State of the Field: Proposed Suture Anchor Design for Rotator Cuff Repair in Osteoporotic Bone

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Introduction

Rotator cuff tears (RCT) are a common cause of shoulder pain and disability. In the United States (US) alone, RCT account for 4.5 million office visits and 250,000 surgeries per year, resulting in over $3 billion in total healthcare costs.[1, 2] RCT are especially prevalent among older populations, affecting up to 25% of patients 60 years old and up to 50% of patients 80 years and older.[3] Given the aging US population and increasing labor force participation among older populations, the burden of RCT is expected to rise in the future.

Surgical repair of RCT in individuals with osteoporosis remains a challenge due to systemic low bone mineral density (BMD) and lower rates of bone-tendon healing following repair.[4] Moreover, the proximal humerus is a region that is especially susceptible to osteoporotic bone loss, resulting in a higher rate of complications due to suture anchor loosening, migration, and pullout before adequate bone-tendon healing can take place.[4, 5] Chung et al. reported RC repair failure rates as high as 42% in patients with osteoporosis as compared to 9% for patients with normal BMD.[4] Furthermore, in a study of 80 patients with RC repair failure, Djurasovic et al. found that 10% of RC repair failures were due to suture anchor-bone interface.[6] Given the significance of the suture anchor as an important cause of RC repair failure in osteoporotic patients, suture anchor design represents an important field of research driving improvements in rotator cuff repair outcomes.[7]

Suture Anchor Design: Mechanical Design

Mechanical design, anchor material, and reinforcement represent three important aspects of suture anchor design. The mechanical design of the suture anchor, which refers to the interface between the suture anchor and the bone, contributes to the pullout strength of the anchor. There are three primary interfaces—the threaded anchor, the wedge fit anchor, and the all-suture anchor. In a biomechanical study, Tingart et al. showed that threaded, screw-in anchors provided superior pullout strength in osteoporotic bone compared to wedge-type anchors.[8] Threaded suture anchors themselves vary by pitch, flight depth, thread depth, and length. A biomechanical investigation of threaded anchors by Chae et al. found that pullout strength was positively correlated with the contact surface area between the anchor threads and surrounding bone, as well as the overall length, number of threads, and depth of the thread of the suture anchor.[7] The authors also noted that the relative effect of these design factors upon pullout strength varied with the direction of applied force. Specifically, the contact surface area was the most important design factor when tension was applied at 0° and 45° relative to the long-axis of the screw, while screw length was the predominant design factor at a direction 75° from the long-axis of the screw.[7] In contrast, the pullout strength of all-suture anchors, which are reliant deformation of the suture within the drill hole, is positively correlated with the number of sutures anchored together.[9] For example, triple-loaded anchors have been shown to be stronger than double-loaded anchors, and double-loaded anchors have been shown to be stronger than single-loaded anchors.[9]

Suture Anchor Design: Suture Material

Suture anchor material affects the physiologic response from the body and dictates how well the suture anchor will perform over time. Non-biodegradable anchors are typically made of metal (e.g., steel or titanium alloys) or polymers (e.g., polyethylene), while biodegradable anchors are typically made of poly-L-lactic acid and polyglycolic acid copolymers.[10, 11] Generally speaking, non-biodegradable anchors have the short-term advantage of greater mechanical stability while biodegradable anchors have the long-term advantage of replacement by bone over time.[10] However, the etiology of this osteogenic effect is unclear, and some patients experience a lack of bone regrowth with biodegradable anchors. The lack of bone regrowth can lead to tunnel widening, effusion, and cyst formation at the implantation site which may ultimately lead to anchor pullout.[12-15] In a recent biomechanical study comparing the titanium TwinFix anchor (Smith and Nephew, Memphis, Tenn), the

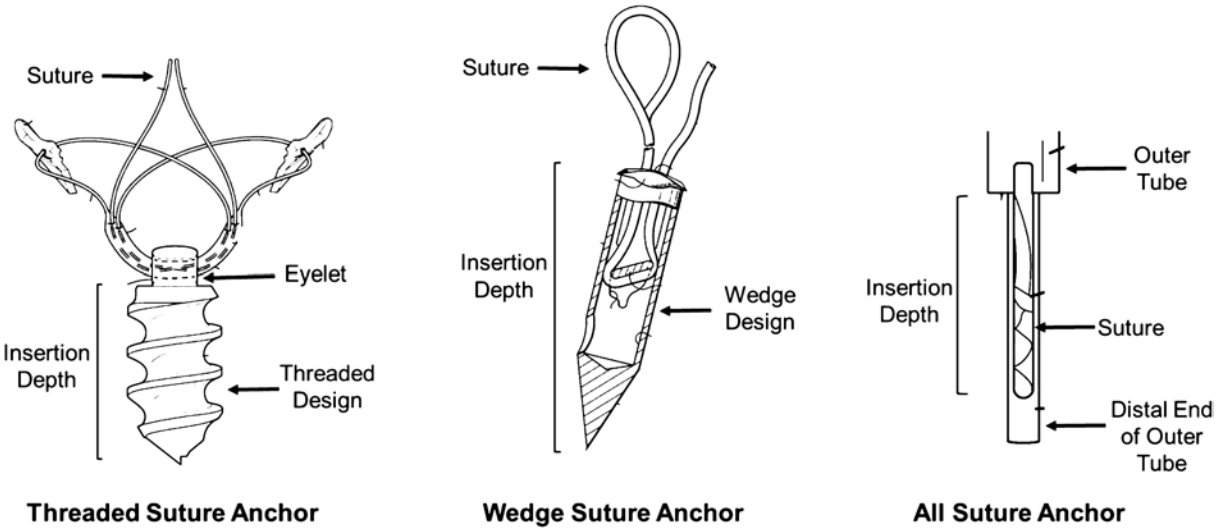

Figure 1. The three primary mechanical designs of suture anchor.

bioresorbable Healix anchor (DePuy Mitek, Raynham Mass.), and the all-suture Iconix anchor (Stryker, Kalamazoo, MI) in an osteoporotic bone model, Rosso et al. found that all three anchors could withstand physiologic loads of 250 N. However, the bioabsorbable suture underwent greater deformation following cyclic loading than the titanium suture anchor (0.40 mm vs 0.22 mm), suggesting that metal anchors have greater RC repair stability in osteoporotic bone.[16]

Suture Anchor Design: Reinforcement

Metallic suture anchors placed into osteoporotic bone are frequently reinforced with either polymethylmethacrylate (PMMA) or bioabsorbable tricalcium phosphate (TCP) cement.[17, 18] In a biomechanical study of corkscrew suture anchors, Er et al. found that TCP augmentation improved pullout strength by 86% in simulated osteopenic bone and by 364% in simulated severely osteoporotic bone. Similarly, PMMA augmentation increased pullout strength by 148% and 524%, respectively.[19] The use of bone cement augmentation with biodegradable anchors and all-suture anchors has not been reported in the literature. Despite the mechanical advantages of anchor augmentation with bone cement, arthroscopic injection of cement into the anchor hole is technically demanding due to the risk of spillage into the joint space.[19] While the Jamshidi needle has been successfully repurposed for the injection of TCP cement, the development of new tools for the arthroscopic injection of bone cement are needed.[19]

Proposed Suture Anchor Design for Osteoporotic Bone

Given the existing literature, the authors of this study see a need to develop an improved suture anchor design for increased RC repair stability in osteoporotic bone. We suggest using a conical, threaded suture anchor to increase anchor-bone surface area for increased pull-out strength. We also suggest using a bioresorbable design using PLLA and B tricalcium phosphate, which will afford increased resistance to deformation following cyclic loading and not induce cavitary lesions in the greater tuberosity. Given the evidence supporting the use of TCP augmentation, we also suggest using TCP to reinforce suture anchors in osteoporotic bone. A new supporting device can be developed that assists the surgeon in precise injection of TCP into the anchor hole, which will give a near immediate increase in fixation upon bone 'cement' curing. A paucity of user friendly designs may be one reason that TCP is not frequently used for arthroscopic suture anchor augmentation. Our design will facilitate injection of TCP immediately upon anchor insertion and obviate the need for PMMA or the usage of a larger anchor.

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