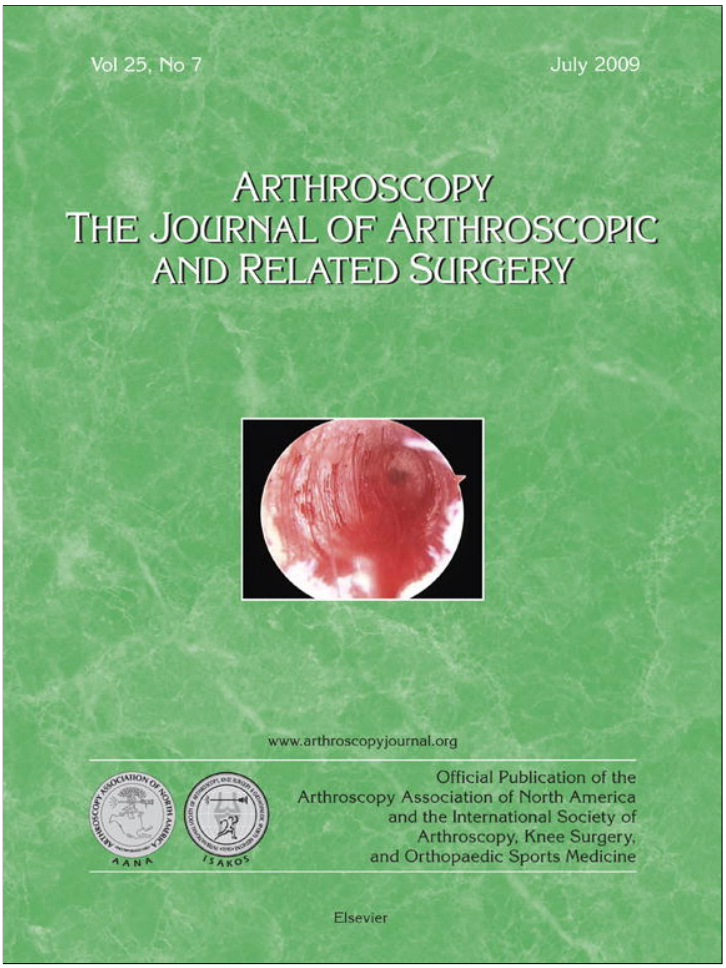

Concise Review

Bioabsorbable Anchors in Glenohumeral Shoulder Surgery

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Abstract: The use of implants to provide glenohumeral soft tissue fixation has changed dramatically over the past few decades, from point tack fixation to metallic suture anchors to bioabsorbable suture anchors. Bioabsorbable suture anchors have largely replaced metallic anchors because of concerns of implant loosening, migration, and chondral injury. Although the safety and efficacy of bioabsorbable anchors has been well documented, there are numerous reports regarding the early failure related to implant bioabsorbable implant breakage or premature degradation. Patients with anchor-related complications generally present with pain and/or stiffness, and the surgeon should have a high index of suspicion if a patient does not progress as expected. Glenohumeral synovitis, glenoid osteolysis, loose bodies, and chondral injury are some of the notable complications that have been reported. Careful attention to proper anchor insertion techniques can limit the potential for complications. Newer materials, such as polyetheretherketone and other composites, have recently been introduced. These materials may address concerns of biocompatibility and material strength, but additional rigorous in vitro and in vivo trials need to be conducted before their use becomes widespread. **Key Words:** Bioabsorbable anchors—Metallic anchors—Shoulder arthroscopy—Suture anchors.

The suture anchor is arguably the most important innovation in arthroscopic glenohumeral shoulder surgery. The ability to provide fixation of soft tissue to bone dramatically changed shoulder surgery from open repair to arthroscopic repair techniques. Before the suture anchor, there were a number of devices that attempted to repair the glenoid labrum, including metallic staple capsulorrhaphy, removable rivet capsulorrhaphy, cannulated screw fixation, the transglenoid suture technique, and glenoid tacks.[1]

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Metallic devices implanted in the glenohumeral joint have historically performed very well. To achieve optimal success with metallic anchors, careful attention to proper insertion depth, in an area of adequate glenoid bone stock, and with optimal angle of insertion are all paramount to the prevention of devastating glenohumeral joint complications. However, metallic anchor migration, loosening, and breakage all have been described, which can result in severe premature degenerative changes of the glenohumeral joint. Because of concerns with metallic devices, a bioabsorbable alternative was first developed with a tack fixation device (Suretac; Smith & Nephew, Andover, MA), which provides point fixation of labral tissue to the glenoid.[2] Suture anchors were introduced thereafter and since then have essentially replaced tissue tack devices.[3]

EVOLUTION OF SUTURE ANCHOR MATERIALS

Metallic suture anchors (G1; DePuy Mitek, Raynham, MA) loaded with simple braided polyester sutures were the first to be introduced and widely used in

shoulder arthroscopy. When introduced, these offered a viable alternative to transosseous suture techniques. Biomechanical studies reported a pull-out strength similar to that of transosseous bone tunnels,[4] and the initial studies reported favorable results.[5] These first-generation metallic anchor constructs failed by suture rupture through the metallic eyelet,[6] and therefore there was a shift away from the use of simple braided polyester sutures, such as No. 2 Ethibond (Ethicon, Somerville, NJ) toward hybrid sutures with a core of ultrahigh molecular weight polyethylene (UHMWPE) surrounded by braided polyester. De Carli et al.[7] examined failure mode and observed that Fiberwire (Arthrex, Naples, FL) constructs tended to fail by anchor slippage or eyelet rupture, whereas Ethibond constructs failed by suture breakage. After metallic anchor usage became common, reports emerged of complications associated with metallic anchors, including loosening, migration, chondral injury, difficulty with revision surgery, and interference with postoperative magnetic resonance imaging.[8,9]

Alternative materials were developed to avoid these potential devastating complications. Speer and Warren[10] outlined 4 criteria for a bioabsorbable implant used in shoulder arthroscopy: (1) the implant must have an initial fixation strength to coapt the soft tissues to bone; (2) the material property and time to degradation of the implant must allow satisfactory strength while the healing tissues are regaining mechanical integrity; (3) the implant must not degrade too slowly to avoid the complications of metallic implants; and (4) the materials of the implant must not cause toxicity, antigenicity, pyrogenicity, or carcinogenicity.

BIOABSORBABLE MATERIAL PROPERTIES

Bioabsorbable materials used in orthopedic applications are natural, synthetic, or biosynthetic polymers that are biocompatible with the body and not supposed to elicit a foreign body reaction.[11] Currently, there are at least 40 types of polymers that have been developed for use in surgery, but the most commonly used polymers are polyglycolic acid (PGA), polylactic acid enantiomers (PLA), and poly-D-L-lactic acid copolymer polyglycolic acid (PDLLA-co-PGA).[11] The polymers are long-chain macromolecules composed of multiple convalently bonded subunits (monomers) and can be composed of a single repeating monomer or combinations of more than 1 monomer.[11,12]

The mechanical properties of a bioabsorbable implant changes over time in a physiologic environment as determined by the molecular weight (MW) and degree of crystallinity. The PGA implants have a degradation time of 3 to 4 months, whereas the PLLA implants have a degradation time between 10 to over 30 months, depending on the stereoisomers or self-reinforcement.[11] The MW and crystallinity can be altered to optimize mechanical strength of an implant. For example, the polymers with a higher degree of crystallinity are stronger and degrade slower than amorphous polymers with the same chemistry.[12] In vitro and in vivo studies indicate that these polymers degrade by nonspecific hydrolytic clipping of ester bonds.[13,14] In the initial phase of degradation, chemical hydrolytic scission of the molecular chains occurs upon contact with water.[13,15-18] The large degradation products cannot be phagocytized by local macrophages, leading to an acidic environment and further increasing the rate of hydrolysis.[13,15] Once the structural integrity of the implant is compromised, microfractures occur within the implant, causing further hydrolysis until the monomers are able to be phagocytized by local macrophages and polymorphonuclear leukocytes.[12]

The first bioabsorbable tack was composed of (PGA) polymers (Suretac) which provided point fixation of soft tissue to bone. Early reports showed a rapid loss of fixation strength resulting in loose bodies, synovitis, and osteolysis.[19-21] Warner et al.[22,23] obtained histopathologic specimens and determined that giant cell reaction to the polyglyconate caused polymer debris. Because of the early resorption of PGA, suture anchors were manufactured with poly-L-lactic acid (PLLA), which degraded at a much slower rate. There were concerns that an excessively long period of degradation would not allow for complete osseous replacement and complications associated with metallic anchors.[24,25] There are concerns that complete degradation of PLLA requires several years, and that complete osseous replacement has not reported in the literature.[26-28] Incomplete or partial osseous replacement can result in the replacement of fibrous or fatty-fibrous tissue.[29] PLLA was further refined to alter the amorphous nature by introducing copolymers of the levo- and dextro-stereoisomers, ultimately affecting the rate of degradation. Self-reinforcement of copolymers can also affect the mechanical properties of the bioabsorbable materials.[11]

LITERATURE REVIEW

There have been a number of case series and case reports about complications related to the use of bio-

absorbable suture anchors used in shoulder surgery (Fig 1). The authors have observed a number of bioabsorbable suture anchors that break with screw-in insertion. Additionally, the authors report that there appears to be an inconsistency in the quality of the bioabsorbable material. Barber[30] reported 2 cases of failed bioabsorbable suture anchors. The first case was a result of rapid degradation of the suture anchor resulting in the nonabsorbable suture acting as a loose body. In the second case, the upper portion of the anchor and eyelet was detached from the implanted portion, and the author believes that it was the result of degradation of the implanted anchor and cyclic loading of the upper portion causing the anchor breakage. Cole and Provencher[31] state that the technical issues related to anchor placement cannot be overem-

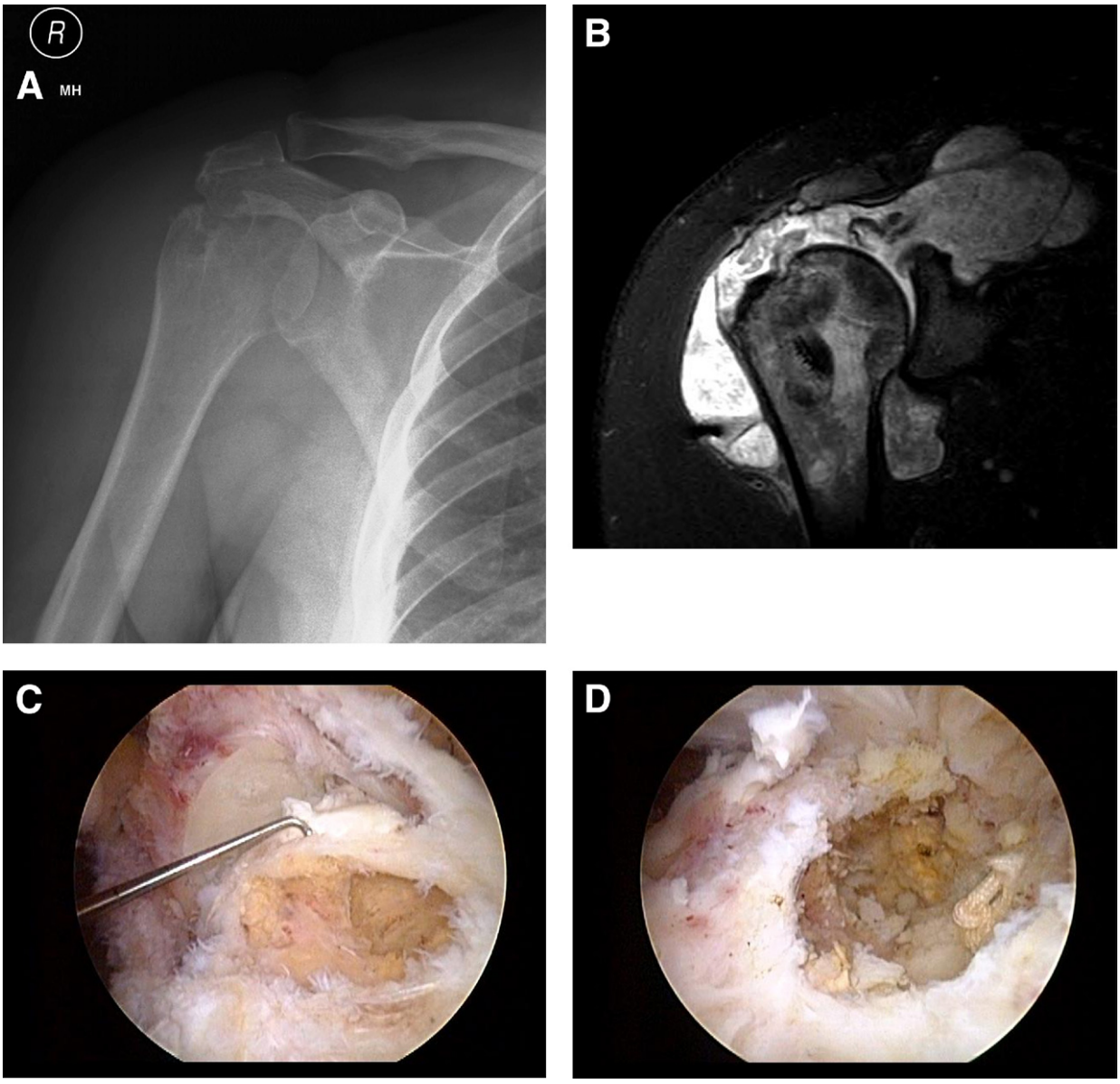

Figure 1. Severe osteolysis 3 years after mini-open rotator cuff repair with bioabsorbable suture anchor fixation. (A) Plain radiograph of anteroposterior view with osteolystic lesion in the greater tuberosity. (B) T2-weighted coronal magnetic resonance imaging scan showing severe osteolysis with subsidence of the bioabsorbable anchor into the proximal humerus. There is also a massive rotator cuff tear with high signal throughout the supraspinatus muscle belly and extensive synovitis. (C) Arthroscopic image shows osteolytic lesion of the greater tuberosity. (D) Arthroscopic image of the osteolytic lesion with remaining suture without evidence of the bioabsorbable anchor.

TABLE 1. *Complications Associated With Bioabsorbable Suture Anchors*

Reference	No. of Cases/ Total Cases (%)	Anchor	Material	Procedure(s)	Complications
Athwal et al.[32]	4/25 (16)	Bioknotless	PLLA	SLAP, Bankart	Osteolysis of glenoid and arthropathy
Muller et al.[34]	7/15 (47%)	Bioresorbable	PLLA	Stabilization	Asymptomatic, no arthropathy
Freehill et al.[33]	10/52 (19%)	Bankart tack	PLLA/PDLLA	Stabilization	Glenohumeral synovitis (10); arthropathy (3)
Glueck et al.[9]	1/1 (100%)	Biocorkscrew	PDLLA	RCR	Osteolysis of greater tuberosity
Kelly[37]	1/1 (100%)	5.0-mm absorbable anchor	PDLLA	RCR	Early disintegration

NOTE. The Bioknotless suture is manufactured by Mitek. Bioresorbable is manufactured by AO-ASIF Development Institute (Davos, Switzerland). The Bankart tack is manufactured by Bionx Implants (Blue Bell, PA). The Biocorkscrew and 5.0-mm absorbable anchor used in the study by Kelly[37] are manufactured by Arthrex.

Abbreviations: PDLLA, poly-D-L-lactic acid; PLLA, poly-L-lactic acid; RCR, rotator cuff repair.

phasized and may limit the failure of bioabsorbable anchors.

Athwal et al.[32] reported the occurrence of osteolysis and arthropathy after the use of bioabsorbable knotless suture anchors composed of PLLA. Two of the 4 patients had complaints of pain, one had subtle instability and eventually pain, and the last patient reported a "grinding" sensation in the shoulder. All underwent repeat shoulder arthroscopy between 3.5 to 18 months after the index surgery and were found to have cartilage destruction of both the glenoid and the opposing humeral head, loose bodies, one or more loose anchors, and reactive synovitis. There were several factors that contributed to failure, including the large number of anchors per case, the fact that knotless anchors require deeper penetration of the anchor, and that bioknotless design resists pullout by frictional resistance. Freehill et al.[33] reported 10 of 52 patients (19%) who underwent arthroscopic stabilization with PLLA polymer tacks. The patients presented with pain and progressive stiffness an average of 8 months after surgery. Repeat arthroscopy revealed synovitis (n = 10), gross implant debris (n = 9), and full-thickness chondral damage (n = 6) and underwent debridement, synovectomy, and removal of loose bodies, respectively. Seven patients reported no or minimal pain with full range of motion. The 3 patients with chondral damage had persistent symptoms of pain and stiffness (n = 2) and difficulty with overhand throwing (n = 1). Muller et al.[34] reported 7 cases of asymptomatic glenoid osteolysis after stabilization with PLLA anchors, but none required repeat surgery or showed progressive arthritis (Table 1).

FUTURE DIRECTIONS

Alternative materials have recently been developed. Composite materials are generally a blend of tricalcium phosphate (TCP) and PLA, and several polymers have been developed for tendon-to-bone fixation (30% TCP and 70% PLGA—Biocryl Rapide, DePuy Mitek; 15% TCP and 85% PLA—BioComposite SutureTak, Arthrex). These were reported to have minimal tissue reaction with complete absorption followed by bone ingrowth (Fig 2). The PLGA copolymer is composed of 15% PGA and 85% PLLA.[35] Studies performed by the manufacturer have showed resorption between 18 and 24 months and bone ingrowth by 24 months postsurgery (http://www.jnjgateway.com/public/USENG/MiagroWhitePaper.pdf).

Polyetheretherketone (PEEK) is a material that has been widely used in trauma, orthopedics, and spine applications. PEEK-based implants are strong, relatively inert, radiolucent, and can be drilled out during revision cases.[35] Several companies have already introduced suture anchors with PEEK material (Table

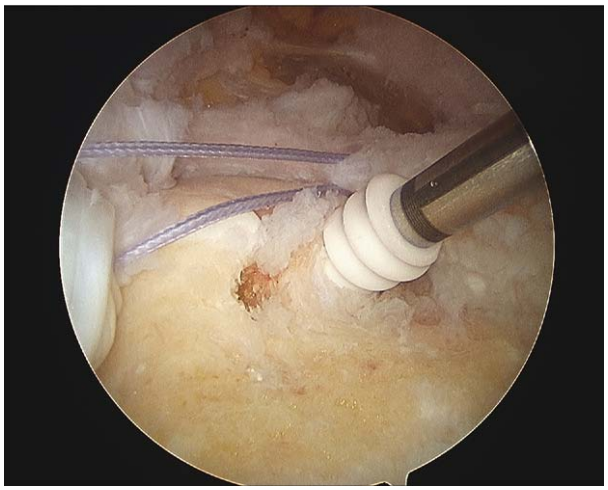

FIGURE 2. Composite suture anchor insertion.

TABLE 2. *Polyetheretherketone Suture Anchor Specifications*

Anchor	Material	Size(s) (mm)	Suture	Manufacturer
Kinsa	PEEK-OPTIMA	2.9	No. 2 Ultrabraid (knotless)	Smith & Nephew
Kinsa RC	PEEK-OPTIMA	5.5	No. 2 Ultrabraid (knotless)	Smith & Nephew
Footprint PK	PEEK-OPTIMA	5.5 and 6.5	No. 2 Ultrabraid	Smith & Nephew
BioRaptor 2.3 PK	PEEK-OPTIMA	2.3	No. 2 Ultrabraid	Smith & Nephew
TwinFix PK FT	PEEK-OPTIMA	5.5 and 6.5	No. 2 Ultrabraid	Smith & Nephew
Healix PEEK	PEEK	4.5, 5.5, and 6.5	No. 2 Orthocord	DePuy Mitek
VersaLok	Titanium, PEEK	4.9 (expands to 6.3)	No. 2 Orthocord	DePuy Mitek
PEEK Corkscrew FT	PEEK	4.5, 5.5, and 6.5	No. 2 FiberWire	Arthrex
PEEK Pushlock	PEEK	2.9, 3.5, 4.5, and 5.5	No. 2 FiberWire	Arthrex
PEEK SutureTak	PEEK	3.0	No. 2 FiberWire	Arthrex
PEEK SwiveLock	PEEK	5.5	2-mm Fibertape	Arthrex
Hitch	PEEK-OPTIMA	2.4	Nos. 1 and 2 MaxBraid	Biomet

Abbreviation: PEEK, polyetheretherketone.

2). There are efforts to develop PEEK composites.[36] Barber et al.[35] published a recent in vitro study to compare the pullout strength of the newer generation of suture anchors, including those composed of PEEK and Biocryl Rapide. This recent generation of anchors all showed remarkably high load-to-failure, and the fully threaded screw designs had the highest failure strength.[35] To date, there are no published clinical reports of failures or complications as a result of these recently introduced materials.

CONCLUSIONS

Suture anchors that enable tendon-to-bone fixation have changed dramatically over the past few decades from metallic to bioabsorbable. With increased use, there has been a growing body of literature of case reports and small case series of failures and/or complications related to the use of bioabsorbable suture anchors. Bioabsorbable implant breakage or premature degradation raises concerns about the biomechanical strength and material properties. Reports of synovitis, glenoid osteolysis, loose bodies, cartilage injury, and the devastating potential end result of arthropathy have all been reported with suture anchors. Adherence to proper anchor insertion techniques should limit and hopefully eliminate the possibility of iatrogenic injury. Advancements in suture anchor technology have brought about dramatic change in shoulder arthroscopy, but enthusiasm for innovation must be tempered with scientific evidence and judicious oversight.

REFERENCES

1. Yahiro MA, Matthews LS. Arthroscopic stabilization procedures for recurrent anterior shoulder instability. *Orthop Rev* 1989;18:1161-1168.
2. Altchek DW. Arthroscopic shoulder stabilization using a bioabsorbable fixation device. *Sports Med Arthrosc* 1993;1:266-271.
3. Hoffmann F, Reif G. Arthroscopic shoulder stabilization using Mitek anchors. *Knee Surg Sports Traumatol Arthrosc* 1995;3:50-54.
4. Hecker AT, Shea M, Hayhurst JO, Myers ER, Meeks LW, Hayes WC. Pull-out strength of suture anchors for rotator cuff and Bankart lesion repairs. *Am J Sports Med* 1993;21:874-879.
5. Ozbaydar M, Elhassan B, Warner JJ. The use of anchors in shoulder surgery: A shift from metallic to bioabsorbable anchors. *Arthroscopy* 2007;23:1124-1126.
6. Nho SJ, Yadav H, Pensak M, Dodson CC, Good CR, MacGillivray JD. Biomechanical fixation in arthroscopic rotator cuff repair. *Arthroscopy* 2007;23:94-102, 102.e1.
7. De Carli A, Vadala A, Monaco E, Labianca L, Zanzotto E, Ferretti A. Effect of cyclic loading on new polyblend suture coupled with different anchors. *Am J Sports Med* 2005;33:214-219.
8. Silver MD, Daigneault JP. Symptomatic interarticular migration of glenoid suture anchors. *Arthroscopy* 2000;16:102-105.
9. Gaenslen ES, Satterlee CC, Hinson GW. Magnetic resonance imaging for evaluation of failed repairs of the rotator cuff. *J Bone Joint Surg Am* 1996;78:1391-1396.
10. Speer KP, Warren RF. Arthroscopic shoulder stabilization. A role for biodegradable materials. *Clin Orthop Relat Res* 1993;291:67-74.
11. Gunja NJ, Athanasiou KA. Biodegradable materials in arthroscopy. *Sports Med Arthrosc* 2006;14:112-119.
12. Siparski PN, Gramen P, Gall K, DAmbrosia R. Bioabsorble polymers used in knee arthroscopy, part 1: Basic science and application. *Tech Knee Surg* 2006;5:193-198.
13. Athanasiou KA, Agrawal CM, Barber FA, Burkhart SS. Orthopaedic applications for PLA-PGA biodegradable polymers. *Arthroscopy* 1998;14:726-737.
14. Farrar DF, Gillson RK. Hydrolytic degradation of polyglyconate B: The relationship between degradation time, strength and molecular weight. *Biomaterials* 2002;23:3905-3912.
15. Ciccone WJ 2nd, Motz C, Bentley C, Tasto JP. Bioabsorbable

implants in orthopaedics: New developments and clinical applications. *J Am Acad Orthop Surg* 2001;9:280-288.
16. An YH, Woolf SK, Friedman RJ. Pre-clinical in vivo evaluation of orthopaedic bioabsorbable devices. *Biomaterials* 2000; 21:2635-2652.
17. Weiler A, Hoffmann RF, Stahelin AC, Helling HJ, Sudkamp NP. Biodegradable implants in sports medicine: The biological base. *Arthroscopy* 2000;16:305-321.
18. Radford MJ, Noakes J, Read J, Wood DG. The natural history of a bioabsorbable interference screw used for anterior cruciate ligament reconstruction with a 4-strand hamstring technique. *Arthroscopy* 2005;21:707-710.
19. Edwards DJ, Hoy G, Saies AD, Hayes MG. Adverse reactions to an absorbable shoulder fixation device. *J Shoulder Elbow Surg* 1994;3:230-233.
20. Speer KP, Warren RF, Pagnani M, Warner JJ. An arthroscopic technique for anterior stabilization of the shoulder with a bioabsorbable tack. *J Bone Joint Surg Am* 1996;78:1801-1807.
21. Burkart A, Imhoff AB, Roscher E. Foreign-body reaction to the bioabsorbable suretac device. *Arthroscopy* 2000;16:91-95.
22. Warner JJ, Miller MD, Marks P. Arthroscopic Bankart repair with the Suretac device. Part II: Experimental observations. *Arthroscopy* 1995;11:14-20.
23. Warner JJ, Miller MD, Marks P, Fu FH. Arthroscopic Bankart repair with the Suretac device. Part I: Clinical observations. *Arthroscopy* 1995;11:2-13.
24. Ticker JB, Lippe RJ, Barkin DE, Carroll MP. Infected suture anchors in the shoulder. *Arthroscopy* 1996;12:613-615.
25. Barber FA. Biology and clinical experience of absorbable materials in ACL fixation. *Tech Orthop* 1999;14:34-42.
26. McGuire DA, Barber FA, Elrod BF, Paulos LE. Bioabsorbable interference screws for graft fixation in anterior cruciate ligament reconstruction. *Arthroscopy* 1999;15:463-473.
27. Barber FA. Poly-D,L-lactide interference screws for anterior cruciate ligament reconstruction. *Arthroscopy* 2005;21:804-808.
28. Barber FA, Elrod BF, McGuire DA, Paulos LE. Preliminary results of an absorbable interference screw. *Arthroscopy* 1995; 11:537-548.
29. Bach FD, Carlier RY, Elis JB, et al. Anterior cruciate ligament reconstruction with bioabsorbable polyglycolic acid interference screws: MR imaging follow-up. *Radiology* 2002;225: 541-550.
30. Barber FA. Biodegradable shoulder anchors have unique modes of failure. *Arthroscopy* 2007;23:316-320.
31. Cole BJ, Provencher MT. Safety profile of bioabsorbable shoulder anchors. *Arthroscopy* 2007;23:912-913.
32. Athwal GS, Shridharani SM, O'Driscoll SW. Osteolysis and arthropathy of the shoulder after use of bioabsorbable knotless suture anchors. A report of four cases. *J Bone Joint Surg Am* 2006;88:1840-1845.
33. Freehill MQ, Harms DJ, Huber SM, Atlihan D, Buss DD. Poly-L-lactic acid tack synovitis after arthroscopic stabilization of the shoulder. *Am J Sports Med* 2003;31:643-647.
34. Muller M, Kaab MJ, Villiger C, Holzach P. Osteolysis after open shoulder stabilization using a new bio-resorbable bone anchor: A prospective, non-randomized clinical trial. *Injury* 2002;33:B30-B36 (suppl 2).
35. Kurtz SM, Devine JN. PEEK biomaterials in trauma, orthopedic, and spinal implants. *Biomaterials* 2007;28:4845-4869.
36. Barber FA, Herbert MA, Beavis RC, Barrera Oro F. Suture anchor materials, eyelets, and designs: Update 2008. *Arthroscopy* 2008;24:859-867.
37. Kelly JD II. Disintegration of an absorbable rotator cuff anchor six weeks after implantation. *Arthroscopy* 2005;21:495-497.