Original Research

All-Suture Anchor Deployment Configurations in Arthroscopic Bankart Repair: A Comparative Analysis of Clinical and Radiological Outcomes

Jae-Hoo Lee,* MD, PhD, and Sang-Jin Shin,†‡ MD, PhD
Investigation performed at Ewha Womans University, Seoul Hospital, Seoul, Republic of Korea

Background: All-suture anchors have various configurations during deployment and different biomechanical characteristics because of their soft anchor bodies.

Hypothesis/Purpose: This study aimed to analyze the clinical and radiological differences of all-suture anchors in arthroscopic Bankart repair based on their deployment configurations. It was hypothesized that each all-suture anchor would yield comparable clinical outcomes regardless of radiological differences in the pattern of glenoid bone reaction.

Study Design: Cohort study, Level of evidence, 3.

Methods: A total of 141 patients who underwent arthroscopic Bankart repair using all-suture anchors were enrolled. Patients were divided into 4 groups based on the configurations after deployment of the all-suture anchors used: (1) group A (38 patients)—1.3-mm all-suture anchor with a *spherical* configuration; (2) group B (25 patients)—1.4-mm anchor with a *cloverleaf* configuration; (3) group C (31 patients)—1.7-mm anchor with an *omega* configuration; and (4) group D (47 patients)—1.4-mm anchor with a *cylindrical* configuration. Clinical outcomes were evaluated preoperatively and 2 years postoperatively. The labral healing and the diameter and length of the anchor tunnel were measured on the postoperative 1-year computed tomography arthrograms.

Results: No significant difference was observed in the preoperative demographic data of the 4 groups. The all-suture anchor tunnel's mean diameter in group A (3.9 $\pm$ 0.4 mm) was significantly larger than that of groups B (3.3 $\pm$ 0.3 mm), C (3.7 $\pm$ 0.4 mm), and D (2 $\pm$ 0.3 mm; $P < .01$). The tunnel's length in group D (8.7 $\pm$ 1.8 mm) was significantly longer than that of groups A (4 $\pm$ 0.4 mm), B (3.3 $\pm$ 0.5 mm), and C (3.7 $\pm$ 0.6 mm; $P < .01$). In radiological analysis, the diameter of the suture anchors was larger in the inferior region (3.3 $\pm$ 1.3 mm) compared with the superior region (2.9 $\pm$ 1 mm; $P < .01$). No significant differences were found in terms of the postoperative functional outcomes and healing rates among the groups.

Conclusions: All-suture anchors with various deployment configurations produced different tunnel diameters and lengths. In addition, the diameter of the tunnel was more pronounced at the inferior region of the anterior glenoid compared with the superior region. Despite this, the deployment configurations and radiological characteristics of the all-suture anchors did not affect the clinical outcomes or occurrence of postoperative complications after Bankart repair.

Keywords: arthroscopy; Bankart lesions; recurrent instability; suture anchor

In managing anterior shoulder instability, inserting sufficient suture anchors at optimal positions is an important and decisive factor in successful arthroscopic Bankart repair.[20] In particular, the suture anchor position for relocating the anterior bundle of the inferior glenohumeral ligament is critical in arthroscopic Bankart repair. An all-suture anchor is widely used because of its flexibility and curved guide, which allows the suture anchor to be firmly inserted into the inferior part of the glenoid.[4,6,10] In addition, the preservation of the glenoid bone during the insertion of the all-suture anchor can be a surgical advantage compared with a conventional biodegradable suture

The Orthopaedic Journal of Sports Medicine, 13(3), 23259671251319533
DOI: 10.1177/23259671251319533

anchor.[9] Despite these advantages, postoperative glenoid bone reactions—including tunnel enlargement or the development of perianchor cysts—occurring after arthroscopic Bankart repair have been reported in several clinical studies.[9,18,19] Furthermore, despite a lack of negative reports regarding the effect of glenoid bone reaction in clinical outcomes, the occurrence of glenoid rim fracture has been reported in cases where a large number of all-suture anchors are inserted.[5,8,18,19]

All-suture anchors are versatile in terms of configuration, characterized by their unique shape after deployment because the main body of the anchor is composed of a soft ultrahigh molecular weight polyethylene (UHMWP).[1] From a biomechanical perspective, different types of all-suture anchors have varying results in terms of their ultimate load, displacement after cyclic loading, and failure mode in biomechanical studies.[1,2] However, comparative studies on the effects of the shape of all-suture anchors on tunnel enlargement, as well as on the clinical outcomes based on the specifications and configurations of various types of all-suture anchors after deployment, are currently lacking.

This study aimed to assess the effects of the deployment configuration of the all-suture anchor used in arthroscopic Bankart repair on the clinical outcomes and radiological findings in patients with recurrent anterior shoulder instability. The study was undertaken with the hypothesis that each all-suture anchor would yield comparable clinical outcomes regardless of radiological differences observed in the pattern of glenoid bone reaction 1 year after arthroscopic Bankart repair.

METHODS

Patient Selection

This study was designed as a retrospective cohort study, and patients who underwent primary arthroscopic Bankart repair using single-loaded all-suture anchors for recurrent anterior shoulder dislocation in 1 institute between February 2017 and December 2021 were included in this study. The inclusion criteria were as follows: (1) confirmation of a Bankart lesion with symptomatic anterior instability through arthroscopic surgery; (2) utilization of a singular type of all-suture anchor during suturing for a Bankart lesion, employing a straightforward suture technique for repair; (3) clinical outpatient follow-up for at least 2 years after surgery; and (4) 1-year postoperative computed tomography arthrogram (CTA) to confirm the tunnel size of the all-suture anchor and assess the healing of the labrum. The exclusion criteria were as follows: (1) patients <15 or >50 years old at the time of surgery; (2) engaging or off-track Hill-Sachs lesions identified as a result of preoperative radiological examination and during arthroscopic Bankart repair, where a remplissage procedure was performed simultaneously; (3) a glenoid bone fragment large enough to require a special fixation procedure to achieve union of the bone fragment; and (4) significant glenoid bone defect requiring surgical options such as additional bone grafting.

During the study period, all-suture anchors were used at different times along with the introduction in the author's hospital. Patients who underwent arthroscopic Bankart repair using all-suture anchors were divided into 4 groups based on the configurations of the anchors after deployment. Group A comprised patients who underwent surgery with a 1.3-mm single-loaded all-suture anchor (Y-Knot flex; ConMed Linvatec) that developed into a *spherical* shape (Figure 1A). Group B included patients with a 1.4-mm single-loaded all-suture anchor (Iconix 1; Stryker Endoscopy) that developed into a *cloverleaf* shape (Figure 1B). Group C included patients with a 1.7-mm single-loaded all-suture anchor (Suturefix Ultra; Smith & Nephew) that developed into an *omega* shape (Figure 1C). Group D included patients with a 1.4-mm single-loaded all-suture anchor (FiberTak, Arthrex) that developed into a *cylindrical* shape (Figure 1D). Each all-suture anchor was predrilled before insertion into the glenoid, and the diameter and depth of predrilling were 1.3 and 21 mm for group A, 1.4 and 21 mm for group B, 1.7 and 19 mm for group C, and 1.7 and 24 mm for group D, respectively.[20] All of the all-suture anchors requiring knot tying used in the patients included in this study consisted of a single No. 2 braided UHMWPE suture. This retrospective study was approved by the institutional review board (IRB). Because of the retrospective nature of the study, the IRB waived the requirement for informed consent.

Surgical Technique and Postoperative Rehabilitation

All of the operations were performed under general anesthesia by the senior author (S.J.S.), with the patient in a lateral decubitus position. With the arm abducted at approximately 40°, a load was applied through the traction tower and slight anterior elevation was performed. Using the anterosuperior portal as a viewing portal, arthroscopic

[‡]Address correspondence to Sang-Jin Shin, MD, PhD, Department of Orthopaedic Surgery, Ewha Womans University Seoul Hospital, 260, Gonghang-daero, Gangseo-gu, Seoul, 07804, Republic of Korea (email: sjshin622@ewha.ac.kr).

*Department of Orthopaedic Surgery, Inje University, Ilsan Paik Hospital, Goyang-si, Republic of Korea.

[†]Department of Orthopaedic Surgery, Ewha Shoulder Disease Center, Seoul Hospital, Ewha Womans University School of Medicine, Seoul, Republic of Korea.

Final revision submitted August 13, 2024; accepted September 10, 2024.

One or more of the authors has declared the following potential conflict of interest or source of funding: This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2022R1A2C1009316). AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval for this study was obtained from The Institutional Review Board of Ewha Women's University (SEUMC 2023-07-039).

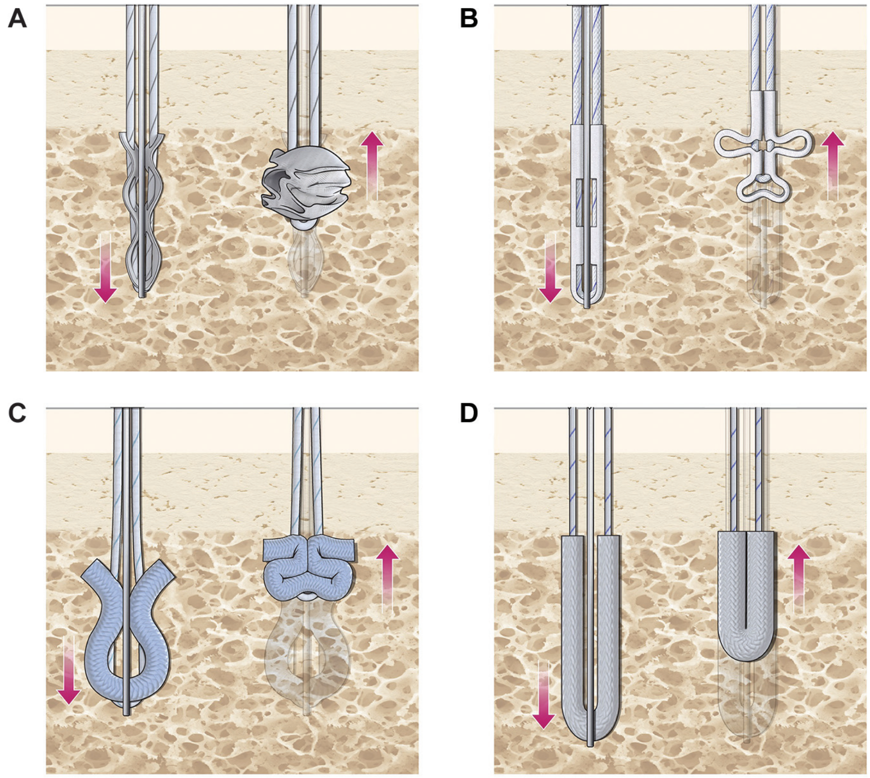

Figure 1. Schematic representations of the configuration after the intraosseous insertion and deployment of the all-suture anchors. (A) A 1.3-mm single-strand all-suture anchor (Y-Knot flex; ConMed Linvatec) is deployed in a *spherical* shape and the anchor is inserted after drilling a 1.3-mm pilot hole to a depth of 21 mm. (B) A 1.4-mm single-strand all-suture anchor (Iconix 1; Stryker Endoscopy) is deployed in a *cloverleaf* shape. (C) A 1.7-mm diameter all-suture anchor (Suturefix Ultra; Smith & Nephew) is deployed in an *omega* shape. (D) A 1.4-mm all-suture anchor (FiberTak; Arthrex) is deployed in a *cylindrical* shape.

instruments were used to access the glenohumeral joint through the anteroinferior and posterior portals. To repair the anteroinferior capsulolabral complex, an appropriate amount of soft tissue was released at the tear site, allowing the labrum to be sufficiently moved to the edge of the glenoid with the grasper without tension. Starting from the lowest position, the curved guide was placed where the anchor was to be inserted, which was followed by predrilling to the depth specified in the manufacturer's guidelines. In all patients, an all-suture anchor with a single strand for the glenoid was inserted. After anchor insertion, the suture limb was manually pulled back with sufficient force to confirm that the deployed all-suture anchor had mechanical resistance within the glenoid. The capsulolabral complex was penetrated with a curved suture passer at an appropriate site according to the tissue condition and then the strand of the suture anchor was passed through the tissue using the shuttle relay technique. The paired 2 suture limbs were tied using the sliding locking knot technique and all knots were located on the outside, away from the articular surface of the glenoid.

The same postoperative rehabilitation protocol was applied to all patients in all groups. Immobilization with an abduction brace was maintained for 4 weeks after arthroscopic Bankart repair. A passive range of motion (ROM) and active-assisted exercise in all directions were allowed 4 weeks after immobilization was stopped. Shoulder muscle strengthening exercises were initiated 8 to 12 weeks postoperatively. Patients were allowed to return to vigorous physical activity, including sports, after 6 months.

Clinical Evaluation

All participants completed questionnaires regarding their preoperative sports activity level, the mechanism of injury, age at the first dislocation, number of dislocations, and comprehensive demographic information—including age, sex, and arm dominance. The level of sports participation before surgery was categorized into 4 grades: grade 1—no sports participation; grade 2—participation in recreational sports that did not involve the use of the upper extremities; grade 3—upper extremity recreational sports participation, such as basketball or swimming; and grade 4— participation in professional sports. An independent physician assistant, not affiliated with this study, assessed patients using the shoulder ROM, the Rowe score, and the American Shoulder and Elbow Surgeons (ASES) score, both preoperatively and at the final follow-up. Redislocation was defined as the postoperative dislocation of the glenohumeral joint identified through radiographic examination or reduced by the clinician. Subjective instability was confined to cases

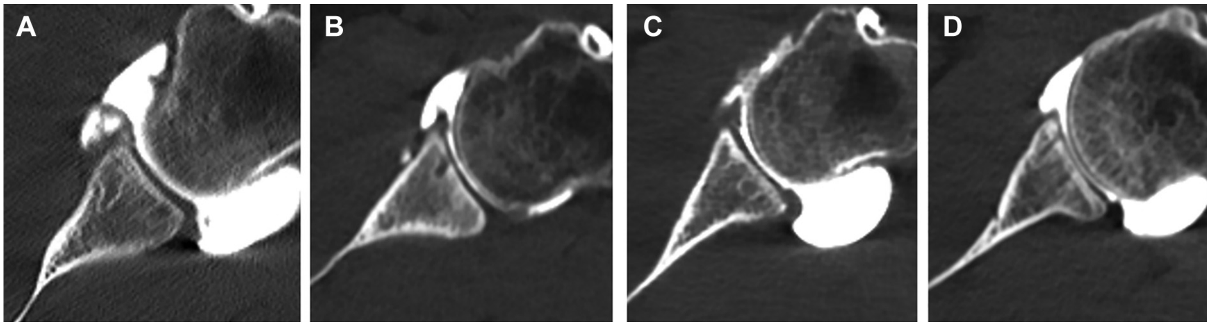

Figure 2. The radiological pattern of suture anchor tunnels observed in axial images of CTA performed 1 year after surgery for each of the all-suture anchors. (A) CTA findings in a 24-year-old male patient who underwent surgery with a 1.3-mm Y-knot all-suture anchor. (B) A relatively small suture anchor tunnel and well-healed labrum are observed on CTA in a 19-year-old male patient who underwent surgery with a 1.4-mm Iconix anchor. (C) Multiple suture anchor tunnels are observed at the insertion site of the 1.7-mm Suturefix anchor in a CTA in a 28-year-old male patient. (D) A relatively long and thin cylindrical shape of the suture anchor tunnel is observed at the insertion site of a 1.4-mm FiberTak anchor in a CTA of an 18-year-old male patient. CTA, computed tomography arthrogram.

exhibiting persistent subjective complaints of apprehension and a positive apprehension test until the last follow-up. Postoperatively, patients' sports activity levels were also assessed to evaluate the effect of the procedure on their ability to engage in physical activities.

Radiological Evaluation

Preoperative simple shoulder radiograph series, 3-dimensional CT, and magnetic resonance images were evaluated by an orthopaedic surgeon (J.H.L.), and the size and status of the labral lesion, bony Bankart, glenoid bone loss, and Hill-Sachs lesion, superior labral anterior and posterior lesion, intra-articular loose body, and partial rotator cuff tear were measured. In the CTA image obtained 12 months after surgery, labral healing and the tunnel size of the anchor insertion site were measured. Two experienced observers (including J.H.L.) independently conducted radiological evaluations using the Picture Archiving and Communication System (PACS). Each observer randomly reviewed the medical images of selected patients through the PACS system. Each observer performed a self-assessment of the images using a designated form or evaluation scale. The 2 observers worked independently to minimize interobserver communication. The assessment results were recorded in a separate database and stored in an appropriate format for future statistical analysis. Healing of the labrum at the glenoid was determined in accordance with the definitions of previous studies.[13,14] To ensure no errors in the order and recognition of the suture anchors, the insertion location and type of each anchor were accurately ordered by the 2 observers based on the information in the operative record by cross-checking. The diameter and length of the suture anchor tunnel measured on axial, sagittal, and oblique coronal CTA images were recorded based on the radiological measurement methods and definitions described in a previous study.[9] The definition of the glenoid bone reaction observed postoperatively in all-suture anchors is controversial, and the terms tunnel enlargement or perianchor cyst have been used interchangeably in clinical studies, depending on the size and extent of the reaction.[5,9,15,18-20] In our study, the diameter of the suture anchor was measured on CTA performed at 1 year postoperatively (Figure 2). To measure the size of the tunnel created by the all-suture anchors based on their insertion location, the size of the tunnel was further evaluated by categorizing it into 3 subgroups: superior—anchors located in the upper third of the anterior glenoid; middle—anchors located in the middle third of the anterior glenoid; and inferior—anchors located in the lower third of the anterior glenoid. Two observers (including J.H.L.) reviewed the CTA images and estimated the dimensions of the tunnels independently to maintain interobserver reliability.

Statistical Analysis

Given the clinical prevalence of the disease, the frequency of surgeries, and the challenges associated with utilizing a singular product for each group, a predetermined sample size for statistical analysis was not established through calculation. Instead, all eligible patients within the clinical cohort who adhered to the inclusion and exclusion criteria were prospectively recruited throughout the study period. To ascertain measurement consistency between the 2 observers, Pearson correlation coefficients were computed for the dimensions of the tunnel, and the results were graphically represented using a scatterplot.

Independent t tests were employed to assess differences between groups in quantitative variables, encompassing demographic, radiological, and clinical measurements. Paired t tests were utilized to evaluate differences in the pre- and postoperative ASES and Rowe scores. The extent of tunnel enlargement among the 4 distinct all-suture anchors was compared using analysis of variance with Tukey post hoc tests. For categorical variables, we used

TABLE 1
Patients' Characteristics and Preoperative Functional and Sports Activity[a]

	Group A	Group B	Group C	Group D	*P*
No. of patients	38	25	31	47	
Sex, male:female	36:2	22:3	29:2	40:7	.420
Age at first dislocation, y	22 ± 6.6	21.7 ± 7	22.2 ± 6.1	21.3 ± 7	.953
No. of dislocations	7.7 ± 4.4	7.2 ± 4.4	6.8 ± 3.8	6.8 ± 3.8	.790
Age at operation, y	28.5 ± 7.2	27.8 ± 8	29.9 ± 8.1	29.1 ± 8	.801
Excessive ligamentous laxity[b]	6 (15.8)	4 (16)	6 (19.4)	9 (19.1)	.968
BMI, kg/m^2	25.8 ± 3	25.1 ± 3.3	25.7 ± 3.4	24.7 ± 2.7	.319
Dominant shoulder	28 (73.7)	13 (52)	20 (64.5)	29 (61.7)	.360
Bony Bankart	7 (18.4)	5 (20)	4 (12.9)	8 (17)	.896
% of glenoid defect[c]	10.8 ± 2.4	11.2 ± 2.2	10.4 ± 3.1	10.7 ± 2.4	.747
Preop ROM, deg					
Active forward flexion	169.6 ± 13.7	165.2 ± 19.2	167.1 ± 15.5	165.4 ± 17.2	.933
External rotation	78.2 ± 17.4	73.2 ± 21.5	75 ± 19.2	74.1 ± 13.2	.666
Preop functional score					
ASES	45.2 ± 14.6	46.2 ± 11.1	43.1 ± 14	46.3 ± 14.2	.756
Rowe	46.6 ± 20.2	44.8 ± 14.5	45.8 ± 16	49.9 ± 17.4	.569
Preop sports level[d]					.554
I	18 (47.4)	11 (44)	16 (51.6)	24 (51.1)	
II	8 (21.1)	9 (36)	6 (19.4)	15 (31.9)	
III	12 (31.6)	5 (20)	9 (29)	8 (17)	

[a]Values are presented as mean ± SD or n (%). ASES, American Shoulder and Elbow Surgeons; BMI, body mass index; Preop, preoperative; ROM, range of motion.
[b]Defined as a total Beighton score of ≥4 out of 9, based on hyperextension of the little finger, thumb, elbow, and knee, and the ability to touch the ground with the palms while bending forward.
[c]Reported as a percentage of bone loss in the anteroinferior glenoid.
[d]Preoperative level of sports participation was categorized into 4 grades as follows: grade 1—no sports participation; grade 2—participating in recreational sports that do not involve the use of the upper extremities; grade 3—upper extremity recreational sports participation such as basketball or swimming; and grade 4—professional sports participation.

the Pearson chi-square test and the Fisher exact test, as appropriate. All statistical analyses were conducted using R Version 4.3.1 (R Foundation for Statistical Computing). Statistical significance was set at $P < .05$.

RESULTS

Out of the 175 patients undergoing surgery during the observation period, 141 patients meeting the inclusion criteria were ultimately enrolled in the study. The distribution of patients across the groups was as follows: 38 patients in group A; 25 patients in group B; 31 patients in group C; and 47 patients in group D.

No significant differences were found in the preoperative demographic data among the 4 groups (Table 1). No statistically significant differences were observed in the postoperative clinical outcomes—including shoulder function, redislocation rate, and subjective instability—among the groups. Furthermore, no significant differences were observed in postoperative active forward flexion (group A, $P = .17$; group B, $P = .09$; group C, $P = .90$; group D, $P = .45$, respectively) and external rotation (group A, $P = .22$; group B, $P = .78$; group C, $P = .47$; group D, $P = .09$) compared with the preoperative status. Postoperative Rowe and ASES scores were significantly improved in all groups (ASES score: group A, $P < .01$; group B, $P < .01$; group C, $P < .01$; group D, $P < .01$; Rowe score: group A, $P < .01$; group B, $P < .01$; group C, $P < .01$; group D, $P < .01$). The ASES and Rowe scores assessed at the final follow-up did not differ significantly among the groups. In terms of the level of postoperative sports activity and the rate of postoperative recovery, no significant differences were found among the groups (Table 2).

The Pearson correlation coefficient for the reliability of tunnel size measurement for each suture anchor in each group ranged from 0.977 to 0.999. Also, the interobserver reliability in tunnel measurements demonstrated excellent agreement, with intraclass correlation coefficients of 0.988 (95% CI, 0.986-0.989) for the diameter and 0.997 (95% CI, 0.997-0.998) for the length. The status of intra-articular lesions observed during surgery and the number of suture anchors used are presented in Table 3. No significant differences were observed between the groups. In radiological evaluation, significant differences were found in the mean diameter and length of the tunnels of the suture anchors between the groups ($P < .001$, respectively). In terms of the mean diameter of the tunnel size, group A (3.9 ± 0.4 mm) exhibited a significantly larger diameter compared with groups B (3.3 ± 0.3 mm; $P < .01$), C (3.7 ± 0.4 mm; $P = .012$), and D (2 ± 0.3 mm; $P < .01$). The mean diameter of group B was smaller than that of group C ($P < .01$) and

TABLE 2
Postoperative Clinical Outcomes and Complications[a]

	Group A	Group B	Group C	Group D	*P*
Duration of postop follow-up, mo	30.2 ± 5.9	26.8 ± 4.8	27.5 ± 5.1	26.3 ± 4	.011[b]
Subjective instability	6 (15.8)	5 (20)	6 (19.4)	12 (25.5)	.736
Redislocation	2 (5.3)	1 (4)	2 (6.5)	4 (8.5)	.931
Postop ROM, deg					
Active forward flexion	164.5 ± 13.4	161.6 ± 11.3	166.9 ± 12.6	164.9 ± 13.2	.433
External rotation	73.4 ± 12.6	71.6 ± 11.6	72.1 ± 15	69.9 ± 14.2	.692
Functional outcomes					
ASES	90.3 ± 14.7	89 ± 18	90.8 ± 13.4	89.6 ± 12.4	.969
Rowe	92 ± 12.7	90.6 ± 14.2	92.1 ± 11.9	90.6 ± 13.8	.938
Postop sports level					.996
I	23 (60.5)	16 (64)	20 (64.5)	31 (66)	
II	10 (26.3)	7 (28)	7 (22.6)	11 (23.4)	
III	5 (13.2)	2 (8)	4 (12.9)	5 (10.6)	
Recovery to preop sports level[c]					.748
Under	10 (26.3)	7 (28)	6 (19.4)	9 (19.1)	
Same	28 (73.7)	18 (72)	25 (80.6)	38 (80.9)	

[a]Values are presented as mean ± SD or n (%). ASES, American Shoulder and Elbow Surgeons; postop, postoperative; preop, preoperative; ROM, range of motion.
[b]Statistical significance.
[c]Recovery at the final follow-up after surgery compared with the preoperative level of sports activity.

TABLE 3
Intra-articular Labral Lesion and Number of Suture Anchors Used in Arthroscopic Bankart Repair[a]

	Group A	Group B	Group C	Group D	*P*
Concomitant labral pathology					
SLAP	11 (28.9)	8 (32)	13 (41.9)	20 (42.6)	.518
Posterior labral tear	5 (13.2)	4 (16)	5 (16.1)	6 (12.8)	.951
Total number of suture anchors	5.8 ± 1	5.9 ± 0.8	6 ± 0.9	6 ± 0.9	.653
Number of suture anchors for Bankart repair	5.2 ± 0.7	5.4 ± 0.6	5.4 ± 0.6	5.3 ± 0.6	.473

[a]Data are presented as mean ± SD or n (%). SLAP, superior labrum anterior and posterior.

larger than that of group D ($P < .01$), while the mean diameter of group C was larger than that of group D ($P < .01$). The tunnel length of group A (4 ± 0.4 mm) demonstrated no significant differences compared with groups B (3.3 ± 0.5 mm; $P = .085$) and C (3.7 ± 0.6 mm; $P = .737$). In addition, no significant difference was observed between the tunnel lengths of groups B and C ($P = .524$). However, group D (8.7 ± 1.8 mm) showed a significantly larger tunnel length compared with groups A, B, and C ($P < .01$) (Figure 3). The healing rate of the repaired labrum showed no significant differences among the groups (Table 4).

Regarding radiological analysis based on the anchor location, the diameter of suture anchor tunnel was observed to be larger in the inferior region compared with the superior region of the anterior glenoid (the first and second position, 2.9 ± 1 mm; the third position, 3.2 ± 1.2 mm; the fourth and fifth positions, 3.3 ± 1.3 mm; $P < .01$). However, the length did not vary with location (the first and second position, 5.1 ± 3.1 mm; the third position, 5.5 ± 3.1 mm; the fourth and fifth position, 5.6 ± 3.1 mm; $P < .01$). When comparing between the groups, both groups A and B showed an increase in both diameter and length toward the inferior region. However, no significant change was found in group C based on location. In group D, the diameter was found to be larger in the inferior region. However, no differences in the length were observed based on the location (Table 5). No postoperative glenoid fracture was found in any of the groups during the study period.

DISCUSSION

Arthroscopic Bankart repair using all-suture anchors with different configurations after deployment showed satisfactory clinical outcomes regardless of the deployment shapes. However, some radiological differences were found in the diameter and depth of the tunnel size among the different all-suture anchors. Despite these differences, no significant distinction in the occurrence of postoperative complications was observed among the various anchor configurations.

The bone reaction of all-suture anchor occurs frequently after deployment, which is a necessary procedure for

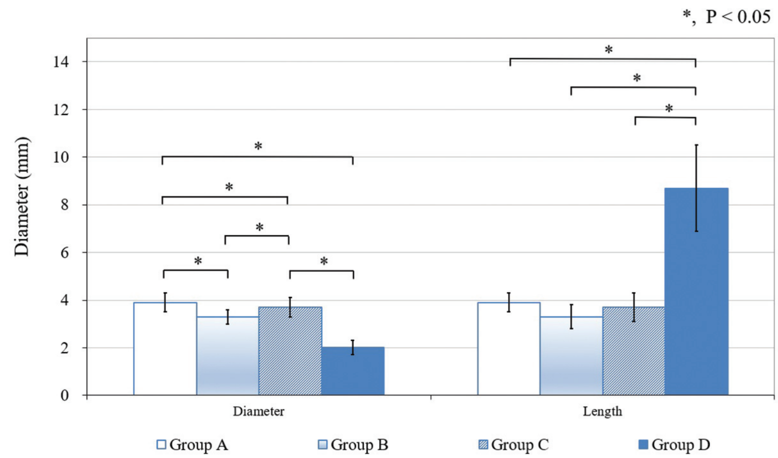

Figure 3. Mean values of the tunnel diameter and length for each group measured by CTA 12 months after surgery. CTA, computed tomography arthrogram. *Statistical significance.

TABLE 4
Analysis of the Healing Status of the Anteroinferior Labrum After Surgery According to All-Suture Anchor Types[a]

	Group A	Group B	Group C	Group D	*P*
Healing of the labrum at the Bankart repair site					.846
Complete healed	33 (86.8)	21 (84)	25 (80.6)	37 (78.7)	
Partial healed	3 (7.9)	1 (4)	4 (12.9)	6 (12.8)	
Retear	2 (5.3)	3 (12)	2 (6.5)	4 (8.5)	

[a]Data are presented as n (%).

TABLE 5
Comparison of All-Suture Anchor Tunnel's Diameter and Length According to Location[a]

	First and Second Suture Anchors	Third Suture Anchor	Fourth and Fifth Suture Anchors	*P*
Diameter of the tunnel, mm				
Group A	3.7 ± 1	4 ± 1.3	4.3 ± 1	<.001[b]
Group B	3 ± 0.7	3.3 ± 0.7	3.6 ± 0.9	<.001[b]
Group C	3.5 ± 0.9	3.8 ± 0.9	3.8 ± 1	.054
Group D	1.9 ± 0.6	2 ± 0.5	2.1 ± 0.7	.033[b]
Length of the tunnel, mm				
Group A	3.8 ± 0.9	4.1 ± 1	4.3 ± 1	<.001[b]
Group B	2.8 ± 0.9	3.4 ± 1	3.6 ± 0.9	<.001[b]
Group C	3.6 ± 1	3.8 ± 1.1	3.8 ± 1.2	.147
Group D	8.5 ± 3.2	8.9 ± 3.1	8.7 ± 3.3	.535

[a]The insertion positions of the first to fifth suture anchors were numbered from superior to inferior portion, and the third anchor was mainly located at the 4 o'clock position based on the right shoulder.
[b]Statistical significance.

ensuring secure fixation after insertion in the glenoid.[8,19,20] The description of the incidence and appearance of glenoid bone reaction of various all-suture anchors in clinical studies present a broad spectrum, influenced by the definition used.[8,9,18-20] In a CT analysis study of glenoid bone reaction in 143 all-suture anchors (Iconix and Suturefix anchors) in 33 patients, tunnel enlargement or cystic lesions were reported in 30.1% of patients.[18] Jin and Chun[5] reported that the incidence of perianchor cyst formation was very low (3.2%) when an all-suture anchor was used in arthroscopic Bankart repair. On the other hand, Tompane et al[19] used an all-suture anchor (1.4 mm, JuggerKnot; Biomet Sports Medicine) in arthroscopic Bankart repair in 30 patients and analyzed the glenoid bone reaction by dividing it into cyst formation and tunnel widening. In their cohort, tunnel widening was confirmed in approximately 80% of patients and cyst formation in 3% of patients postoperatively, which became apparent on serial CT scans obtained 6 months postoperatively.[19] In this study, we measured the size of the tunnel in all-suture anchors because we considered any tunnel larger than the predrilled diameter as tunnel enlargement, which was observed in all patients regardless of the type of anchor.[5,8,9,16,18-20] Most studies have reported that glenoid bone reactions around all-suture anchors do not show evidence of adverse clinical effects or associations with postoperative complications.[9,18,19] In our study, a mean of 5.3 ± 0.6 suture anchors was inserted and no postoperative instability with glenoid rim fracture was observed.

In biomechanical experiments designed to measure the mechanical properties—including the stiffness, early displacement, ultimate failure load, and failure mode of all-suture anchors for the glenoid cavity—no significant differences were observed between anchors with similar diameters.[1] However, there was a difference in its distribution in suture break and anchor pullout in the failure mode. Of the suture anchors compared in this biomechanical study, the 1.4-mm single-loaded clover leaf-shaped all-suture anchor had 3 anchor pullouts, 9 anchor breaks, and 11 suture breaks in a total of 23 tests, while the 1.3-mm single-loaded spherical shaped all-suture anchor had 14 anchor pullouts and 5 suture breaks in a total of 19 tests.[1] The suture break observed in the cloverleaf-shaped all-suture anchor was not observed in the spherical-shaped all-suture anchor, which is inferred to be a result of the difference in configuration. Erickson et al[3] reported in a cadaveric biomechanical study that the second-generation omega-shaped all-suture anchor (Suturefix; Smith & Nephew) performed better than the first-generation omega-shaped all-suture anchor (Juggerknot; Biomet) in the initial 2 mm of displacement. The authors concluded that the advanced configuration and deployment geometry of the latest generation all-suture anchors may alleviate the biomechanical concerns of load reduction associated with the failure of the previous generation all-suture anchors. However, in our study, all 4 all-suture anchors showed equivalent results in terms of clinical outcomes and incidence of postoperative complications and did not reflect any differences in terms of biomechanical failure modes.

Considering that the diameters of the initial drilling and all-suture anchors are very small (range, 1.3-1.7 mm), the glenoid bone reaction is commonly observed, as reported in previous studies.[8,9,18,19,21] Unlike biodegradable anchors, in which the mechanism for maintaining fixation within the bone is interlocked with the surrounding trabecular bone, the all-suture anchor is maintained by its resistance to hard bone after deployment.[15] The all-suture anchors used in the present study differed in terms of their configuration after deployment. According to the specifications provided by each manufacturer, the 1.3-mm Y-knot has a spherical anchor body after deployment with a diameter of approximately 5 mm. In the 1.4-mm Iconix, the anchor body expands to 3 mm in diameter and 4.5 mm in length in the air. After deployment of the 1.7-mm Suturefix, the distal part of the anchor body is extracted, resulting in a diameter of approximately 2.6 mm. However, FiberTak deployed by bending the main strand, maintains its fixing force with the body diameter thickening to approximately 3.6 mm in the same U-shape form without any additional bending parts upon extraction. Although the deployed suture body is expected to maintain its shape and size, as designed and intended by the manufacturer, its composition of UHMWP makes it difficult to accurately estimate what shape it will maintain within the glenoid of young patients who have excellent bone density. However, in our study, FiberTak showed a significantly narrower and longer tunnel widening pattern on CTA 1 year after surgery compared with the other anchors. The difference in the deployment mechanism of all-suture anchors might result in these various radiological findings.

In this study, the suture anchor's tunnel diameter showed a tendency to increase in the region below the glenoid; however, no effect on the depth was observed. This trend was also consistent with our previous radiological study on the serial changes of the tunnel enlargement of the 1.3-mm single-loaded Y-knot suture anchor, in which the diameter of the tunnel was larger in the anchor inserted in the anteroinferior region (mean diameter, 3.3 ± 0.7 mm) of the glenoid than in the anchor inserted in the superior region of the glenoid (mean diameter, 2.6 ± 0.7 mm).[8] This phenomenon likely occurs because the inferior suture anchor in the Bankart repair is primarily used to reattach the anterior bundle of the inferior glenohumeral ligament to the glenoid bone.[8,18] Considering that, histologically, all boundaries of the cystic lesions derived from all-suture anchors have a densely compacted bone layer—micromotion could be the reason for tunnel widening occurring in the all-suture anchors.[15] In a biomechanical study of all-suture anchors based on their position in the glenoid, insertion at the 2:30 o'clock position in the glenoid resulted in a greater stiffness, yield load, and ultimate load compared with insertion at the 4:00 and 5:30 positions under preload and cycling load tests.[7] Furthermore, considering that the quality and thickness of the cortical bone play a crucial role in the fixation strength of an all-suture anchor, the fact that the cortical thickness of the superior part of the glenoid was thicker than that of the inferior part may also contribute to this result.[17] Decortication can be a critical negative factor in maintaining pullout strength after all-suture anchor placement, as it can thin the subchondral bone of the glenoid articular surface or the cortex of the glenoid neck.[12]

Limitations

This study has several limitations. First, this was a retrospective clinical study, and 4 different all-suture anchors were used at different times. To counteract this, during the observation period, the surgical techniques were standardized even if there was a difference in the timing of anchor use. Second, the proportion of patients who participated in elite or contact sports was relatively low among the study cohort. Nakagawa et al[11] reported that in a cohort of patients with high athletic activity, the all-suture anchor group had a higher incidence of postoperative redislocation with anterior glenoid rim fracture compared with the metal-suture anchor group. Although none of the patients in our study cohort developed a glenoid rim fracture, a longer period of observation or the effects of trauma from contact sports may have led to an association with a perianchor cyst. Third, bone ingrowth in the suture anchor tunnel and attenuation on CT could not be evaluated in our study. In our clinical setting, CTA was used to assess labral healing 1-year postoperatively and to allow contact and collision sports. Previous studies observing serial changes in the suture anchor tunnels of all-suture anchors have not found evidence of significant bone ingrowth. However, how the size and attenuation of suture anchor tunnels created by different anchors change over time remains poorly understood.[8] Last, the inability to ascertain the precise dimensions of the tunnel in the immediate postoperative period after the insertion of all-suture anchors precluded the accurate measurement of tunnel expansion on CTA imaging 1 year after surgery.

CONCLUSION

All-suture anchors with various deployment configurations produced different tunnel enlargements. In addition, The tunnel's diameter was more pronounced at the inferior region of the anterior glenoid compared with the superior region. Despite this, the deployment configurations and radiological characteristics of the all-suture anchors did not affect the clinical outcomes or occurrence of postoperative complications after Bankart repair.

ORCID iD

Sang-Jin Shin https://orcid.org/0000-0003-0215-2860

REFERENCES

1. Barber FA, Herbert MA. All-suture anchors: biomechanical analysis of pullout strength, displacement, and failure mode. *Arthroscopy*. 2017;33(6):1113-1121.
2. Barber FA, Herbert MA. Cyclic loading biomechanical analysis of the pullout strengths of rotator cuff and glenoid anchors: 2013 update. *Arthroscopy*. 2013;29(5):832-844.
3. Erickson J, Chiarappa F, Haskel J, et al. Biomechanical comparison of a first- and a second-generation all-soft suture glenoid anchor. *Orthop J Sports Med*. 2017;5(7):2325967117717010.
4. Frank RM, Mall NA, Gupta D, et al. Inferior suture anchor placement during arthroscopic Bankart repair: influence of portal placement and curved drill guide. *Am J Sports Med*. 2014;42(5):1182-1189.
5. Jin S, Chun YM. Peri-anchor cyst formation after arthroscopic Bankart repair: comparison between biocomposite suture anchor and all-suture anchor. *Clin Shoulder Elb*. 2020;23(4):178-182.
6. Karns MR, Epperson RT, Baran S, et al. Revisiting the anterior glenoid: an analysis of the calcified cartilage layer, capsulolabral complex, and glenoid bone density. *Arthroscopy*. 2018;34(8):2309-2318.
7. Lee JH, Itami Y, Hedayati B, et al. Biomechanical effects of position and angle of insertion for all-suture anchors in arthroscopic Bankart repair. *Clin Biomech (Bristol, Avon)*. 2018;60:45-50.
8. Lee JH, Kang JS, Park I, Shin SJ. Serial changes in perianchor cysts following arthroscopic labral repair using all-suture anchors. *Clin Orthop Surg*. 2021;13(2):229-236.
9. Lee JH, Park I, Hyun HS, Kim SW, Shin SJ. Comparison of clinical outcomes and computed tomography analysis for tunnel diameter after arthroscopic Bankart repair with the all-suture anchor and the biodegradable suture anchor. *Arthroscopy*. 2019;35(5):1351-1358.
10. Levy DM, Cole BJ, Bach BR Jr. History of surgical intervention of anterior shoulder instability. *J Shoulder Elbow Surg*. 2016;25(6): e139-150.
11. Nakagawa S, Hirose T, Tachibana Y, Iuchi R, Mae T. Postoperative recurrence of instability due to new anterior glenoid rim fractures after arthroscopic Bankart repair. *Am J Sports Med*. 2017;45(12): 2840-2848.
12. Ntalos D, Huber G, Sellenschloh K, et al. All-suture anchor pullout results in decreased bone damage and depends on cortical thickness. *Knee Surg Sports Traumatol Arthrosc*. 2021;29(7):2212-2219.
13. Oh JH, Lee HK, Kim JY, Kim SH, Gong HS. Clinical and radiologic outcomes of arthroscopic glenoid labrum repair with the BioKnotless suture anchor. *Am J Sports Med*. 2009;37(12):2340-2348.
14. Park JY, Lee SJ, Lhee SH, Lee SH. Follow-up computed tomography arthrographic evaluation of bony Bankart lesions after arthroscopic repair. *Arthroscopy*. 2012;28(4):465-473.
15. Pfeiffer FM, Smith MJ, Cook JL, Kuroki K. The histologic and biomechanical response of two commercially available small glenoid anchors for use in labral repairs. *J Shoulder Elbow Surg*. 2014;23(8): 1156-1161.
16. Ro K, Pancholi S, Son HS, Rhee YG. Perianchor cyst formation after arthroscopic rotator cuff repair using all-suture-type, bioabsorbable-type, and PEEK-type anchors. *Arthroscopy*. 2019;35(8):2284-2292.
17. Roth CA, Bartolozzi AR, Ciccotti MG, et al. Failure properties of suture anchors in the glenoid and the effects of cortical thickness. *Arthroscopy*. 1998;14(2):186-191.
18. Ruiz Ibán MA, Vega Rodriguez R, Díaz Heredia J, et al. Arthroscopic Bankart repair with all-suture anchors does not cause important glenoid bone osteolysis: a volumetric CT study of 143 anchors. *Knee Surg Sports Traumatol Arthrosc*. 2021;29(7):2152-2158.
19. Tompane T, Carney J, Wu WW, et al. Glenoid bone reaction to all-soft suture anchors used for shoulder labral repairs. *J Bone Joint Surg Am*. 2018;100(14):1223-1229.
20. Trofa DP, Bixby EC, Fleischli JE, Saltzman BM. All-suture anchors in orthopaedic surgery: design, rationale, biomechanical data, and clinical outcomes. *J Am Acad Orthop Surg*. 2021;29(19):e950-e960.
21. Willemot L, Elfadalli R, Jaspars KC, et al. Radiological and clinical outcome of arthroscopic labral repair with all-suture anchors. *Acta Orthop Belg*. 2016;82(2):174-178.