoperative course of rehabilitation. Intimately associated with the required patient motivation is patient age. Although some authors have shown that the results of rotator cuff repair are independent of age, other investigators have demonstrated that the results tend to be poorer in patients aged over 65 years.^{12,13} Anecdotally, our older patients with rotator cuff tears seem more apprehensive about the rehabilitation and convalescence required after repair. Therefore, patient motivation and patient age play a large role in patient selection for repair. A comparison of mean patient age in the series of biceps tenotomy with series of rotator cuff repair in the literature illustrates our use of age in the selection of patients in whom we believe biceps tenotomy is more appropriate than rotator cuff repair. Biceps tenodesis is preferred to tenotomy in more active patients and in those under the age of 60 years.

An isolated biceps tenotomy or tenodesis is contraindicated for patients with a rotator cuff tear who present with true pseudoparalysis of the shoulder despite rehabilitation, and a reverse shoulder arthroplasty is performed for those patients.^{36,37} It is crucial to differentiate between patients with true pseudoparalysis of the shoulder and those with painful loss of elevation. The primary difference is that a shoulder with true pseudoparalysis is nonfunctional, exhibiting an ineffective shrug with attempted elevation of the arm, whereas a shoulder with painful loss of elevation is functional but active elevation is limited because of pain. The examiner must look for anterosuperior subluxation of the humeral head between the acromion and the coracoid when a patient tries to elevate or abduct the arm, which is not always easy to observe.^{38,39} (Fig. 1). Performing the "landing test" can help to differentiate between the 2 entities.⁴⁰ A patient with true pseudoparalysis of the shoulder will not be able to actively maintain his/her arm just above the horizontal level (between 90 and 120 degrees), which position was achieved passively by the examiner. The arm will fall down despite the patient's efforts, which is related to muscle weakness and not to pain. Additionally, infiltration of the shoulder with Xylocaine may help to differentiate by relieving the shoulder pain and allowing active elevation.

In regard to arthritis staging by the Hamada classification,⁴ patients who have a functional shoulder without glenohumeral osteoarthritis (stages 1 to 3) are candidates for a tenotomy or tenodesis, which is contraindicated in the patients with glenohumeral osteoarthritis or humeral head necrosis (stage 4 or 5). They are candidates for a reverse shoulder arthroplasty³⁶⁻³⁸ (Fig. 2).



FIGURE 1. Pseudoparalysis of the shoulder (an ineffective shrug of the shoulder with anterosuperior subluxation while the patient attempts to elevate the arm and an inability to actively maintain the arm above the horizontal level) is a contraindication to a biceps tenotomy or tenodesis. Pain may be suppressed, but a functional shoulder is not restored with this procedure.

PREOPERATIVE PLANNING

Patient history and clinical examination are the hallmarks for diagnosing pathology of the long head of the biceps and concomitant rotator cuff pathology. Patients often complain of pain in the anterior region of the shoulder with occasional distal radiation along the anterior aspect of the upper arm. However, these symptoms are often concomitant with impingement symptoms, such as overhead and night pain. Speed's test can be helpful in the preoperative examination. However, we have found that tenderness with palpation of the bicipital groove is very often present with bicipital tenosynovitis, partial rupture, subluxation, and/or dislocation. Tenderness with passive external rotation of the arm, as the examiner palpates the bicipital groove, is also a common sign.

Radiographic examination should include a standard roentgenographic series (anteroposterior views in neutral, internal, and external rotation, an axillary view, and a supraspinatus outlet view), to rule in or out any associated abnormalities. We also use specialized imaging studies (magnetic resonance imaging with gadolinium, computed tomographic arthrography, and ultrasound imaging) to assist in diagnosing pathology of the biceps tendon and rotator cuff pathologies before surgery. These

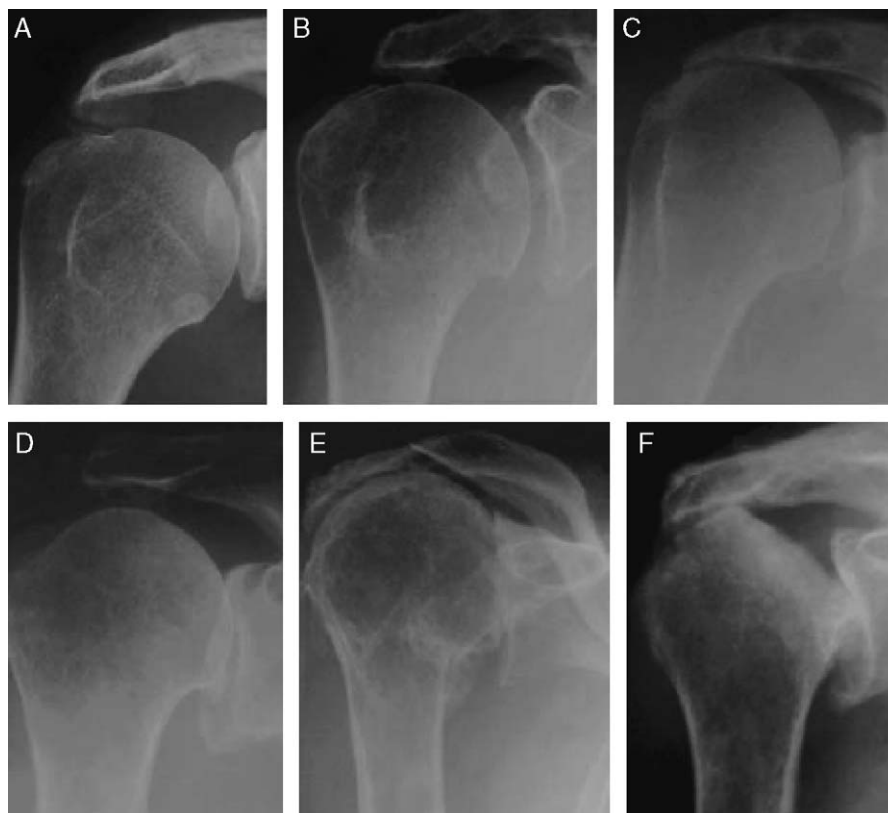


FIGURE 2. Classification of arthritis in chronic rotator cuff tears. A, Stage 1: acromiohumeral distance (AHD) greater than 6 mm. B, Stage 2: AHD < 6 mm. C, Stage 3: AHD < 6 mm with acetabularization of acromion. D, Stage 4a: AHD < 6 mm with glenohumeral arthritis without acetabularization. E, Stage 4b: AHD < 6 mm with acetabularization and glenohumeral arthritis. F, Stage 5: AHD < 6 mm with osteonecrosis of humeral head.

studies can be very helpful in the preoperative counseling of a patient with shoulder pain and in the preoperative decision-making.

SURGICAL TECHNIQUE AND POSTOPERATIVE MANAGEMENT

The procedure is performed arthroscopically with the patient in the beach-chair position and under general anesthesia or regional anesthesia as an interscalene block. The patient can be positioned in the lateral decubitus position as well. A posterior portal is used for visualization, and routine diagnostic arthroscopic examination is performed. An anterolateral working portal is used for instrumentation. Synovectomy and bursectomy are only performed as needed for visualization. Biceps tenotomy is performed by simply sectioning the tendon at its origin at the supraglenoid tubercle and superior labrum. The tendon is allowed to retract out of the glenohumeral joint. In cases in which the biceps is unable to retract as a result of enlargement or attritional changes, the intra-articular portion of the biceps is resected to allow for retraction out of the glenohumeral joint.

In the case of tenodesis the previously described technique can be used.^{33,34} The tendon is brought out of the groove distal to the biceps pulley, doubled over for a length of 2.5 cm, and then fixed into a bone socket in the floor of the groove by means of a bioabsorbable interference screw (Tenoscrew; Phusis, St Ismier, France).

An associated acromioplasty can be performed in patients with an anterior acromial spur and a centered head as determined on radiography (acromiohumeral interval ≥ 7 mm).

Postoperatively, the arm is placed in a simple sling. Passive range of motion exercises are started on the day after surgery. Active mobility exercises are incorporated as tolerated by the patient. After 2 weeks, the patients are encouraged to begin hydrotherapy and swimming program until 3 months postoperative. Strengthening exercises are avoided to prevent development of pain and stiffness. The patients who are treated with the tenodesis are allowed to carry out activities of daily living as tolerated after the second postoperative week because the interference screw fixation is sufficient for these tasks.

RESULTS OF BICEPS TENOTOMY AND TENODESIS

Our 2 studies demonstrated that in selected cases, arthroscopic biceps tenotomy and tenodesis yields favorable clinical results in the treatment of full thickness rotator cuff tears.^{40,41}

Walch et al⁴¹ recently reported the long-term results of biceps tenotomies in 307 shoulders (57.0% female, 77.9% dominant-sided), as palliative treatment for rotator cuff tears. The average age at the time of surgery was 64.3 years (39 to 81y). Follow-up averaged 57 months (24 to 168 mo). In 110 cases, tenotomies were performed with a concomitant acromioplasty. A significant improvement occurred in all aspects of the Constant

score at latest follow-up with an average final score of 67.6 points.^{42,43} By use of the age-adjusted and sex-adjusted Constant score, 71.6% of the shoulders were rated as excellent or good. Subjectively, 86% of patients rated their result as excellent or good. Use of a concomitant acromioplasty was only beneficial in regard to functional results in patients with a normal acromiohumeral distance.⁴¹

Boileau et al analyzed the results of 68 patients (72 shoulders) with a massive, irreparable rotator cuff tear who underwent either an isolated arthroscopic biceps tenotomy or an isolated arthroscopic biceps tenodesis. The average age at the time of surgery was 68 years (52 to 85 y). There were 42 women and the dominant arm was affected in 88% of the cases. Subjectively 78% of the patients were satisfied or very satisfied with the result at an average of 35 months postoperatively. The Constant score increased by an average of 20 points, with an average final score of 66.5 points.⁴⁰

In both studies, improvements in function, range of motion, and activity level were secondary to pain reduction. Even with a longer follow-up, pain relief and functional improvement have remained favorable. Interestingly, in the former study fatty infiltration of the subscapularis and infraspinatus had a dramatic, negative influence on the results of arthroscopic biceps tenotomy just as with rotator cuff repair. However, in the latter, neither fatty infiltration of the subscapularis or infraspinatus nor the acromiohumeral distance had a measurable effect on the final result with a smaller numbers available. In both studies active external rotation was not improved after the surgery, as was expected. Teres minor atrophy in patients with severe fatty infiltration of the infraspinatus negatively influenced many postoperative clinical and radiographic outcome parameters (postoperative external rotation, Constant score, acromiohumeral distance, and arthritic changes during follow-up period). The result of a tenotomy or tenodesis is, therefore, improved if the infraspinatus or teres minor can provide active external rotation.^{31,40,41} Preoperative knowledge of the status of the remaining rotator cuff can help the surgeon and patient to arrive at the best treatment option. When a patient has a severe external rotation deficit (Hornblower and dropping signs) with teres minor deficiency, and the goals are more than just palliation, we now perform an additional latissimus dorsi and teres major tendon transfer to improve this function.^{39,44}

Our results have further shown that, at a mean follow-up approaching 5 and 3 years, the complication and reoperation rate with biceps tenotomy are acceptably low, with only 1% of patients undergoing a subsequent attempt at rotator cuff repair and less than 2% requiring further surgery for cuff tear arthropathy.

Radiographically, the mean acromiohumeral distance decreased during the follow-up period (1.3 and 1.1 mm, respectively, of the 2 studies), which is commensurate with the natural history of massive rotator cuff tears or biceps tenotomy^{4,11,45} (Fig. 3). Moreover, the

acromiohumeral narrowing observed in our study is equivalent to that seen after simple debridement and less than that seen after acromioplasty.^{18,19,46,47} Our clinical observation confirms the findings of the biomechanical studies by Yamaguchi et al⁴⁸ and Levy et al,⁴⁹ who found that the long head of the biceps is unlikely to be an active humeral head depressor, even in patients with a massive rotator cuff tear. This is in contrast with other biomechanical studies suggesting the active role of the long head of biceps in shoulder stabilization.^{50,51} Tenotomy of the long head of the biceps tendon could potentially be implicated as a contributing factor to the observed decrease in the acromiohumeral distance, however, we have never observed immediate superior migration of the humeral head on postoperative radiographs after biceps tenotomy. Nové-Josserand et al³⁵ have shown that rupture of the long head of the biceps tendon did not statistically influence the acromiohumeral interval in 264 shoulders with rotator cuff tears. They additionally proved that fatty infiltration of the infraspinatus has the greatest influence over the acromiohumeral distance, a finding confirmed by the study of Walch et al⁴¹ (Fig. 4).

In addition, arthritis according to the Hamada classification significantly progressed as well (21.5% and 29.1% of our cases progressed at least 1 radiographic stage). Despite the encouraging clinical results, arthroscopic tenotomy does not seem to alter the progressive radiographic changes that occur with long standing rotator cuff tears. The development of both acromiohumeral and glenohumeral arthritis seems a legitimate concern when treating patients with rotator cuff tears with biceps tenotomy without repair of the rotator cuff. Development of true rotator cuff tear arthropathy as described by Neer et al⁴⁵ is not inevitable in patients with massive rotator cuff tears, however, occurring in only 4%

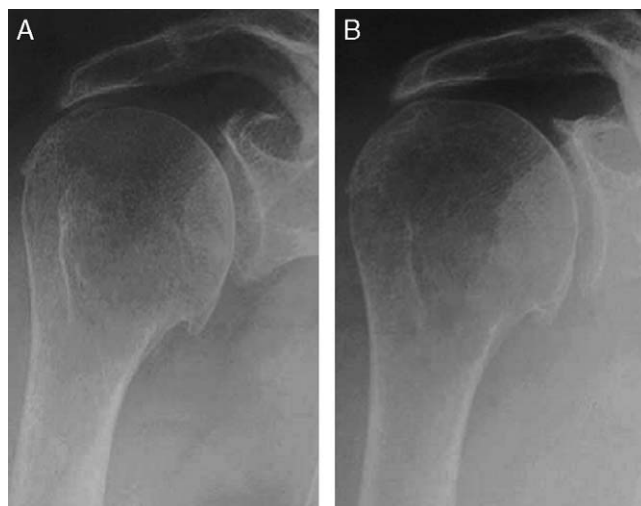


FIGURE 4. A, Radiograph of a 60-year-old woman just before arthroscopic biceps tenotomy and acromioplasty (stage 1 arthritis). B, No progression of the arthritis has occurred at 9 years' follow-up.

of patients with massive rotator cuff tears. Hamada et al⁴ reported that in 7 of their patients even with nonoperatively treated massive rotator cuff tears and arthritis, 2 shoulders remained radiographically stable whereas 5 shoulders progressed at least 1 grade radiographically at greater than 8 years follow-up. The presence or development of acromiohumeral arthritis and acetabularization of the acromion (Hamada stage 3) on the preoperative or final radiographs did not seem to be related to the final Constant score or Constant pain subscore.⁴⁰ Acromial acetabularization represents a functional adaptation to a chronic massive rotator cuff tear: as long as the



FIGURE 3. A 64-year-old man suffering of chronic pain of the left nondominant shoulder despite 2 years of conservative treatment. The patient was seen in 1989 (A), clinical examination and arthro computer tomography revealed rupture of supraspinatus and infraspinatus tendons. At that time, he declined open rotator cuff repair and an arthroscopic biceps tenotomy was carried out under interscalene block. Seventeen years later (C), he is still happy, has no pain in the ADL but still complains of loss of strength. The x-rays performed over the last 18 years show a progressive decrease of the acromio-humeral distance without gleno-humeral involvement (A–C). ADL indicates activity of daily living.

coracoacromial ligament is intact, the deltoid and the remaining rotator cuff can compensate for loss of the superior portion of the rotator cuff.^{4,41,45} In this situation, there is a risk that an acromioplasty will destabilize the shoulder, converting a painful functional shoulder into a painful nonfunctional one with loss of active elevation.²²

In the study of Boileau et al there was no difference in the Constant score at the time of follow-up between the group of patients with tenotomy and tenodesis. As expected, the prevalence of muscle belly retraction (the Popeye sign) was significantly higher in the tenotomy group (62% compared with 3%). The Popeye sign was 50% in the study of Walch et al, however, the cosmetic deformity of the arm is usually not bothersome to the patient. Furthermore, no patient characterized their result as fair or poor based on cosmesis. Boileau et al observed a higher prevalence of muscle belly discomfort in the tenotomy group (21% compared with 9%); however, this was not significant.^{40,41}

The high rate of patient acceptance of the cosmetic deformity seen after the tenotomy may be explained by the age of our patients: 10 to 15 years older than the series of traumatic or spontaneous biceps rupture.^{28,29} We have noted that our patients aged 45 to 55 years become concerned about deformity after spontaneous rupture of the long head of the biceps tendon. After 65 years of age, however, we have rarely found it necessary to treat a spontaneous rupture of the biceps tendon. In these older patients, the characteristic deformity may not occur because of muscle atrophy and age-related loss of muscle tone and definition.

It has been reported in the literature that 20% of forearm supination strength and 8% to 20% of elbow flexion strength are lost after spontaneous proximal biceps rupture.²⁹ Additionally, patient complaints of discomfort and muscle cramping with resisted elbow flexion forearm supination (turning a screwdriver) were noted. We did not note these specific complaints in our patients and performed no strength testing of the elbow and forearm. Because of concerns of poor cosmesis and decreased elbow and forearm strength, we are hesitant to recommend biceps tenotomy in patients younger than 55 years of age. Indeed, it is fortunately rare that a younger patient is a candidate for biceps tenotomy; most young patients do not have irreparable tears and/or severe fatty infiltration of the rotator cuff musculature, and most young patients are willing to undergo the rehabilitation required after rotator cuff repair. In this age group, we generally recommend rotator cuff repair with biceps tenodesis if necessary.

Some authors have proposed arthroscopic biceps tenodesis as an alternative to arthroscopic biceps tenotomy in patients with an irreparable rotator cuff tear.^{1,40} We believe this to be a reasonable approach in patients who have maintained good muscle tone and definition and are concerned with the prospect of a deformity of the arm.

In summary, arthroscopic biceps tenotomy and tenodesis yields favorable clinical results in patients with

full thickness rotator cuff tears in whom repair is not possible and/or desirable. Although it does not improve shoulder strength, tenotomy or tenodesis reduces pain and improves the functional range of motion. Arthroscopic biceps tenotomy carries a low complication and reoperation rate. The preservation of some of the posterior part of the rotator cuff, particularly the teres minor, results in improved external rotation and therefore a better functional result. Fatty infiltration of the rotator cuff negatively influences the results of arthroscopic biceps tenotomy just as with rotator cuff repair. Despite encouraging clinical results of arthroscopic biceps tenotomy, the natural progressive radiographic changes that occur with long standing rotator cuff tears are unaltered.

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