

# Suture Anchors and Tacks for Shoulder Surgery, Part 1

## Biology and Biomechanics

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The development and successful clinical application of suture anchors and tacks have revolutionized the surgeon's ability to secure soft tissues to bone via open or arthroscopic surgical techniques. When used carefully and with proper technique, these devices provide viable options for the repair and reconstruction of many intra-articular and extra-articular abnormalities in the shoulder, including rotator cuff tears, shoulder instability, and biceps lesions that require labrum repair or biceps tendon tenodesis. Like many technologies, however, the successful application of these devices requires an understanding of the biology and biomechanics that affect their use in the shoulder as well as knowledge of the factors that can affect subsequent clinical outcomes, including complications.

**Keywords:** shoulder; anchors; fixation; rotator cuff; instability; labrum

The attachment of soft tissue to bone remains an important part of the practice of orthopaedic surgery. The surgeon's armamentarium for attaching ligaments, tendons, or other tissues to bone includes pullout suture techniques, keyhole techniques, smooth or barbed soft tissue staples, and fixation with screws and washers.<sup>51</sup> Each of these devices and techniques has advantages and disadvantages, depending on the surgical situation and the clinical application.

The development of suture anchors and tacks, which have revolutionized soft tissue fixation to bone, has paralleled the development of arthroscopic surgical techniques and is particularly applicable to surgical procedures for the shoulder joint. Suture anchors and tacks have been used successfully for rotator cuff repairs, shoulder reconstructions for instability, the repair of biceps anchor lesions (eg, superior labrum anterior posterior [SLAP] lesions), and biceps tenodesis. The continuing evolution of suture anchors and tacks has produced a variety of types, such as absorbable, nonabsorbable, screw-in, hooked, and knotless

anchors and tacks, as well as those that lock into the bone on insertion. Sutures, too, are available in several forms, including braided, unbraided, absorbable, nonabsorbable, and hybrid types (eg, FiberWire, Arthrex, Naples, Fla; Orthocord, DePuy-Mitek, Norwood, Mass; and ForceFiber, Stryker Endoscopy, San Jose, Calif).

Because one type of anchor or tack may be more appropriate than another for a particular surgical procedure, the clinician should understand the basic biomechanical principles, biological interaction, and precautions for anchor and tack use. The goals of part 1 of this 2-part article are to review the biological and biomechanical factors that influence the successful evaluation and use of these products (Table 1). Part 2 will identify complications of suture anchors and tacks used in shoulder surgery, address methods for avoiding these complications, and present treatment options if they do occur in the shoulder.

### BIOLOGY OF SOFT TISSUE FIXATION DEVICES

The goal of soft tissue fixation devices is to achieve a close approximation between the tissue and the bone to allow the former to heal securely to the latter. The rate of tissue healing depends on many factors, including tissue type, tissue vascularity, bone quality, and the health of the patient (eg, nutritional, hormonal, and hereditary factors).<sup>37</sup> The type of device chosen, whether suture anchor or tack, may influence the healing rate of the soft tissue to bone, depending on how it interacts with those 2 elements.<sup>17,26,40</sup>

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TABLE 1  
Important Information to Obtain  
About a Suture Anchor or Tack<sup>a</sup>

1. Is the device absorbable or nonabsorbable?
2. If absorbable, what is its degradation over time (PLA or PGA)?
3. Is the suture absorbable or nonabsorbable?
4. What is the size of the suture material?
5. Is the suture stiff, and does it tend to tear the tissue?
6. If the suture is absorbable, how fast does it degrade?
7. What is the shape of the eyelet of the device? Does it have sharp edges?
8. If the anchor is absorbable, does the eyelet area degrade faster than the rest of the anchor?
9. How does the device perform in cortical bone or cancellous bone?
10. Does the device need to be predrilled or tapped in cortical bone?
11. How strong is the device when it is pulled out of bone?
12. When the device is tested after implantation, what part of it fails and at what strength?
13. When the device is tested in cyclic loading, what part fails and at what strength?
14. Are there any animal studies using the device?
15. Are there any human clinical studies using the device?
16. How does one get the device out if it fails or gets infected?

<sup>a</sup>PLA, polylactic acid; PGA, polyglycolic acid.

The biology of soft tissue healing to bone has been studied extensively.<sup>28,52,59,67</sup> In animal models, the healing of soft tissue to bone undergoes 3 phases: inflammation, repair, and remodeling. The gap between the tissue and bone, which is filled initially by inflammatory cells and hematoma, is gradually invaded by blood vessels, allowing cells that remove debris and cells that form collagen to enter the gap. The formation of collagen and the restoration of the bone-soft tissue interface progresses until the interface is restored. For tendons attached to bone, healing consists of the normal 4 histologic phases of the tendon-bone transition: tendon fibers, uncalcified fibrocartilage, calcified fibrocartilage, and bone.<sup>18</sup>

The restoration of the interface between soft tissue and bone occurs over several weeks, but the creation of a secure fixation of the soft tissue and a strong tendon-bone interface usually requires approximately 12 weeks.<sup>52</sup> The healing rate may be shortened and made more robust by placement of the tendon in a tunnel in the bone, but in the shoulder, that process is usually an option only with the biceps tendon. St Pierre et al<sup>59</sup> showed that, in the presence of a cancellous bone base, the formation of the collagen fiber-bone interface occurred by 12 weeks whether the rotator cuff tendon was attached directly to the cortical surface of the greater tuberosity or via a bony trough in the tuberosity. Miyahara et al<sup>46</sup> reported that, in a dog model of rotator cuff repairs, the 4 zones of a tendon insertion site were restored by 24 weeks. In contrast, Gerber et al<sup>31</sup> found no histologically normal infraspinatus tendon-bone interface in a goat model even at 6 months after surgery. These studies indicate that

healing rates vary in different animal models and with different types of constructs used for soft tissue repair to bone.

The biology of the healing of soft tissue to bone is a critical issue because it determines how quickly the surgical construct can be moved after surgery and how rapidly it can accommodate stress. If the healing is incomplete and the fixation of the soft tissue to the bone is insecure, then healing may not occur, and the repair will fail.<sup>44</sup> Unfortunately, in the human shoulder, the amount of force applied to the soft tissues at their attachments to the bone is unknown, although some estimations have been recorded. For example, Rodosky et al<sup>53</sup> estimated that the maximum force on the biceps tendon was approximately 130 to 160 N. Another study suggested that the estimated force on the rotator cuff tendons with abduction was 300 N, or about half of the body weight.<sup>60</sup> France et al<sup>27</sup> tested normal supraspinatus tendons in human cadavers of unspecified age and found the failure load to be  $601 \pm 170$  N. However, Gerber et al<sup>30</sup> found that the amount of force necessary to pull a normal human supraspinatus tendon from bone was similar to that of sheep supraspinatus tendons, which may be as high as 2400 N.<sup>59</sup>

Because the exact amount of force a tendon-bone or capsule-bone construct can withstand before it fails in the first 12 weeks is unknown, also unknown are the mechanical requirements of a tendon-bone repair during that time period. Several animal studies show that the maturation of the healing of the tendon to bone requires a prolonged period of time. For example, Gerber et al<sup>31</sup> found in a goat model that the load to failure of an infraspinatus tendon repair was 30% that of a normal goat infraspinatus tendon-bone construct at 6 weeks, 52% after 3 months, and 81% at 6 months. St Pierre et al<sup>59</sup> found that the load to failure with repair of the infraspinatus tendon in goats was 21% of controls after 6 weeks and 36% at 12 weeks.

This issue of how strong the construct must be to provide a successful result has important implications for the surgeon who wants to make decisions about which implant is best in a particular situation, and the surgeon must realize that laboratory findings are not always directly transferable to the clinical setting. An implant shown to have biomechanical properties inferior to other anchors during laboratory pullout testing may perform well in a biological environment,<sup>56</sup> and a suture material shown to have superior strength characteristics compared with the traditionally used No. 2 braided polypropylene suture may not provide any advantage in the biological setting.<sup>23,30</sup> Although most physicians assume that "stronger is better," this concept may not necessarily be so in terms of how the anchor or tack behaves in vivo.

The rate of the healing response of the soft tissue to the bone is particularly important when considering the use of absorbable implants. Implants made of large amounts of purely polyglycolic acid (PGA) polymers have the potential to degrade rapidly secondary to hydrolysis of the polymer.<sup>36</sup> One study suggested that the Suretac device (Acufex Microsurgical, Mansfield, Mass), which consists mostly of PGA, undergoes rapid loss of strength in the first 3 to 4 weeks after implantation.<sup>58</sup> Another study found that implants made of polylactic acid (PLA) tend to dissolve very slowly and may remain in place for years after implantation.<sup>8</sup> Hybrid

devices with a variety of copolymers appear to degrade more slowly than PGA but more quickly than PLA, and the degradation rate depends in part on the ratio of PLA to PGA.<sup>36</sup> The manufacturer of the Panalok anchor (DePuy-Mitek) suggests that it retains 90% of its strength at 9 months.<sup>57</sup>

It is important for the clinician to realize that the rate of degradation for most of the suture anchors and tacks currently on the market is unknown or has not been reported in peer-reviewed publications. It is also unknown how long these absorbable implants need to retain their integrity and strength before the tissue heals adequately to the bone to resist stress. With a uniaxial load to failure in a sheep tibial model, Demirhan et al<sup>25</sup> examined the pullout strength of a biodegradable wedge-type suture anchor primarily made of PGA (TAG, Acuflex Microsurgical). They found that the load to failure of this particular implant to pullout decreased by 75% of its initial pullout strength within 3 weeks, 84% in 6 weeks, and 85% in 12 weeks. They believed that weakening of the anchor's eyelet secondary to degradation of the PGA might have contributed to the failures, and they recommended strengthening the eyelet of absorbable implants. It should be noted that they found no degradation of the strength of the nonabsorbable implants of similar shape during the 12-week study period. A recent *in vitro* study compared a newer hybrid type of suture material (FiberWire) to Ethibond (Ethicon Inc, Johnson & Johnson, Somerville, NJ). The results uniaxially indicated that absorbable implants are prone to eyelet-suture failure secondary to the increased strength of the suture material.<sup>23</sup> However, eyelet-suture failure has not been reported as a frequent problem in clinical studies, and the importance of the *in vitro* findings to surgical practice awaits additional *in vivo* investigation.

Clinical studies give some support to the impression that, when used for rotator cuff repair<sup>21</sup> or shoulder instability<sup>29,33,38,41</sup> procedures, most suture anchors and tacks may provide a clinical result similar to that of transosseous suturing techniques. In a review of the literature, Freedman et al<sup>29</sup> found statistically significant differences in the failure rates of arthroscopic and open shoulder stabilization, but they suggested that there was no difference in failure rate when bioabsorbable tacks were compared with transglenoid suture techniques. On the other hand, Cummins et al<sup>21</sup> found that rotator cuff repair with a bioabsorbable-headed screw implant had significantly worse clinical results at 1 year than repairs performed with a nonabsorbable implant; it should be noted that the implants were of different designs.

In summary, the biological requirements of tacks and suture anchors are largely unknown. The clinician should consider that biological implants may degrade sooner than metal implants, but the exact length of time and the amount of force they are required to withstand are unknown. Early degradation of biological implants may lead to suture pullout of the eyelets of suture anchors or to fracture of a tack's shaft head. Fortunately, most devices appear to perform well clinically despite these potential limitations. Definitive conclusions require additional study of the biological interaction of suture anchors and tacks with the bone, suture, and tissue interfaces.

## BIOMECHANICAL CONSIDERATIONS

### General

The biomechanics of soft tissue fixation to bone via suture anchors and tack devices has been the subject of numerous studies.<sup>†</sup> These studies tested either all aspects of the bone-device-tissue interfaces or just 1 aspect of the construct. For suture anchors, the interfaces included the interaction between the suture and the tissue, between the suture and the anchor, and between the anchor and the bone. For tacks, the interfaces included the interaction between the tissue and the anchor head and between the anchor shaft and the bone.

Generally, testing of these device interfaces should include (1) uniaxial load to failure and (2) cyclical testing to failure. These tests give the clinician different information about the biomechanical behavior of the device. Likewise, testing of the material properties of the suture and the anchor may determine the optimum use of that particular device because those characteristics may contribute to the device's mechanism of failure *in vitro* and *in vivo*.

### Device-Tissue Interface Variables

The interface between these devices and the soft tissue may be the one that is the most clinically important, and it has been studied extensively.<sup>‡</sup> The clinical significance of this interface for suture anchors was documented by Cummins and Murrell,<sup>20</sup> who found that the most common mode of failure for rotator cuff repair was pullout of the suture from the tissue. Barber et al<sup>4</sup> suggested that the weakest link in the bone-anchor-suture-tendon construct was usually the suture-tissue interface. Similarly, tacks have been shown to cut through the tissue, sometimes leading to failure of rotator cuff repairs.<sup>20</sup>

Most studies on tissue-device interface have used human cadaveric or animal models.<sup>§</sup> These studies often do not separate the performance of the whole construct (ie, bone-device, tissue-device interactions) from the biomechanical characteristics of the tissue-device interface. When evaluating these studies, it is important to note the study design, what type of testing was performed, where the failures occurred, and whether different failure modes were compared.

The suture material used in suture anchors may play an important role in the success or failure of the repair of soft tissue around the shoulder. The suture should be strong enough to withstand the forces applied to it, and it should show little creep during the healing period. Ideally, the suture material should be easy to use, should allow knots to slide smoothly, and should not cut out of the tissue. The suture interfaces with the tissue, the bone, and the anchor

<sup>†</sup>References 1-5, 7, 9, 11-14, 16, 19, 21, 22, 25-27, 30, 32, 34, 35, 39, 43, 45, 47-49, 55-57, 61-64, 66, 68.

<sup>‡</sup>References 1, 3-6, 11, 16, 19-22, 24-26, 30, 32, 42, 43, 47, 51, 55, 62-66, 68.

<sup>§</sup>References 24, 26, 27, 30, 31, 47, 48, 50, 57, 60.

have been recognized as important variables for the surgeon to consider when using these devices.<sup>30</sup>

Two variables in material properties are important when considering the use of one suture type rather than another: (1) the ultimate strength or load to failure of the suture and (2) the ability of the suture to withstand abrasion against the anchor. With regard to a suture's ultimate strength to failure, generally the larger the suture, the greater the strength to failure.<sup>30</sup> Although newer suture types generally have a higher load to failure than the older versions, it is unknown whether this strength is needed for clinical success or whether the increased stiffness of these new suture materials might lead to the suture cutting through the soft tissue.<sup>13,15,40,54</sup>

The configuration of the suture in the soft tissue is an important part of the success or failure of a surgical procedure around the shoulder.<sup>20</sup> Several studies have found that simple sutures in the rotator cuff do not perform biomechanically as well as other suture techniques.<sup>30,31,57</sup> Specifically, a modified Mason-Allen stitch was found to have superior strength in load-to-failure testing than was a simple suture or mattress configuration.<sup>30</sup>

#### Device-Suture Interface Variables

Another factor in choosing a suture anchor is abrasion of the suture material against the device's eyelet.<sup>7,44,45,56</sup> Rupp et al<sup>56</sup> studied a construct of suture anchors with No. 2 Ethibond in porcine bone. They found that uniaxial testing to failure resulted in most of the constructs failing when the suture broke at the knot or at the anchor eyelet. However, under cyclic loading, the critical factor was the abrasion of the suture on the anchor eyelet. In metallic anchors, the surfaces tended to be rough with sharp edges,<sup>56</sup> but the absorbable implants typically had smoother edges, so sutures for those devices tended not to abrade or break when subjected to cyclic loads.

The suture–anchor eyelet interface also may be affected by the angle of the suture in the implant under stress. Two studies have shown that the sharp edges of metal anchors can contribute to suture failure if the suture is not directly in line with the anchor eyelet.<sup>7,44</sup> In some eyelet designs, the anchor can rotate so that the suture is not located in the eyelet channels for the suture, resulting in more suture wear and early failure.<sup>44</sup>

#### Device-Bone Interface Variables

The performance of tacks or suture anchors that screw into bone is influenced by the same mechanical characteristics that affect screws of all types: the design, such as the pitch of the threads and the overall size<sup>5,30</sup> and how they interact with different types of bone. Some anchors and tacks perform better biomechanically in cancellous bone, and other anchors afford superior holding in cortical bone.<sup>4,24,35,55,56</sup> Rupp et al<sup>56</sup> found that, in general, most anchors perform better when inserted into cortical bone. Roth et al<sup>55</sup> cyclically loaded 2 types of anchors inserted into human glenoids and found that the fatigue life was related to the magnitude of

the load and the cortical thickness into which the anchor was inserted.

Bone density has been found to be an important variable affecting the biomechanical performance of suture anchors and tacks placed in the proximal humerus.<sup>3,32,62,63</sup> Tingart et al<sup>63</sup> found that the anterior and proximal tuberosity of the proximal humerus had denser bone than did the posterior and distal tuberosity. As one would expect, the pullout strengths of anchors in the anterior and proximal areas of the tuberosity were higher than those in the posterior or more lateral locations in the proximal humerus.<sup>62,63</sup> These investigators also found that in those areas of stronger bone, there was no statistical difference in pullout strength between screw-in anchors and biodegradable hook-type anchors. However, in the distal locations where the bone density was lower, the screw-in anchors had statistically higher pullout strengths than did the hook-type anchors.<sup>62</sup>

Another biomechanical consideration when using anchors or tacks is the angle of implantation relative to the tissue and to the angle of the pull of the attached suture.<sup>42,62,63</sup> Burkhart<sup>10</sup> has suggested that the suture anchor should be placed so that it has a “deadman” relationship to the tissue. This suggestion is based on the concept of a stabilizing wire for a fence post.<sup>10</sup> However, in an *in vitro* study with cadaveric humerus specimens, Liporace et al<sup>42</sup> found that the load to failure was not affected significantly by the angle of implantation between the bone and the device.

#### SUMMARY

In summary, the biological and biomechanical performance of suture anchors and tacks depends on multiple variables that the clinician should consider when selecting a device. Biologically absorbable devices have been shown clinically to provide satisfactory results despite a paucity of information about their degradation rates. The important considerations for absorbable tack devices include (1) the ability to hold soft tissue without tissue necrosis and without dissolving before tissue healing and (2) concerns about the suture cutting out of the anchor eyelet before soft tissue healing.

Biomechanically, it has been found that although bigger and stronger suture materials have been developed, it is unknown whether this additional strength is necessary for successful clinical application. When tested *in vitro*, stronger suture materials tend to shift the failure mechanism from knot failure to anchor pullout from bone. Generally, screw-in anchor devices fail at higher loads than do hooked or interference-fit devices, and the larger the screw-in device, the higher is the load to failure for the bone-anchor interface. In low-density bone, screw-in devices tend to perform better than hooked devices. Generally, tacks tend to have a lower load to failure than suture anchors do, depending on the testing conditions. However, the clinical significance of most of these variables has not been established, and the clinician should evaluate and select a device based on the perceived clinical requirements of the procedure.

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