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Curved-guide system is useful in achieving optimized trajectory for the most inferior suture anchor during arthroscopic Bankart repair

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Background: A curved–drill guide system was recently introduced to achieve a better trajectory for a low anteroinferior anchor during arthroscopic Bankart repair. However, the clinical performance of such a device remains unclear. The purpose of this study was to evaluate the trajectory and position of the low anteroinferior suture anchor with use of the curved-guide system in clinical cases.
Methods: We enrolled 41 cases of arthroscopic Bankart repair in this study. Of these cases, 9 were repaired using the curved drill guide whereas 32 were repaired using a conventional straight guide. Postoperative computed tomography scans were obtained, and 3-dimensional models of the scapula were reconstructed. Notable perforations of the opposite cortex by the most inferior anchors were recorded. The clock-face angle, insertion angle, and insertion distance were measured.
Results: The anchor perforation rate in the curved-guide group (11%) was significantly lower than that in the straight-guide group (56%) ($P = .02$). The insertion distance in the curved-guide group was significantly shorter than that in the straight-guide group (4.0 ± 1.6 mm vs. 7.0 ± 2.4 mm, $P < .01$). The clock-face angle and insertion angle were significantly greater in the perforated straight-guide group than in the nonperforated groups. The percentage of anchors in the absolute safe zone (clock-face angle > 135° and < 165° and insertion angle < 100°), where no anchors perforated, was greater in the curved-guide group than the straight-guide group.
Conclusion: Compared with the conventional straight guide, the curved-guide system provides better placement of the most inferior suture anchor during arthroscopic Bankart repair.
Level of evidence: Level III; Retrospective Cohort Design; Treatment Study

Keywords: Arthroscopic Bankart repair; curved-guide system; most inferior suture anchor; anchor trajectory; anchor perforation; 3D reconstruction

Arthroscopic Bankart repair has become the standard surgical procedure for treating traumatic anterior shoulder instability.[18,23] Its favorable clinical outcomes have been demonstrated in midterm to long-term follow-up studies.[1,3,5,6,9,11,23,26,28,33,34] However, failure rates leading

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to shoulder redislocation as high as 20% to 40% have been reported,[6,23,25-27,34] especially in adolescents and young adults.[2,10,22] Malpositioning of the most inferior anchor around the 5-o'clock position of the glenoid surface is thought to be one of the causes of revision surgery after Bankart repair.[17,19,31] Placement of the most inferior anchor is critical to reattach the anterior-inferior soft tissue to the glenoid edge.[4,20,29] However, using a conventional straight drill guide via the standard anterior portal would, by necessity, lead to insertion of the most inferior anchor at a very acute angle to the glenoid surface,[7] which could result in damage to the articular cartilage and even perforation of the anchor out of the opposite cortex.[8,15,16,20] An acute insertion angle and perforation of the cortex were reported to be associated with poor biomechanical performance.[14,20]

To address these issues, alternative portals and curved–drill guide instruments have been introduced. The clinical advantages of a trans-subscapularis portal have been confirmed.[8,12,15] However, concerns about the anatomic risk of injuring the cephalic vein or axillary nerve have been well described by researchers.[21,24] A curved–drill guide system was more recently introduced to achieve better access to the 5- to 6-o'clock position during arthroscopic Bankart repair. However, studies evaluating the performance of such a device are limited. Frank et al[12] compared the anchor trajectory, position, and biomechanical performance between straight and curved drill guides via multiple portals using cadaveric shoulders. No significant difference in the opposite-cortex perforation rate or biomechanical performance was found between the guides. To our knowledge, no clinical evidence has been demonstrated regarding the application of a curved-guide system in arthroscopic Bankart repair. The purpose of this study, therefore, was to evaluate the trajectory and position of the most inferior suture anchor with use of a curved-guide system in clinical cases.

Materials and methods

Patients and surgical techniques

Sixty-two consecutive patients with recurrent anterior dislocation of the shoulder underwent arthroscopic Bankart repair in our hospital from 2009 to 2017. Those who met the following inclusion criteria were retrospectively reviewed: traumatic anterior dislocation of the shoulder, computed tomography (CT) scans obtained before and after surgery, and a minimum follow-up period of 1 year. The exclusion criteria were bilateral dislocations, glenoid defects of greater than 25% of the glenoid width, off-track Hill-Sachs lesions, and revision cases.

A total of 41 patients met the inclusion criteria and were enrolled in this study, comprising 35 male and 6 female patients. The mean age at the time of surgery was 25 years (range, 17-49 years), and 29 right and 12 left shoulders were included.

Arthroscopic Bankart repair was performed by 2 experienced surgeons (N.Y. and E.I.) with the patient in the standard beach-chair position under general anesthesia. For reattachment of the anterior capsule and labrum, 3 to 5 suture anchors were inserted at the edge of the glenoid between the 1:30 and 5:30 clock-face positions in a right shoulder (or between the 6:30 and 10:30 clock-face positions in a left shoulder) through the standard anterior portal just above the subscapularis tendon. In 9 cases, a curved–drill guide system (Osteoraptor Curved Suture Anchors and Guide System; Smith & Nephew, Andover, MA, USA) was used to insert the most inferior suture anchor. This system provided 25° of curvature on the tip of the guide, allowing the surgeons to place the anchor in a less tangential direction using the conventional portal. In the remaining 32 cases, a conventional straight guide (Gryphon anchor; DePuy Mitek, Raynham, MA, USA) was used. Postoperative range-of-motion exercises were started after 3 weeks of immobilization in a sling in all patients.

Radiographic evaluation

All patients underwent CT scanning on their affected shoulders for postoperative evaluation. The CT scans were performed using a Somatom Definition (Siemens AG, Munich, Germany) or BrightSpeed (GE Healthcare, Chalfont St Giles, UK) CT scanner at a mean of 16 months after the surgical procedure. The thickness of each CT slice was 0.5 mm, and the pixel matrix was 512 × 512. The scans were stored as Digital Imaging and Communications in Medicine (DICOM) data and were imported into Mimics software (Materialise, Leuven, Belgium).

For each case, the scapula model was reconstructed 3-dimensionally, and the superior-inferior (SI) (12- to 6-o'clock position) axis of the glenoid was then drawn on the glenoid surface. Another axis, the anterior-posterior (9- to 3-o'clock position) axis, was created at the widest portion of the glenoid perpendicular to the SI axis; if the anterior edge of the glenoid was defective, the mirror image of the contralateral 3-dimensional model of the glenoid was used to obtain the anatomic details of the anterior glenoid edge (Fig. 1, *A*). A line parallel to the anterior-posterior axis and passing through the midpoint (point O) of the SI axis was drawn (line A'P'). These 2 axes defined a clock-face plane (plane A) with point O as the center of the clock face. The most inferior drill hole was identified on the anterior edge of the glenoid, and the center (point E) of the drill hole was defined as the insertion point of the most inferior anchor. Point E' was the projected point of point E to plane A; we measured the obtuse angle created by line OE' and the SI axis and defined it as the clock-face angle (Fig. 1, *B*). The location and orientation of the most inferior drill hole were checked in the coronal and axial planes. If a bone hole of the cortex opposite the entrance hole was observed on CT images in both planes, as well as the 3-dimensionally reconstructed image, then it was defined as a "perforation" of the opposite cortex (Fig. 2). A perpendicular plane to plane A and passing through line OE' was defined as plane B (Fig. 3, *A-C*). The center of the deepest point of the drill hole was defined as point T (if the drill hole perforated the opposite cortex, then the center of the cortex hole was point T), and its projection on plane B was defined as point T'. The angle created by line S (passing through the edge of the glenoid and tangential to the glenoid surface curvature) and line ET' was defined as the insertion angle. In addition, the distance between

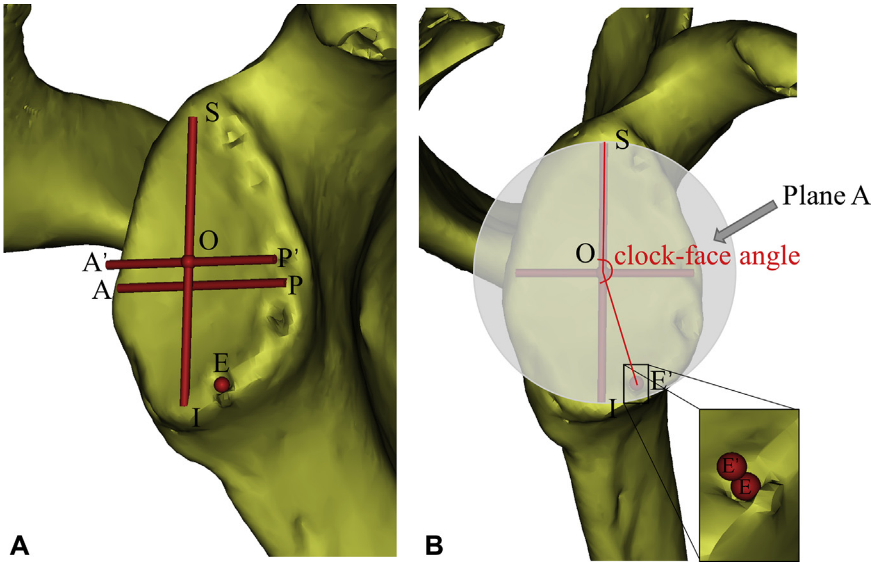

Figure 1 Examples of superior-inferior (*SI*) axis and anterior-posterior (*AP*) axis of glenoid. (**A**) A parallel line (*A'P'*) to the AP axis passes through the midpoint (*O*) of line SI. The center of the drill hole is indicated (*E*). (**B**) Plane A is defined by the SI axis and line A'P'. *E'* is the projected point of point E to plane A, and the angle enclosed by the SI axis and line OE' is the clock-face angle (insertion position).

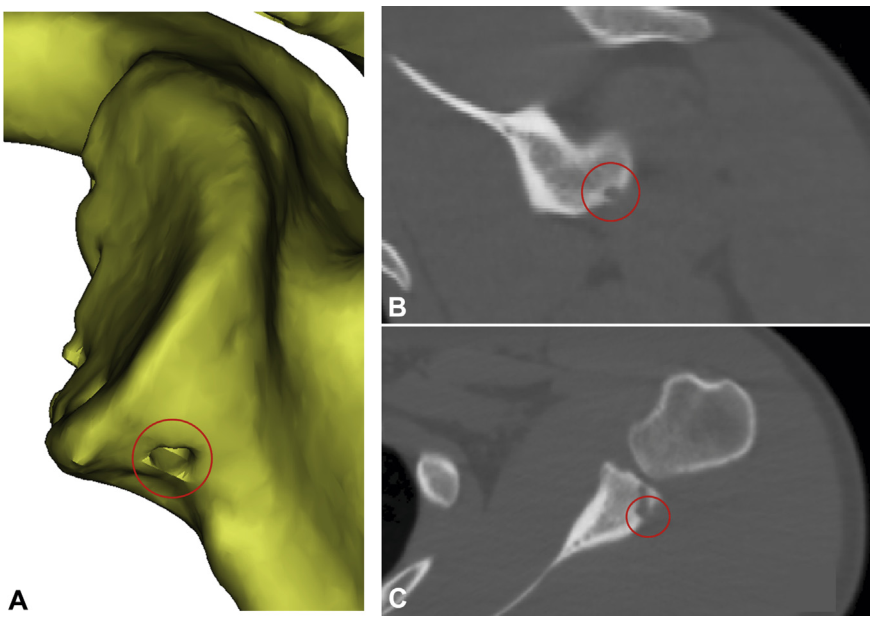

Figure 2 The bone hole is indicated (◯) on the far cortex of the glenoid in a 3-dimensionally reconstructed model (**A**), the coronal plane (**B**), and the cross-sectional plane (**C**), which suggests perforation of the most inferior anchor.

point E and the glenoid edge was defined as the insertion distance (Fig. 3, *D*).

Statistical analyses

The data in each group were divided into perforated and nonperforated subgroups based on perforation of the anchor. Because the data were parametric, the perforation rates between the curved- and straight-guide groups were compared using the χ^2 test. The clock-face angle, insertion angle, and insertion distance were compared between the curved- and straight-guide groups using the 2-sample Student *t* test. Analysis of variance was used to compare the differences in the clock-face angle, insertion angle, and insertion distance among the 4 subgroups, and post hoc tests were applied for multiple comparisons with the Fisher least significant difference method. The measurements in the perforated curved-guide group were excluded from the analysis because this group included only 1 case. The statistical significance level was set at $P < .05$ (95% confidence intervals).

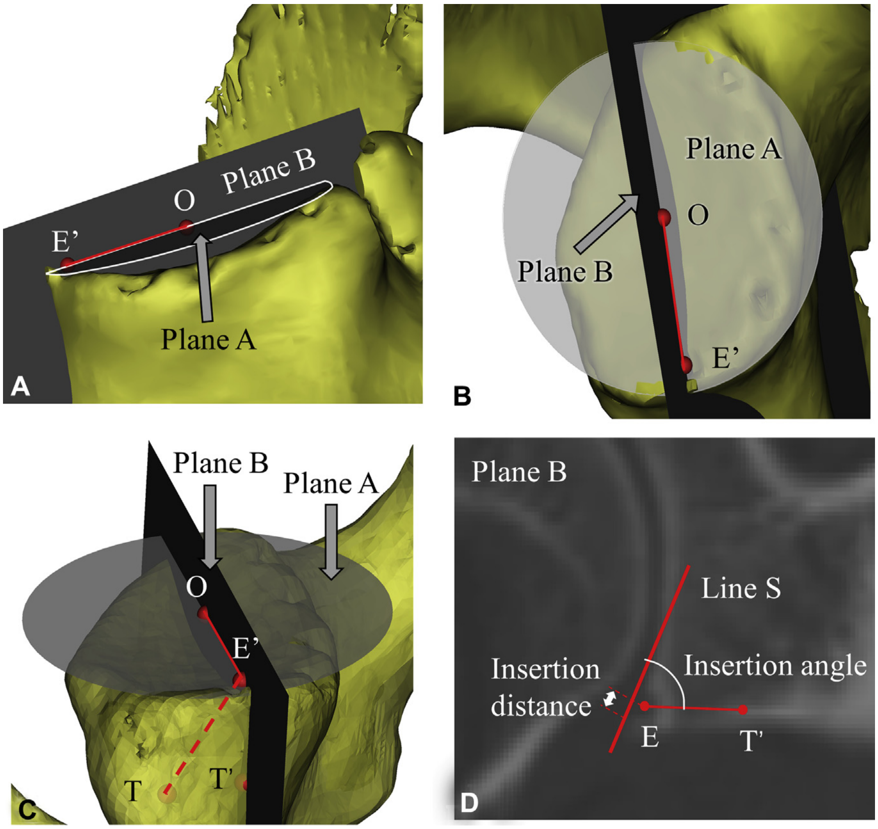

Figure 3 (**A, B**) Plane B is the perpendicular plane of plane A passing through line *OE'*. Line *TE* indicates the anchor trajectory, and point *T'* is the projection of point *T* (the tip of the anchor trajectory) on plane B. (**C**) The computed tomography scans were resliced according to plane B. (**D**) The angle enclosed by the projected anchor trajectory on plane B (line *T'E*) and the glenoid surface line (line *S*) is the anchor insertion angle; the distance between the insertion point of the anchor and the glenoid edge indicates the anchor insertion distance.

Results

The anchor perforation rate was 11% (1 of 9 cases) in the curved-guide group and 56% (18 of 32 cases) in the straight-guide group. Perforation occurred significantly less in the curved-guide group ($P = .02$). Comparison between the different drill guides showed that the insertion distance in the curved-guide group (4.0 ± 1.6 mm) was significantly shorter than that in the straight-guide group (7.0 ± 2.4 mm, $P < .01$). On the other hand, the clock-face angle and insertion angle did not show significant differences between the groups (Fig. 4). On subgroup analysis, the clock-face angle and insertion angle were significantly greater in the perforated straight-guide group than in the nonperforated curved- and straight-guide groups, whereas the insertion distance was significantly shorter in the nonperforated curved-guide group than in the other groups (Fig. 5). The scatter diagram between the clock-face angle and insertion angle demonstrated that the absolute safe zone (none of the cases showed perforation in this zone) had a clock-face angle greater than 135° (4:30 clock-face position) but less than 165° (5:30 clock-face position) and an insertion angle less than 100°, whereas the relative safe zone (all the nonperforated cases were distributed in this zone) had a clock-face angle greater than 135° (4:30 clock-face position) but less than 180° (6-o'clock position) and an insertion angle less than 105° (Fig. 6).

Discussion

Our study demonstrated that a significantly lower rate of opposite-cortex perforation was observed in the curved-guide group, the clock-face angle and insertion angle were significantly smaller in the nonperforated straight- and curved-guide groups, and the insertion distance was significantly shorter in the curved-guide group than in the straight-guide group. These findings confirmed the advantages of using a curved-guide system for placement of the most inferior anchor.

The risk of anchor perforation during arthroscopic Bankart repair has been documented in the literature. Lim et al[20] evaluated the biomechanical performance of inferior anchors and their penetration using cadaveric shoulders. This study suggested greater cyclic displacement with the most inferior anchors, all of which caused penetration, compared with anchors at the 4-o'clock position, which had

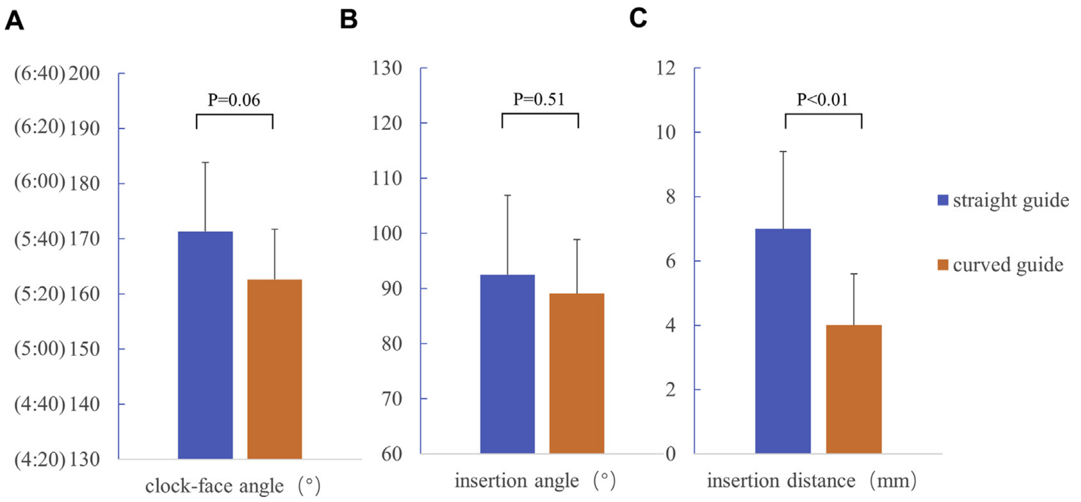

Figure 4 Clock-face angle (**A**), anchor insertion angle (**B**), and anchor insertion distance (**C**) bar charts comparing the results of the straight guide and curved guide.

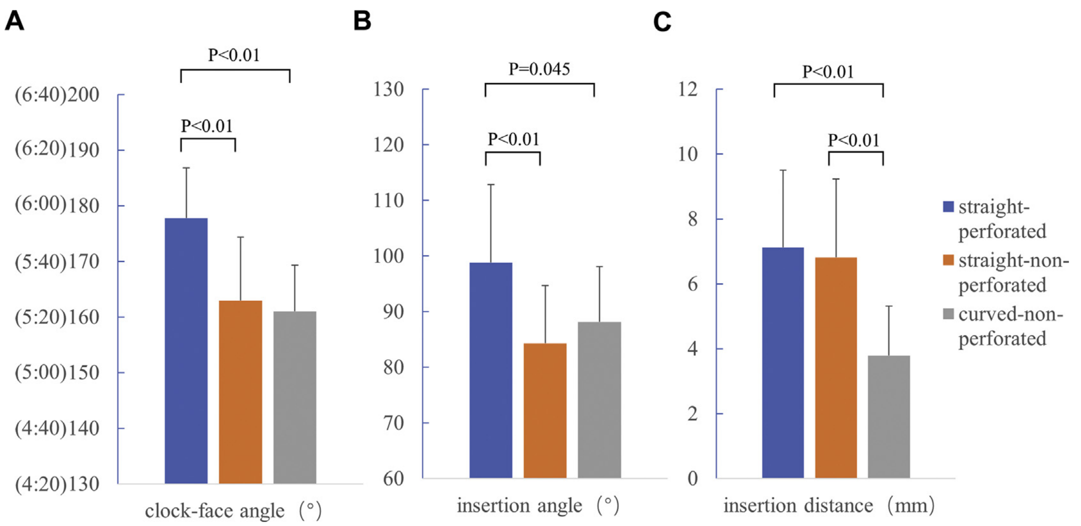

Figure 5 Clock-face angle (**A**), anchor insertion angle (**B**), and anchor insertion distance (**C**) bar charts comparing the results of the perforated straight-guide, nonperforated straight-guide, and nonperforated curved-guide groups.

only a 33% chance of penetration. Jazini et al[15] reported a cadaveric study that compared pullout strength between groups with high (60%) and low (10%) chances of penetration when different portals were used. It was shown that higher pullout strength was associated with the low penetration group when a trans-subscapularis portal was used. Cases of loosening of the suture anchor were also reported with anchor protrusion.[13,30] It is clear that perforation should be avoided as much as possible when inserting a suture anchor. By use of the conventional straight-guide system, the perforation rate was reported to be as high as 40% to 100% for the most inferior anchor during arthroscopic Bankart repair.[8,12,15,16,20,35] In our study, we found a similar result for the perforation rate using the conventional straight guide (56.3%). With the curved-guide system, the perforation rate was only 11.1%. Such an advantage is expected to enhance the biomechanical performance of the most inferior anchor.

Anchor perforation was reported to be associated with a greater anchor insertion angle in either the axial plane or oblique coronal plane.[8,35] Our study confirmed that the insertion angle was greater in the perforated anchors than in the nonperforated anchors. Although the methods of angle measurement were different, our study supported the previous findings.[8,35]

We found that the clock-face angle was significantly greater in the perforated anchors than in the nonperforated anchors. This means that the anchor located more inferiorly tended to cause perforation. The nonperforated anchors were located closer to the ideal 5-o'clock (150°) position, whereas the perforated anchors were located more inferiorly, around the 6-o'clock (180°) position.

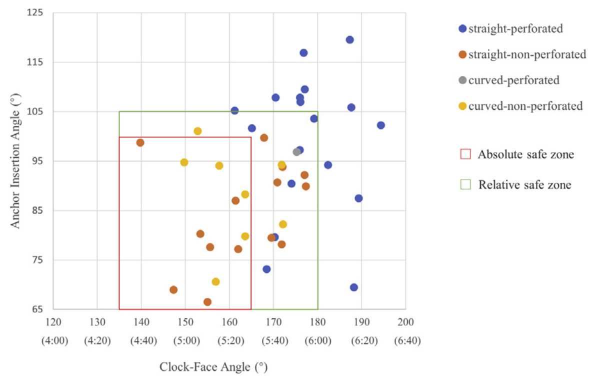

Figure 6 A scatter diagram was established based on the clock-face angle and anchor insertion angle to demonstrate the perforated and nonperforated anchors using the curved and straight guides. The values beneath the clock-face angles indicate the corresponding insertion positions on the glenoid. The absolute safe zone (*red*) for inserting the most inferior anchor was drawn involving no perforated cases and 12 nonperforated cases (5 [55.6%] in curved-guide group and 7 [21.9%] in straight-guide group), and the relative safe zone (*green*) was drawn involving 7 perforated cases (1 [11.1%] in curved-guide group and 6 [18.8%] in straight-guide group) and all 22 nonperforated cases (8 [88.9%] in curved-guide group and 14 [43.8%] in straight-guide group).

The scatter diagram showed the relationship between the clock-face angle and the insertion angle (Fig. 6). We set the absolute and relative safe zones in this scatter diagram. If an anchor is in the absolute safe zone between the 4:30 (135°) and 5:30 (165°) clock-face positions with the insertion angle less than 100°, the chances of perforation are 0%, which coincides with the ideal placement of the most inferior anchor proposed by other researchers.[16,20,32] When the insertion position is lower than the 5:30 clock-face position, the risk of perforation increases, and it becomes 100% if it is located over the 6-o'clock position. It is notable in the diagram that the anchors in the straight guide were located more inferiorly than those in the curved guide, and the anchors located over the 6-o'clock position were all inserted with the straight guide. This was generally attributed to medial placement of the anchors by the surgeons to obtain more bone stock beneath the entry point when using the straight guide. By use of our method of measuring the clock-face angle (Fig. 1, *B*), the anchor entry point would be more inferior than its intended location. However, we believe if the anchors were placed at the edge of the intended clock-face location, with less bone beneath, the perforation rate would be even higher in the straight-guide group. Regarding the insertion angle, similarly, if the insertion angle is more than 100°, the anchor is likely to perforate the posterior cortex. In all cases, the angle was shown to be greater than 65°; thus, we cannot report the risk of perforation with an insertion angle smaller than 65°.

The insertion distance was significantly greater in the straight-guide group. This finding is quite understandable because when the straight guide is used at the 5-o'clock position or 5:30 clock-face position, there is a very small amount of bone beneath the entry point. To achieve better anchoring, the surgeons try to shift the entry point slightly more medial to the center of the glenoid surface. This would make the insertion distance greater and substantially make the clock-face angle greater in the straight-guide group. This type of anchor insertion on the glenoid surface is less effective in terms of tissue healing because there is no healing between the capsuloligamentous tissues and the articular cartilage.

There are limitations involved in this study. First, the sample size was small, and only 9 cases in which the curved guide was used were included. Second, surgical outcomes, such as scoring of function and pain, and the revision rate of our cases were not evaluated in this study. However, because the follow-up term in curved-guide cases was short, comparison of the clinical outcomes between the 2 guide systems was questionable. As such, we just focused on the location, direction, and perforation of the anchors related to these 2 guide systems. A large-volume study with minimum 2-year follow-up is needed in the future. Third, perforation of the anchor depends on not only the location and trajectory of the insertion point but also the width and length of the anchor. It would have been ideal if we could have used the same suture anchor with the curved and straight guides.

Conclusion

To our knowledge, this is the first clinical study to demonstrate the benefits of a curved-guide system in arthroscopic Bankart repair. Using the curved-guide system, surgeons were able to insert the most inferior anchor more accurately to an ideal position with less chance of perforation compared with the straight guide.

Disclaimer

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