A Comparison of Ultimate Pullout Strength of Four Bioabsorbable Tacks

Leslie Haugen
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A COMPARISON OF ULTIMATE PULLOUT STRENGTH OF FOUR BIOABSORBABLE TACKS

by

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Bachelor of Science in Physical Therapy
University of North Dakota, 2000

An Independent Study
Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Master of Physical Therapy

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2001
This Independent Study, submitted by Leslie M. Haugen in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Signatures and names)

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(Graduate School Advisor)

(Chairperson, Physical Therapy)
PERMISSION

Title A Comparison of Ultimate Pullout Strength of Four Bioabsorbable Tacks

Department Physical Therapy

Degree Master of Physical Therapy

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ABSTRACT

The purpose of this study was to evaluate the pullout strength, both parallel and perpendicular to that tack shaft, of four different bioabsorbable tacks: Suretac A, Suretac B, Bionx A and Bionx B. These tacks were fixated into a foam block and tension was placed on each tack until point of failure between the tack-foam interface. Results were analyzed via the one-way ANOVA and Scheffe’s test was used for post hoc analysis. Results indicated that the Bionx B tack withstood the greatest mean ultimate parallel pullout strength with a mean of 292.04 N and failed at a force significantly higher than all other tack types ($p = .000$). The Bionx A failed at 150.25 N, Suretac B at 147.64 N and Suretac A at 79.19 N. Suretac A failed at a force significantly lower than all other tack types ($p = .01$). Results indicated that Bionx B withstood the greatest ultimate perpendicular pullout strength with a mean of 468.47 N and failed at a force significantly higher than all other tack types ($p = .01$). Suretac B failed at 354.02 N, Bionx A at 290.64 N and Suretac A at 279.75 N. The results indicate that Bionx B is the strongest tack in terms of pullout strength. Failure modes of each tack type were also assessed with the result of tack shaft breakage of the Bionx tacks and shaft bending of the Suretac designs.

The results of this study indicated that bioabsorbable tacks have qualities similar to other surgical fixation devices being used for surgical repair of the supraspinatus tendon. It is crucial that the physical therapist have an appropriate amount of knowledge
regarding surgical procedures when working with patients with rotator cuff repairs. This knowledge will assist the therapist in designing an appropriate rehabilitation program following the surgeon’s guidelines or protocol and based on the needs of each individual patient.
CHAPTER I
INTRODUCTION/LITERATURE REVIEW

The shoulder joint is one of the most commonly treated joints in physical therapy clinics.\textsuperscript{1} Regardless of age, inability to perform functional activities has frequently been found to be a result of shoulder dysfunction. This extremely complex joint uses large movement patterns for activities such as leisure, work, activities of daily living and athletics. These large movement patterns are possible because the shoulder joint sacrifices stability for increased mobility, but with consequences such as increased risk of injury.\textsuperscript{2,3}

One common shoulder injury is a rotator cuff tear. Rotator cuff tears can either be treated non-operatively or with surgical techniques. Regardless of the treatment chosen, physical therapists play an intrical part in the rehabilitation process. Physical therapy goals for the patient following surgical repair of the rotator cuff are to optimize function, decrease pain, restore mechanics and facilitate healing.\textsuperscript{1} It is very important that the therapist takes into consideration the surgical procedure that was performed as well as the length of immobilization prescribed by the doctor.

The rate of progression of post-operative management will vary with each patient, however general guidelines should be followed. Typically, physicians often require immobilization of the shoulder for approximately four to six weeks after surgery to allow for appropriate tendon to bone healing.\textsuperscript{4} During this immobilization or protection phase,
passive motion is carried out to reduce the development of adhesions as well as promote wound healing.

In order to provide an appropriate post-surgical rehabilitation program, it is important for the physical therapist to have an adequate understanding of shoulder anatomy and biomechanics, appropriate time frames for healing and the surgical procedure used to repair the rotator cuff.

Research has provided many interesting and positive outcomes regarding surgical procedures of rotator cuff repairs. However, current surgical techniques may require long hours in the operating room and tedious manual skills by the surgeon. Non-bioabsorbable fixation devices used in surgery to repair the rotator cuff may lead to post-operative complications months to years later. Bioabsorbable tacks have successfully been used for years to repair non-contractile, labral tissue in the shoulder joint. These tacks are relatively easy to implant and decrease the risk for post-operative complications. Surgeons have recently begun using these tacks for tendon repair. Minimal research using bioabsorbable tacks for tendon repair has been conducted and further research is needed to assure an appropriate post-surgical rehabilitation protocol.

Through this review of the literature, the focus was to provide the physical therapist with a knowledge of shoulder joint anatomy and function, treatment options for rotator cuff tears, different surgical procedures to repair rotator cuff tears and lastly, information on the biodegradable tacks analyzed in this study.

Glenohumeral Joint Anatomy

The shoulder complex is made up of four articulations or joints which are necessary to provide movement in directions from flexion and extension to rotation and
circumduction. The shoulder joint is made up of four true joints:

1. Glenohumeral joint
2. Acromioclavicular joint
3. Sternoclavicular joint
4. Scapulothoracic joint

While each of these articulations are essential for optimal function of the shoulder complex, for the purpose of this study the focus will be specifically on the glenohumeral joint. The glenohumeral joint is a ball and socket, synovial joint surrounded by a capsule, several ligaments, muscles and bursae (Figure 1). Together, the humeral head and glenoid fossa comprise this articulation. Attached to the periphery of the glenoid fossa is a rim of fibrous tissue known as the glenoid labrum. This non-contractile tissue serves to deepen the fossa.

The entire glenohumeral joint is surrounded by a large capsule which is loose anteriorly and inferiorly and taut superiorly. This capsule is twice the size of the humeral head. The laxity of this capsule, although necessary to allow for greater range of motion at the shoulder, sacrifices biomechanical stability. Anteriorly, the glenohumeral joint capsule is reinforced by three glenohumeral ligaments (superior, middle and inferior) and superiorly reinforced by the coracohumeral ligament. All four ligaments assist in checking lateral rotation of the humerus. The glenohumeral ligaments also check anterior gliding of the humeral head. The coracohumeral ligament is taut when the arm is at the side and serves an important function by providing passive support for the arm against the pull of gravity.
One bursa associated with the glenohumeral joint is the subacromial bursa, which separates the supraspinatus tendon and the humeral head from the acromion, coracoid process, coracoacromial ligament and deltoid muscle. This bursa allows for smooth gliding between the humerus and supraspinatus tendon. Failure of this gliding mechanism may cause pain and limitation of motion of this joint.

The subacromial bursa and supraspinatus tendon lie within the subacromial space. This space is bounded superiorly by the coracoacromial arch and inferiorly by the humeral head. The coracoacromial arch consists of the acromion of the scapula and the coracoacromial ligament (Figure 2). This arch protects the humeral head, muscles, tendons and bursae from direct trauma from above and also prevents the humeral head from dislocating superiorly. The drawback of this arch is that the impact of the humeral head into the arch may cause painful impingement of the supraspinatus tendon and subacromial bursa within the space. Furthermore, various anatomical differences in the shape of the acromion may also contribute to impingement by decreasing the size of the subacromial space and causing irritation to the structures within that space.

Three different shapes of the acromion have been identified: Type I (flat), Type II (curved) and Type III (hooked). It should be noted that the Type III (hooked) acromions are more commonly associated with irritation or tearing to the muscles surrounding the glenohumeral joint. These muscles are commonly referred to as the rotator cuff.

The Rotator Cuff

The rotator cuff is made up of four muscles, the supraspinatus, infraspinatus, teres minor and subscapularis, that originate on the scapula and insert on the tuberosities of the humerus. The tendons of these four muscles fuse together with the lateral part of the
Figure 2. Side view of scapula illustrating coracoacromial arch (Reprinted with permission from Norkin CC, Levangie PK. Joint Structure and Function: A Comprehensive Analysis. 2nd ed. Philadelphia, PA: FA Davis Co; 1992:22).
capsule of the shoulder joint forming a continuous cuff surrounding the humeral head. With the exception of the supraspinatus, all of the rotator cuff muscles assist with rotation of the humerus. These muscles also protect the shoulder joint by providing dynamic stability while holding the head of the humerus in the glenoid cavity of the scapula.\textsuperscript{15,17}

The Supraspinatus Muscle

Many sources agree that the supraspinatus tendon is the most commonly torn tendon of the rotator cuff.\textsuperscript{15,18,19} Due to the high incidence of suprspinatus tearing, this review focuses more closely on the physiological function and tensile properties of this specific muscle.

The high occurrence of injury in the supraspinatus tendon may be due to an area of deficient blood supply. Uhthoff and Lohr\textsuperscript{18} investigated the hypovascularity of the supraspinatus tendon and confirmed that the hypovascular or "critical zone" of the supraspinatus tendon could be found approximately 5 mm proximal to the insertion of the musculo-tendinous junction into bone. A sparse distribution of blood vessels was found in this area of the distal tendon, which is the most common site of tendon rupture. Deficient vascularization weakens the tendon and makes it more susceptible to degenerative changes that may result in tendon failure.

In a study by Rathbun and McNab\textsuperscript{20}, it was demonstrated that vascular filling of this "critical zone" was dependent on arm position with less opportunity for filling when the arm is adducted or brought toward the midline. This is due to lengthening of the tendon when the arm is adducted and compression of the supraspinatus tendon against the humeral head. With abduction of the arm, the supraspinatus tendon is put on slack and there is more opportunity for vascular filling.
In a study by Itoi et al.\textsuperscript{19} the tensile properties of the supraspinatus tendon were investigated. The tendon was divided into 3 strips (anterior, middle, and posterior) and each was loaded to failure. Seventy-six percent of the tendons failed at the insertion point with 21\% failing at midsubstance of the tendon and 3\% sustaining an avulsion fracture of the bone. The ultimate failure load of the anterior strip was 411.1 N, which was significantly greater than the middle and posterior strips. The estimated sum of the ultimate load of the 3 strips averaged to be 652 N which was also similar to the ultimate load of the supraspinatus tendon reported in a study by Wilson and Duff (784 N).\textsuperscript{21}

Howell et. al\textsuperscript{22} conducted a study clarifying the role of the supraspinatus muscle and found that it was active with any motion that involves elevation of the arm at the shoulder joint. According to the length tension curve of the supraspinatus muscle, maximum force was produced at approximately 30\(^{\circ}\) of elevation of the arm.\textsuperscript{23} Wallace\textsuperscript{24} estimated that the supraspinatus produced approximately 300 N of tension at 30\(^{\circ}\) of active abduction in the unloaded arm. This information suggested that in order to exercise a repaired supraspinatus tendon immediately following surgery, the fixation device used in the repair would have to withstand greater than 300 N of force. Because this amount of force would most likely cause a newly repaired tendon to fail, surgeons have often suggested immobilization of the shoulder post-surgery.

Pathology and Prevalence

Rotator cuff tears are an extremely common pathology of the shoulder.\textsuperscript{17} Rotator cuff failure is defined as "a condition in which interference with its function prevents the rotator cuff from fulfilling its physiological role".\textsuperscript{25(p.31)} Uhthoff and Sano\textsuperscript{25} used this definition because they believed that the rotator cuff can fail functionally much earlier
than the point of an actual tear. For example, irritation to the supraspinatus tendon caused by compression of the subacromial space may lead to pain at the shoulder joint and cause the inability to move the shoulder correctly for activities of daily living. Chronic irritation to the tendon may lead to further dysfunction such as a partial or full thickness tear.

Rotator cuff tears can be classified as either partial thickness or full thickness tears. Both partial and full thickness tears present with pain or weakness upon resisted isometric contraction of the involved muscle. Partial tears can be further identified through imaging studies in which thinning of the tendon occurs, however tearing does not extend through the entire tendon. Partial tears are often classified by location of the tear as either articular, bursal or interstitial. Tearing does extend through the entire tendon of a full thickness tear. These tears are classified by the tendon or tendons involved (supraspinatus, infraspinatus, teres minor or subscapularis).

Milgrom and colleagues used ultrasound to study the prevalence of rotator cuff lesions in asymptomatic adults between the ages of 30 years and 99 years old. Their findings suggested that rotator cuff lesions correlated with increasing age and increased markedly after 50 years of age. Partial or full thickness tears were present in over 50% of subjects in their seventh decade and in 80% of subjects in or beyond their eighth decade of life.

This high prevalence of rotator cuff tears can be better understood with knowledge of how these tears occur. The etiology of rotator cuff tears is dependent upon many factors. Tears may result from changes within the tendon or may be secondarily
due to lesions of the bones or soft tissues surrounding the cuff. Changes inside the tendon may be degenerative, traumatic or reactive.

Rotator cuff tears are most commonly due to degenerative changes of the cuff tendon near the insertion into bone. In a study conducted by Wilson and Duff, it was concluded that degenerative changes and incidence of rupture increased with advancing age. They also found that degenerative changes were greater in the dominant shoulder joint due to more frequent muscular contractions. Ruptures of the right shoulder occurred in the majority of cadavers studied by Wilson and Duff. In cases where there was a bilateral rupture, the right shoulder sustained a larger tear than the left shoulder.

Degeneration may lead to tendonitis, which in turn may result in a muscular defect. Rotator cuff failure of traumatic nature may be due to avulsion of the tendon when the tendinous part of the cuff-bone complex is stronger than the bone itself. This fracture may heal naturally, however, if displacement occurs with healing, it may hinder function permanently. Traumatic rotator cuff tears may be caused by athletic activities such as overuse of the arm in the overhead position in throwing athletes.

Reactive rotator cuff failure occurs when there is a decrease in the subacromial space, which leads to irritation and inflammation of the rotator cuff tendon. Over time this irritation may lead to tearing and failure of the rotator cuff. Pathological conditions that may lead to reactive cuff failure include calcific tendonitis, anatomical abnormalities of the acromion, osteophyte formation on the inferior surface of the acromioclavicular joint, and other soft tissue lesions such as subacromial bursitis.
Treatment of Rotator Cuff Tears

Due to high incidence of rotator cuff tears, several treatment options have been explored over the years. The choice of non-operative or operative treatment depends on several factors which include the patient's age and activity level, anticipated functional demands on the shoulder and the reported outcomes of the treatment.\(^\text{16}\)

Non-operative or conservative treatment may consist of rest, heat, massage, anti-inflammatory medication, capsular stretching and muscle strengthening and is most often used when inflammation or muscle strain is present.\(^\text{17}\) If symptoms do not improve within 3 months, an arthrogram is often performed to rule out the possibility of a more traumatic lesion.

Operative or surgical treatment consists of acromioplasty, debridement and/or tendon repair.\(^\text{17}\) Surgical repair of the tendon becomes necessary when the patient continues to experience progressive pain or functional deficits.\(^\text{8}\) According to Samilson and Binder\(^\text{28}\), the following are indications for operative repair of non-acute cuff tears:

1. Patients who are physiologically younger than 60 years old.
2. Patients with a full-thickness cuff tear.
3. Patients who fail to improve with non-operative treatment for a period of 6 weeks or more.
4. Patients with a need for functional use of the injured rotator cuff.
5. Patients with full passive range of motion of the shoulder joint.
6. Patients who have the ability and willingness to cooperate with rehabilitative and post-surgical needs.
7. Patients willing to exchange decreased pain and increase external rotation strength for some loss of active abduction.

The most common technique for tendon reattachment was described by McLaughlin\(^5\) in 1944. This technique involves suturing the tendon into a bony trough through the cortical surface of the greater tuberosity, thus securing the tendon to bone.\(^6\) This technique has become the 'gold standard', and has produced good to excellent results post-operatively.\(^6,9\)

Gazielly et al.\(^{29}\) found improved functional results post-operatively using a functional score, developed by Constant and Murley, in 100 full thickness rotator cuff tears repaired with the McLaughlin technique. All patients in this study received the same surgery (anterior acromioplasty and tendon reattachment into a bony trough with sutures) by the same surgeon. Pre-operative functional status in these patients averaged 46 out of 100 points and was improved post-operatively to 81.51 out of 100 points.

Despite good functional outcomes with the McLaughlin technique, there are drawbacks. According to Kenter and Warren\(^6\), "this technique requires accurate skin incision for optimal exposure and precise soft tissue dissection for correct tunnel placement."\(^{(p.55)}\) Other complications may include failure of fixation due to rupture of the suture material or loss of the sutures grasp on the tendon.\(^9\) Other popular fixation methods include absorbable sutures, staples, suture anchors, screws with plates or washers and suture augmentation with a patch, button or tape.\(^6\)\(^{-10}\)

Suture augmentation is defined as placing a biocompatible material between the suture and underlying bone or soft tissue.\(^8\) Augmentation devices, such as patches, buttons or tape, are used to increase functional surface area and distribute stresses of the
repair over a greater area. In the geriatric population, the use of the augmentation method for repair reinforces weak, osteoporotic bone and has been quite useful. Augmentation in the younger population with healthier bone has been found to be desirable as well when considering the possibility of an earlier and more aggressive rehabilitation program with an earlier recovery.

Caldwell et al. studied the mean ultimate strength of transosseous sutures compared to sutures augmented with the use of a plastic button. Results demonstrated that the ultimate fixation strength improved from $96 \pm 54$ N without augmentation to $183 \pm 57$ N with augmentation.

France et al. evaluated fixation methods that included standard suture, suture repair with patch augmentation, suture repair with tape augmentation and lastly, staples. The researchers found the use of tape augmentation to show no significant increase (105 N) in fixation strength compared to the standard suture repair (117.8 N), however patch augmentation demonstrated significantly higher initial failure loads (211.6 N) when compared to the standard suture repair. France and colleagues suggested that the use of staples for tendon repair should be avoided due to insignificant strength (136.8 N) after repair. The mode of failure was observed as the staple was pulled out of the bone or the tendon tore around the staple. Failure modes in the other 3 types of repair were also observed and included the suture fracturing the cortex and cutting through the bone or by the suture tearing through the tendon. France and colleagues suggested that the mode of failure was due to bone integrity.

Suture anchors are devices used in arthroscopic surgery which allow direct fixation of soft tissues into bone with a tack-like anchor but also include suturing the
This device is being used for anterior cruciate ligament (ACL) repairs, Bankart (labral) repairs and rotator cuff repairs. The use of suture anchors in rotator cuff tears help to shorten surgery time compared to standard sutures, decrease impingement problems and provide optimal pullout strength. Suture anchor repairs have been reported to have significantly greater strength than standard suture repairs.

Reed and colleagues found suture anchors to have a mean strength to failure of 216 ± 69 N compared to 194 ± 70 N in the suture alone. Rossouw and colleagues found the greatest strength of suture anchor repair to be 363 ± 120 N with anchors angled 90° to the lateral cortex of the humeral head versus 299 ± 59 N when placed at a 45° angle. Both methods were significantly stronger than when the suture anchor was placed in the base of the trough, which failed at 147 ± 74 N.

Figure 3 summarizes the ultimate pullout strengths of the above studies of the current surgical techniques used to repair rotator cuff tendons.

Bioabsorbable Tacks

Bioabsorbable tacks were developed to secure soft tissue to bone while facilitating healing of the injured soft tissues to the bone surface. Bioabsorbable tacks have been successfully used in repairing glenohumeral labral tears as well as ACL repairs in knees.

Absorbable fixation devices should weaken over time as the healing tissues gain integrity and are able to accommodate. If the absorbable fixation devices absorb too quickly, the tissues fail due to insufficient healing time and inability to adapt to applied loads. On the other hand, fixation devices that absorb too slowly not only limit the transfer of physiological load to the tissues, but also may react similarly to metal implants.
Figure 3. Ultimate pullout strengths for current surgical techniques.\textsuperscript{1,2,5,6} A) Sutures, B) Button, C) Tape, D) Patch, E) Staples and F) Suture Anchors.
with complications such as breakage, loosening and migration. Bioabsorbable implants have two major advantages over non-bioabsorbable implants: 1) gradual load transfer to healing bone and 2) no need for surgical removal.³⁰

For the purpose of this study, the researchers specifically focused on 4 bioabsorbable tacks: 1) Bionx tack style A, 2) Bionx tack style B both made by Bionx Inc., 3) Suretac style A and 4) Suretac style B both made by Smith and Nephews.

The Bionx tacks consist of a barbed design on the tack shaft and undersurface of the tack head and are generally used in repairs of non-contractile tissue such as labral tears of the glenohumeral joint.⁵¹ These tacks are made of pure Poly-L-lactic acid (PLLA) material, which has been found to be resistant to degradation for periods from 2 years to 6 years in vivo.³¹,³²

In a study by Stahelin et al.³³, 2 PLLA screws were used for bone plug fixation in an ACL repair in a 42-year-old male. Evaluation of the screws was done at 4 and 20 months post surgery with re-arthroscopy. At 4 months, there was no evidence of degradation of the bioabsorbable screw. At 20 months, fragmentation of the screw occurred but without apparent evidence of degradation.

Rupp et al.¹⁴ found no significant difference in terms of fixation strength when comparing a bioabsorbable interference screw, made of PLLA, with a titanium interference screw. This study involved reconstruction of a porcine ACL using the two different screw types. The bioabsorbable screw had an ultimate failure strength of 805.2 N and the titanium screw had an ultimate failure strength of 768.6 N. The failure site in all screws was at the point of attachment with no breakage observed in the bioabsorbable screw.
Both styles of Suretac tacks are also indicated for Bankart tear repair and are made up of a polyglyconate molded from a copolymer of polyglycolic acid (PGA) and trimethylene carbonate. This cannulated tack is designed with ribs on the shaft of the tack to increase its pullout strength. The Suretac also has a broad flat head allowing it to capture soft tissue and hold it to the bone when implanted. The Suretac is degraded by hydrolysis and therefore, exposure to hydrated air for long periods of time will begin this process.

Dr. Mark Walton evaluated the histological response of the Suretac in a sheep study in which he used the tack to re-attach the distal patellar tendon to the tibia. The study showed the Suretac to be considerably degraded by 12 weeks post surgery with the tendon firmly fused onto the bone and fibrous tissue occupying the space left by the absent tack. No evidence of an adverse tissue reaction was noted when monitored at 2, 6 and 12 weeks post-implant. This information suggested that sheep tissue reacted well to the Suretac, even during degradation, and does not reject it as a foreign object.

The Suretac was also implanted into the proximal humerus of canines and degradation rates were studied for up to 24 weeks. The heads of the tacks were loose and displaced at 6 weeks with connective tissue surrounding the implant. At 12 weeks, the heads of the tacks had broken away from the shafts, with pitting of the shaft noted as well as trabecular bone seen in many of the pits. Several tack heads were not distinguishable at 18 weeks. By 24 weeks, all of the implants were degrading and no heads were found. Further research suggested that due to degradation, the Suretac completely loses all of its original strength at 4 weeks post implantation. For example, side bending strength is lost at a rate of 4.13 kg/week, again with a complete loss of
strength at 4 weeks. The Suretac degrades at a considerably faster rate than the Bionx tacks, however it still allows an appropriate time frame for healing tissues.

Walton\textsuperscript{13} compared the graft security of an ACL repair in sheep using an absorbable polyglyconate screw versus a metal interference screw. Results of the study showed comparable pullout strengths between the two screw types with no significant difference in failure strengths. Both screw types showed a decline in mean failure strength over 4 to 6 weeks, then a steady increase to 12 weeks. Walton’s study established that an absorbable screw would be strong enough to hold the graft in position until there was sufficient tissue healing to eliminate the need for the screw.

**Purpose of the Study**

The purpose of this study was to compare and determine the ultimate pullout strength of four types of bioabsorbable tacks, both perpendicular to the tack shaft and parallel to the tack shaft. Mode of failure was also assessed.

**Significance of the Study**

The significance of this study was to determine the ultimate pullout strength of four bioabsorbable tacks and if this had implications on rehabilitation. Bioabsorbable tacks have already been proven to be successful in repairing non-contractile tissue\textsuperscript{12-14} Tendons however are contractile tissue, which will produce a force on the injured tendon as well as the fixation device if the muscle is actively contracted. In order to successfully repair a tendon, the surgical fixation device must be strong enough to resist active contraction as well as a stretch from passive range of motion. Otherwise, the joint must be immobilized until the tissue has healed enough to withstand physiological force without failing.
It is also important to determine the mode of failure of the tack. If the tack does not exit the bone entirely upon ultimate pullout, excess tack fragments could cause irritation to the shoulder joint until degradation and absorption occur.

Research Questions

Through this study the researchers hoped to answer questions regarding the use of bioabsorbable tacks in rotator cuff repairs: 1) What is the pullout strength of the different tack types analyzed in this study? 2) Is there a difference in pullout strength between the 4 tack types? 3) Is the ultimate pullout strength of the tack enough to withstand active contraction produced by the tendon? 4) What is the mechanism of failure if the repair should fail?

Hypotheses

The null hypotheses stated that: 1) There is no significant difference between tacks in pullout strength parallel to the tack shaft. 2) There is no significant difference between tacks in pullout strength perpendicular to the tack shaft.

The alternate hypotheses stated that: 1) There is a significant difference between tacks in pullout strength parallel to the tack shaft. 2) There is a significant difference between tacks in pullout strength perpendicular to the tack shaft.

With this study the researchers hoped to increase the amount of knowledge regarding the use of bioabsorbable tacks in the repair of contractile tissue of the shoulder. It was also hoped to have a better understanding of the strength factor of these tacks and whether an accelerated rehabilitation program would have detrimental effects on the repair. Lastly, a comparison of the four tacks analyzed in this study was hoped to present
knowledge about which tack or tacks would be the most viable option for the repair of a supraspinatus tendon.
CHAPTER II

METHODS

Materials

Four different types of bioabsorbable tacks with two different biochemical compositions were used for this study. They include: 1) Suretac A, 2) Suretac B (Smith & Nephew Inc. 160 Dascomb Rd., Andover MA 01810 U.S.A.), which are polyglyconate absorbable fixators, made from a copolymer of PGA and trimethylene carbonate; 3) Bionx tack A, 4) Bionx B (Bionx Implants Inc. 1777 Sentry Parkway W. Gwynedd Hall, Suite 400 Blue Bell, PA 19422 U.S.A.) which are made of PLLA (Figure 4). A total of 46 tacks were tested: Suretac A (n=20), Suretac B (n=10), Bionx A (n=10), Bionx B (n=6).

The Suretac tacks were separated into A and B categories due to the fact that the groups of tacks were received and tested at separate time intervals. There was not a measurable difference in width or length between the two Suretac styles. The Suretac contains barbs along the outer rim of the undersurface of the head of the tack and ribs along the shaft.

The Bionx tacks were separated into A and B groups based on measureable differences in tack designs. Both Bionx tack styles contain different barb designs on the undersurface and on the tack shaft. The barbs on the undersurface of the head of Bionx A were smaller and rounded in comparison to the longer, more pointed barbs on the Bionx
Figure 4: Comparison of Suretac and Bionx tack types. A) Suretac A & B, B) Bionx A, C) Bionx B.
B tack. Barbs on the shaft of Bionx A were staggered and less flared out from the surface of the shaft in comparison to the evenly placed barbs, which were more flared on the Bionx B tack. Table 1 illustrates the difference in tack dimension designs between the Suretac and Bionx tack styles.

A piece of high-density, polyurethane foam (Pacific Research Labs Inc. 10221 S.W. 188th St. Yashon, WA 98070 U.S.A.) was used to simulate human bone (density of 30 lbs/cubic ft). A preliminary ultimate parallel pullout strength test was done to assess 10#, 15#, 20# and 30# densities of the foam board as compared to the cortical bone in the greater tuberosity of a porcine humeral head. This revealed an equivalent comparison between the 30 lb. foam board and the bone.

Instrumentation

An Omega model LC101 ‘S’ Beam Load Cell was used to measure the force placed on each tack during testing procedures. The load cell was attached to a computer and a ‘Strawberry Tree’ analog input card, model ACPC-12-8, was used to record the data in mV transmitted from the load cell. The data was later converted to Newtons for analysis. A custom-made fixation device (Airlift Technology, 6520 Lake Dr. Grand Forks, ND 58201) was used to secure the test setup (Figure 5).

Procedure

Force measurements were recorded under 2 different test conditions: 1) force applied parallel to and 2) force applied perpendicular to the shaft of each tack. Tacks were implanted into a foam board following the manufacturer's instructions which entailed: pre-drilling a hole into the foam board, placement of each tack on a guide-wire
Table 1. Dimensions of different tack styles measured in inches.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Suretac (A &amp; B)</th>
<th>Bionx A</th>
<th>Bionx B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of tack</td>
<td>.707</td>
<td>.822</td>
<td>.787</td>
</tr>
<tr>
<td>Length of top of tack head to start of</td>
<td>.247</td>
<td>.384</td>
<td>.387</td>
</tr>
<tr>
<td>rib/barb</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter of tack shaft just under tack</td>
<td>.144</td>
<td>.144</td>
<td>.141</td>
</tr>
<tr>
<td>head</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter of tack shaft at tip of shaft</td>
<td>.112</td>
<td>.138</td>
<td>.137</td>
</tr>
<tr>
<td>head</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter of tack head</td>
<td>.294</td>
<td>.280</td>
<td>.276</td>
</tr>
<tr>
<td>Thickness of tack head</td>
<td>.071</td>
<td>.062</td>
<td>.076</td>
</tr>
</tbody>
</table>
Figure 5. Setup of device used for testing pullout strength.
into the hole and pounding the tack with a cannulated driver to secure it into the foam board. A single researcher implanted each tack to ensure consistency of placement and to decrease error. Tacks pulled parallel to the tack shaft were inserted into an aluminum collar/bracket (Northern Valley Machine, 1510 Gateway Dr. NE, East Grand Forks, MN 56721) prior to implantation into the foam board. This collar was used to ensure well-distributed pull on the entire tack (Figure 6). Tacks pulled perpendicular to the tack shaft were implanted directly into the foam board securing a Kevlar tendon between the tack head and foam. The Kevlar tendon was composed of 12 strands of Hexcel’s #710 Farric and was used to simulate the supraspinatus tendon.

The aluminum collar or the Kevlar tendon was attached to the load cell and the entire structure was affixed to the stationary holding device. Slack was then removed from the system by manually tightening a hex nut using a crescent wrench. Force was continually applied to the system until the tack pulled free of the foam board. Force data was measured by the load cell and recorded on the computer.

Data Analysis

Data was analyzed using the Statistical Package for Social Sciences (SPSS) using a one-way, independent measures Analysis of Variance (ANOVA) and Kruska-Wallis which is a non-parametric test. Comparisons of the 4 tacks were analyzed to assess mean ultimate pullout strength, standard deviation, and to determine if a significant difference existed between any of the 4 tack types.

When using a one-way ANOVA to analyze data, three assumptions must be met: 1) homogeneity of variance 2) normal distribution and 3) interval ratio data. When
Figure 6. Collar/Bracket used to apply equal force upon parallel pullout.
analyzing assumptions of parallel pullout strength, homogeneity of variance was not met; for perpendicular pullout strength, normal distribution was not met. This required the use of the non-parametric Kruskal-Wallis test. The calculated $p$ value was less than alpha (for parallel pullout $p = .001$, for perpendicular pullout $p = .007$) on the Kruskal-Wallis indicating that there was a significant difference in pullout strength between tacks. According to Lindquist,\textsuperscript{36} because a significant difference was noted in both Kruskal-Wallis and ANOVA, the ANOVA results can be reported utilizing a higher significance level. Therefore, the alpha level of $p = .025$ was considered significant.
CHAPTER III
RESULTS
Parallel pullout

Table 2 summarizes the mean pullout strength, standard deviation, maximum and minimum scores for each tack. The results indicate that the Bionx B tack withstood the greatest mean ultimate pullout strength at 292.04 N ± 18.31 N compared to the Suretac A which produced the lowest mean ultimate pullout strength at 79.19 N ± 14.87 N. Bionx A produced the largest standard deviation of 55.64 N compared to Suretac A which produced the lowest standard deviation of 14.87 N. Suretac B and Bionx A produced remarkably similar mean ultimate pullout strengths (147.64 N and 150.25 N respectively).

Analysis of the one-way ANOVA indicated a significant difference between tack types pulled parallel to the tack shaft where F(3,21) = 33.30 and p = .000. Scheffe’s test was used for post hoc analysis at a significance level of α=.025. Table 3 summarizes pairwise comparison of the pullout strengths. Results indicate that Suretac A had a significantly lower mean pullout strength than all other tack styles. Bionx A and Suretac B did not have a significantly different mean pullout strength, although the standard deviation of Bionx A was quite different from Suretac B (55.64 N compared to 18.16 N respectively). Bionx B had a significantly higher mean pullout strength than all other tack styles.
Table 2. Comparison of tack pullout strength parallel to tack shaft

<table>
<thead>
<tr>
<th>Tack</th>
<th>n</th>
<th>Mean (N)</th>
<th>Standard Deviation</th>
<th>High Score (N)</th>
<th>Low Score (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suretac (A)</td>
<td>10</td>
<td>79.19</td>
<td>14.87</td>
<td>97.50</td>
<td>50.79</td>
</tr>
<tr>
<td>Suretac (B)</td>
<td>5</td>
<td>147.64</td>
<td>18.16</td>
<td>171.95</td>
<td>120.85</td>
</tr>
<tr>
<td>Bionx (A)</td>
<td>7</td>
<td>150.25</td>
<td>55.64</td>
<td>223.92</td>
<td>75.26</td>
</tr>
<tr>
<td>Bionx (B)</td>
<td>3</td>
<td>292.04</td>
<td>18.31</td>
<td>312.96</td>
<td>278.89</td>
</tr>
</tbody>
</table>

Table 3. Pairwise comparison between tacks when pulled parallel to tack shaft

<table>
<thead>
<tr>
<th>(I) Tacks</th>
<th>(J) Tacks</th>
<th>Mean Difference (I-J)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suretac A</td>
<td>Suretac B*</td>
<td>-68.45</td>
<td>.010</td>
</tr>
<tr>
<td>Bionx A*</td>
<td></td>
<td>-71.07</td>
<td>.003</td>
</tr>
<tr>
<td>Bionx B*</td>
<td></td>
<td>-212.86</td>
<td>.000</td>
</tr>
<tr>
<td>Suretac B</td>
<td>Suretac A*</td>
<td>68.45</td>
<td>.010</td>
</tr>
<tr>
<td>Bionx A</td>
<td></td>
<td>-2.61</td>
<td>.999</td>
</tr>
<tr>
<td>Bionx B*</td>
<td></td>
<td>-144.41</td>
<td>.000</td>
</tr>
<tr>
<td>Bionx A</td>
<td>Suretac A*</td>
<td>71.07</td>
<td>.000</td>
</tr>
<tr>
<td>Suretac B</td>
<td></td>
<td>2.61</td>
<td>.999</td>
</tr>
<tr>
<td>Bionx B*</td>
<td></td>
<td>-141.79</td>
<td>.000</td>
</tr>
<tr>
<td>Bionx B</td>
<td>Suretac A*</td>
<td>212.86</td>
<td>.000</td>
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<tr>
<td>Suretac B*</td>
<td></td>
<td>144.41</td>
<td>.000</td>
</tr>
<tr>
<td>Bionx A*</td>
<td></td>
<td>141.79</td>
<td>.000</td>
</tr>
</tbody>
</table>

* Mean difference is significant at $p < .025$
Failure modes of both Suretac styles occurred by intact and complete pullout from the foam. All Bionx A tacks pulled out intact with the exception of one which failed by complete breakage of the shaft leaving part of the shaft in the foam. Bionx B tacks tested had different modes of failure. Failure occurred by complete shaft breakage, intact pullout and avulsion of the foam with the tack (Figure 7).

Perpendicular pullout

Table 4 summarizes the mean ultimate pullout strength, standard deviation, maximum and minimum scores for each tack. Our results indicated that Bionx B withstood the greatest mean ultimate pullout strength at 468.47 N ± 4.21 N compared to Suretac A which withstood the lowest mean ultimate pullout strength at 279.75 N ± 40.46 N. Suretac B produced the largest standard deviation of 46.33 N compared to Bionx B which produced the lowest standard deviation of 4.21 N. Standard deviations were similar for all tacks with the exception of Bionx B which was much lower.

Analysis of the one-way ANOVA indicated a significant difference between tack types pulled parallel to the tack shaft where F(3,21) = 19.44 and p = .000. Scheffe’s test was used for post hoc analysis at a significance level of α = .025. Table 5 summarizes pairwise comparison of the pullout strengths. Results indicate that Bionx B had a significantly higher mean pullout strength than all other tack styles. Bionx A did not have a significantly higher mean pullout strength than either Suretac styles.

Failure mode of both Suretac styles was intact and complete pullout of the tack from the foam, however bending of the tack shaft did occur (Figure 8). All Bionx A tacks failed by breakage of the tack shaft leaving part of the tack shaft in the foam.
Figure 7. Failure modes of Bionx tack types. A) Avulsion of the foam 
B) Partial fracture of the tack shaft C) Complete fracture of tack shaft 
D) Intact tack for reference.

Figure 8. Failure mode of Suretac. A) Bending of tack shaft 
B) Intact tack for reference.
Table 4. Comparison of tack pullout strength perpendicular to tack shaft

<table>
<thead>
<tr>
<th>Tack</th>
<th>n</th>
<th>Mean (N)</th>
<th>Standard Deviation</th>
<th>High Score (N)</th>
<th>Low Score (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suretac (A)</td>
<td>10</td>
<td>279.75</td>
<td>40.46</td>
<td>377.76</td>
<td>245.05</td>
</tr>
<tr>
<td>Suretac (B)</td>
<td>5</td>
<td>354.02</td>
<td>46.33</td>
<td>413.83</td>
<td>285.32</td>
</tr>
<tr>
<td>Bionx (A)</td>
<td>3</td>
<td>290.64</td>
<td>37.91</td>
<td>314.00</td>
<td>246.90</td>
</tr>
<tr>
<td>Bionx (B)</td>
<td>3</td>
<td>468.47</td>
<td>4.21</td>
<td>472.84</td>
<td>464.45</td>
</tr>
</tbody>
</table>

Table 5. Pairwise comparison between tacks when pulled perpendicular to tack shaft

<table>
<thead>
<tr>
<th>(I) Tacks</th>
<th>(J) Tacks</th>
<th>Mean Difference (I-J)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suretac A</td>
<td>Suretac B</td>
<td>-74.28</td>
<td>.026</td>
</tr>
<tr>
<td></td>
<td>Bionx A</td>
<td>-10.90</td>
<td>.980</td>
</tr>
<tr>
<td></td>
<td>Bionx B*</td>
<td>-188.73</td>
<td>.000</td>
</tr>
<tr>
<td>Suretac B</td>
<td>Suretac A</td>
<td>74.28</td>
<td>.026</td>
</tr>
<tr>
<td></td>
<td>Bionx A</td>
<td>63.38</td>
<td>.220</td>
</tr>
<tr>
<td></td>
<td>Bionx B*</td>
<td>-114.45</td>
<td>.009</td>
</tr>
<tr>
<td>Bionx A</td>
<td>Suretac A</td>
<td>10.90</td>
<td>.980</td>
</tr>
<tr>
<td></td>
<td>Suretac B</td>
<td>-63.38</td>
<td>.220</td>
</tr>
<tr>
<td></td>
<td>Bionx B*</td>
<td>-177.83</td>
<td>.000</td>
</tr>
<tr>
<td>Bionx B</td>
<td>Suretac A*</td>
<td>188.73</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Suretac B*</td>
<td>114.45</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Bionx A*</td>
<td>177.83</td>
<td>.009</td>
</tr>
</tbody>
</table>

*Mean difference is significant at \( p < .025 \)
Bionx B failed in two different modes. Failure occurred once by intact and complete tack pullout and twice by fracturing the tack shaft with complete pullout (Figure 7).

Figures 9 and 10 summarize the mean, standard deviation and significance level for parallel and perpendicular pullout.
Figure 9. Mean ultimate pullout strength of bioabsorbable tacks pulled parallel to tack shaft. (* indicates significant difference, Suretac A is significantly lower than all other tack types where $p = .01$, Bionx B is significantly higher than all other tack types where $p = .000$).

Figure 10. Mean ultimate pullout strength of bioabsorbable tacks pulled perpendicular to the tack shaft. (* indicates significant difference, Bionx B is significantly higher than all other tack types where $p = .01$).
CHAPTER IV
DISCUSSION/CONCLUSION

The goal of this study was to answer questions regarding the use of bioabsorbable tacks for the fixation of contractile tissue during rotator cuff surgery. The researchers hoped to answer questions pertaining to the ultimate pullout strength and the mode of failure once failure occurred between the foam-tack interface.

Ultimate Pullout Strength

Statistical analysis lead the researchers to reject both null hypotheses and accept both alternate hypotheses stating that there is a significant difference between tacks in pullout strength parallel and perpendicular to the tack shaft. The results indicated a variety of different pullout strengths of the 4 bioabsorbable tacks both parallel and perpendicular to the tack shaft. Bionx B however, was the strongest of the 4 tack types tested in this study in terms of pullout strength both parallel and perpendicular, and Suretac A was the weakest. These findings would suggest that if the surgeon were simply looking to use the tack with the greatest ultimate pullout strength regardless of mode of failure, Bionx B would be the tack to use.

Another positive aspect of the Bionx B tack was that the standard deviation of ultimate pullout strength was remarkably lower than the other 3 tack types tested during perpendicular pullout. This would suggest that the manufacturing of this tack is quite consistent and produces a high quality product that will have consistent outcomes.
The variation in ultimate pullout strength of the tacks measured may have to do with the different tack designs and how they were manufactured. The barbed design on the shaft and undersurface of the head of the Bionx tacks would appear to resist more pullout strength than the ribs on the shaft of the Suretac designs. The barbs give the Bionx tacks a better advantage at gripping the bony surface and resisting a higher force of pullout. Also, the tack shaft is longer on both Bionx tack styles versus the Suretac styles, giving the Bionx tack more surface area to grip, thus resisting more force. The length of the tack shaft just under the head of the tack to the start of the barbs (Bionx) or ribs (Suretac) is longer on the Bionx tack styles, which is another factor that may contribute to greater strength to resist pullout.

Composition is another difference in how the tacks were manufactured. The Bionx tacks are composed of PLLA\textsuperscript{13,51b} compared to the Suretac styles which are made up of a polyglyconate molded from a copolymer of PGA and trimethylene carbonate.\textsuperscript{14} When looking at degradation characteristics, the Bionx tacks are composed of material that does not degrade for up to 2-6 years,\textsuperscript{13,51b} whereas both styles of Suretac take only 24 weeks\textsuperscript{56} to degrade. The materials these tacks are composed of may have a significant impact on strength of resistance to force.

A second question regarding ultimate pullout strength pertained to whether or not these bioabsorbable tacks could resist enough force to withstand a contraction from the supraspinatus tendon. The supraspinatus tendon produces approximately 300 N of force at thirty degrees of active abduction in the unweighted arm.\textsuperscript{42,40} In order for active contraction of the muscle to be safe immediately following surgery and without causing failure of the repair, the tack and tendon would need to resist a force of at least 300 N.
Results indicated that mean scores of all 4 tack types did not resist greater than 300 N of pullout strength when pulled parallel to the tack shaft. However, when analyzing angle of pullout, perpendicular pullout is a more realistic value than parallel pullout in terms of how these tacks would be fixated in the shoulder. Mean scores for Suretac B and Bionx B did exceed 300 N of perpendicular pullout strength (354.02 N and 468.47 N respectively).

Although these results indicate a larger force than 300 N, one cannot be absolutely sure that they will resist active contraction of the supraspinatus tendon. These results are a mean or average score, therefore some of the tacks may fail at a lower force and some, a much higher force. Due to the small sample size in each group, generalizing the results to every tack manufactured would be inappropriate. Also, Itoi et al. estimated the supraspinatus tendon to fail at 652 N of force. Measurements of tendon failure were not included as a part of this study and therefore it cannot be determined if a damaged tendon would fail prior to or after the tack would fail.

Based on the results of this study, it can be concluded that Suretac A and Bionx A were not strong enough to withstand the level of force equivalent to an active contraction of the supraspinatus muscle with fixation of the tendon and tack. The contraction would produce too great a force and cause the tack to fail. Ultimate pullout strength is an important aspect to assess when choosing the most appropriate tack for surgical fixation, however there are other factors such as mode of failure of the tack that play a part as well.
Mode of Failure

Evaluation of the failure modes of the tacks provides some insight to post-surgical complications if failure should occur. Both Bionx tack types failed by fracturing the shaft and leaving pieces imbedded in the foam board. If failure would occur using these tacks, tissues within the shoulder complex could perhaps become impinged or irritated until the tack degrades which could take up to 2 to 6 years.\textsuperscript{13,32} This would create the need for the surgeon to go back into the shoulder to remove the broken fragment of the failed tack and repair the structure again.

Both Suretac styles pulled out of the bone entirely leaving nothing behind in the foam board. If a surgeon were to go back into the shoulder due to a failed repair, it would be easier to remove a tack that was in one piece as opposed to fragments of tacks and pieces that are still imbedded in the bone. However, it is still in the best interest of the patient to be free of any complications following surgery. This complication can be minimized by immobilization of the arm following surgery until adequate healing has taken place.

Clinical Implications

The idea of an accelerated rehabilitation program may enter one’s mind with advances in surgical techniques. Third party payers may be especially interested in what the advantages are of using these newer techniques in surgery. Unfortunately, early mobilization of the shoulder following surgery would not be appropriate when using the bioabsorbable tacks tested in this study for the repair of the supraspinatus tendon. The results of this study indicate that immobilization of the shoulder following surgery is appropriate due to insufficient pullout strength of the tacks, specifically Suretac A and
Bionx A. Suretac B and Bionx B do withstand perpendicular pullout forces greater than 300 N, but due to uncertainty regarding other aspects of failure, again it is appropriate to immobilize the shoulder joint following surgery until further studies can determine the load that the damaged tendon can withstand. Although each patient should be treated individually, a standard rotator cuff protocol can be used as a guide during rehabilitation of the shoulder. Precautions advised by the surgeon should also be followed during rehabilitation of patients with rotator cuff surgery.

Limitations of the Study

Limitations of this study included the inability to obtain a sufficient sample size of each tack type to be tested. A sample size of at least 30 is usually suggested to generalize to the population. Therefore, a sample of 6 Bionx B tacks is not an appropriate sample size to make assumptions about the Bionx B tacks to the general population. This study however, is a good baseline for future studies to further analyze the capabilities of these biodegradable tacks in larger sample sizes for repair of contractile tissue.

Another limitation of our study was that during tack fixation into the foam board, we had access to only the arthroscopic fixating device for the Suretac. This device consisted of a drill bit to make a pilot hole into the foam board and was designed for only the diameter of the tack shaft of the Suretac, which is smaller at the tip of the tack shaft than both Bionx tack styles. When fixating the Bionx tacks into the pre-drilled pilot hole, it was apparent to the researchers that this hole was smaller than the diameter of the tack shaft. Fixation of the Bionx tack styles into the foam block using the cannulated driver required greater force by the researchers than did fixation of both Suretac styles. This
could have had an effect on how tight the tack was placed into the foam board and may have skewed our results somewhat by resisting a greater amount of force upon pullout than there would be if the pilot hole had been drilled with the appropriate sized drill bit.

Equipment limitations were also lacking in the area of placing tension on the tack. The manual technique to place tension on the tack was inconsistent with every tack because tension was placed on the tacks at the speed of the researcher by turning a crescent wrench. This inconsistency created a problem when looking at the amount of force placed on the tack for long periods of time. The longer a force is placed on the tack, a greater amount of creep will be added to that tack causing failure at a lower force than a tack that has been resisting tension for a shorter period of time. Therefore, the slower the researcher turned the crescent wrench, the lower the pullout force would be which may have skewed the results of the study somewhat.

Future Studies

This study is a good baseline for future studies to assess the capabilities of bioabsorbable tacks in contractile tissue repair. Increasing the sample size of tacks in future studies would give more powerful results and would make a better comparison to the population of tacks being tested. A sample size of greater than 30 tacks in each testing condition is suggested to increase reliability of the results.

Further research involving a study using human cadaver tendon and bone could be set up quite similar to this study but would assess the capabilities of the tendon as well as the tack. A cadaver study would be a more realistic comparison of how these tacks would react to human tissues and bone. Although cadaver tissue is not an exact replica of living tissue, it is a more realistic comparison than using artificial foam blocks to
replicate human bone and Kevlar to represent human tendon. In an ideal testing situation, these studies would be done in living human tissue. This is obviously not possible, therefore the next best thing would be an animal study possibly using sheep, pigs or dogs.

A study analyzing the functional outcomes of patients who have undergone rotator cuff repairs with these particular biodegradable tacks would be beneficial to evaluate how these tacks function in the human body and if they are truly viable repair options. Aspects of a study such as this could include chart reviews, time frames for rehabilitation, range of motion gains, strength gains, functional gains, follow-up screening and re-occurrence of tendon failure.

Conclusion

Review of the literature presented many different surgical techniques in rotator cuff repair. Tears can be surgically repaired with fixation devices such as sutures, sutures with augmentation, suture anchors, staples, screws and now bioabsorbable tacks. The results of this study have indicated that indeed, bioabsorbable tacks share similar qualities of pullout strength when compared to other surgical fixation devices being used for the repair of contractile tissue.

This study answered many questions pertaining to the capabilities for surgical repair of the 4 bioabsorbable tacks tested in this study. The results concluded that the Bionx B tack was the strongest tack in terms of ultimate pullout strength. However, one must weigh the advantages and disadvantages when choosing the most appropriate surgical fixation device and consider other aspects of repair failure. One such aspect analyzed in this study was mode of failure. Due to its relatively clean mode of failure
leaving no fragments behind, surgeons may prefer the Suretac design over the Bionx design.

Due to the high incidence of rotator cuff tears seen in the physical therapy clinic, it is important that the therapist has an appropriate amount of knowledge regarding the surgical procedure used with each individual patient. This knowledge will assist the therapist in designing an appropriate rehabilitation program following the surgeon's guidelines or protocol and based on individual patient needs.
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