Is it inevitable to have dynamic horizontal acromioclavicular joint instability with a single tightrope?

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Background and purpose
Literature showed that single Tightrope fixation in acromioclavicular joint (ACJ) dislocation cases does not secure horizontal joint stability. A positive clinical cross-body adduction test is a usual outcome finding. We hypothesized that some cases might have some degree of horizontal stability, which might be confirmed with ultrasound examination.

Methods
This clinical study was performed on 27 patients who underwent single Tightrope application in acute ACJ dislocation. Patients were divided into group A which had an arthroscopic technique, and group B which had an open technique augmented with trans-ACJ fixation using two k-wires for 6 weeks. A clinical examination of the operated shoulders was done, and the results were compared with the sound shoulder examination in the same patient at the last 24 months postoperative follow-up visit. Besides, the results of the cross-body adduction test were correlated with ultrasound findings at the same visit. Records, operative details, and postoperative radiography were reviewed to assess if any factors would diminish the dynamic horizontal stability of the ACJ. Body mass index (BMI) was calculated per case.

Results
Group A had 17 patients (three patients had grade III dislocations, and 14 patients had grade V dislocations). Group B had 10 patients (four patients had grade III dislocations, and six patients had grade V dislocations). The clinical cross-body adduction test gave gross positive results in 14 patients out of group A patients while it gave gross positive results in six patients out of group B patients. Group A patients with negative results were 3, while group B patients with negative results were 4. By ultrasound, differences in horizontal translation of the clavicle within the ACJ in resting and cross-arm positions were more obvious in all operated shoulders than in all sound shoulders.

Conclusion
The less the Rockwood grading, the more potential to secure more horizontal stability. An open approach also gives more horizontal stability. With increased BMI, horizontal instability is usually masked. So, some factors may diminish, or mask clinical dynamic horizontal instability, which can be confirmed or rolled out with ultrasound usage.

Keywords:
acromioclavicular joint injuries, cross-body adduction test, dynamic horizontal instability, tightrope

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Introduction

Horizontal acromioclavicular joint (ACJ) instability is a phenomenon that has been recently focused on and researched to improve the results of joint injury management [1]. It was suggested that horizontal stability is achieved by acromioclavicular ligaments, V-shaped orientation of coracoclavicular ligaments, and joint-related muscles such as Trapezius and Deltoid with overlying Delto-Trapezius fascia [2], the latter being questionable [3]. During injuries, these structures are severed, giving rise to joint dislocation, which can be seen in the stance state of the joint or dynamic state during certain joint movements. The degree of horizontal instability depends on which structure is torn; as it will be evident, the more structures are torn [4]. Dynamic instability was found in a portion of patients with mild Rockwood injuries, which are usually managed conservatively, and it was associated with suboptimal clinical results [5].

Clinically, a cross-body adduction test could detect dynamic horizontal instability. It can be performed with the arm elevated to 90 degrees and then adducted across the chest. It is positive when ACJ pain is elicited or when the lateral end of the clavicle protrudes posteriorly through the trapezius muscle [6]. This test has the highest accuracy, with a sensitivity of 0.77–1.00 and a specificity of 0.79 among other ACJ-specific tests. However, it is a nonmeasurable test [7].

Ultrasound was first introduced to describe normal ACJ anatomy [8] and then to help in the detection of low-grade ACJ injuries, which showed that the relationship between the acromion and clavicle should change minimally (<1 mm) in normal ACJ with changing from rest to cross arm position [9]. Both joint space width and ACJ offset on cadavers may change directly with Rockwood stages [10]. However, ACJ offset in the normal population in the resting position is variable due to normal anatomical variations in the relationship between the acromion and clavicle [11].

When addressing ACJ dislocation management by indirect coracoclavicular fixation methods such as using a single tightrope, a single fixation point is established at the clavicle, which is usually situated between conoid and trapezoid footprints on the undersurface of the clavicle and differs from the native two-point attachments of conoid and trapezoid ligaments [12]. This single point provides vertical stability; however, it acts theoretically as a pivot around which the clavicle rotates during shoulder adduction and abduction, giving rise to lateral clavicular end ballottement inside the ACJ up to its escape posteriorly with maximal adduction degrees [13]. This can be seen clinically during postoperative follow-ups with positive cross-body adduction tests.

We hypothesized that not all cases of single tightrope fixation should give a positive clinical cross-body adduction test, and neither the arthroscopic technique nor the open technique reinforced by trans-articular k-wires managed to restore full horizontal stability of the ACJ, which may be confirmed or rolled out with ultrasound usage.

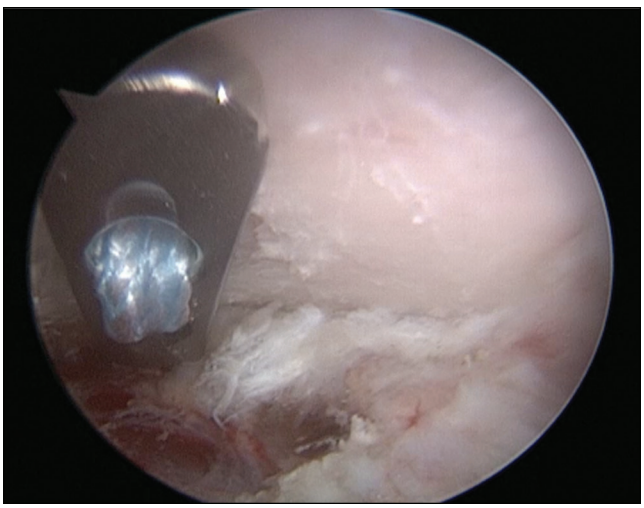
Patients and methods

A prospective clinical and ultrasonographic study was conducted on 27 patients who presented with operable acute ACJ injuries between January 2017 and December 2020. Cases of more than 3 weeks of presentation and cases with associated fractures were excluded. Perioperative radiographs were collected such as radiography plus computed tomography to define the exact preoperative Rockwood stage [14]. Upon enrollment in the study, patients were divided into two groups (either arthroscopic group or open group) and a single adjustable loop-length double-buttons suspensory fixation device (Tightrope, Arthrex, FL, USA) application was achieved in either an open reinforced by trans articular k-wires or arthroscopic approach, which provides secure surface fixation as shown in Fig. 1. K-wires were kept outside the skin for easier extraction. After collecting these data, the included 27 patients underwent clinical and ultrasonographic examination at the 24-month postoperative follow-up visit by the authors.

A cross-body adduction test during the postoperative follow-up visits was done to detect horizontal instability, and a positive cross-body adduction test was defined as either a painful ACJ site, gross deformity in the form of distal clavicular end posterior subluxation within the Trapezius muscle substance, or both when performing this test.

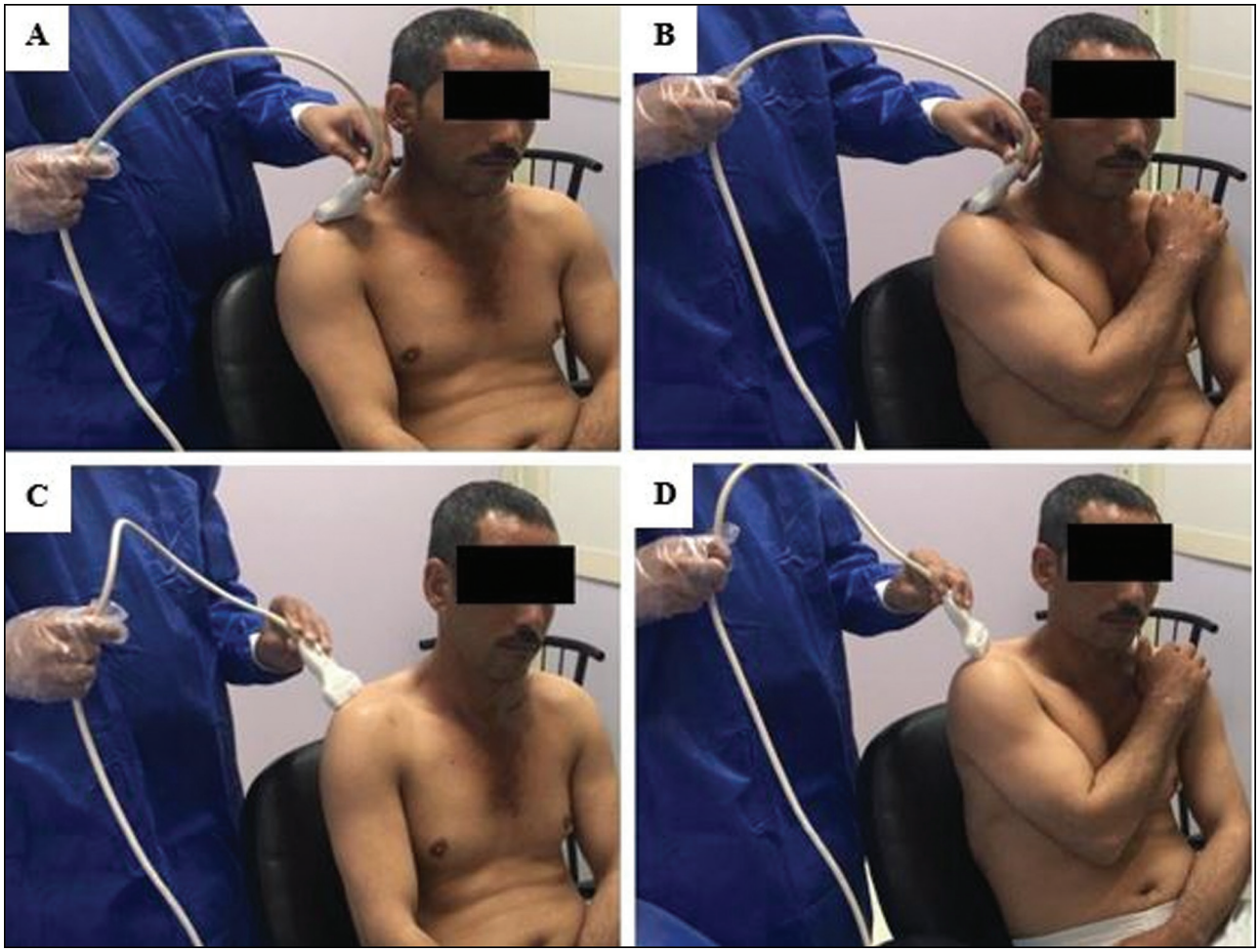
Ultrasound examination of each patient operated and normal shoulders was done in two positions, resting and cross-body adduction using an ultrasound machine (Toshiba, version Aplio 500, Japan origin) at 24 months postoperative follow-up visit. It was done at the same sitting using two techniques: anterior approach and posterior approach to ACJ in the previously described two positions. Different variables were measured as offset with each position and each technique. Also comparing with normal shoulder values of each patient was done as shown in Figs 2 and 3. To calculate the acromial offset over the clavicle for each position by ultrasound. Multiple

Fig. 1



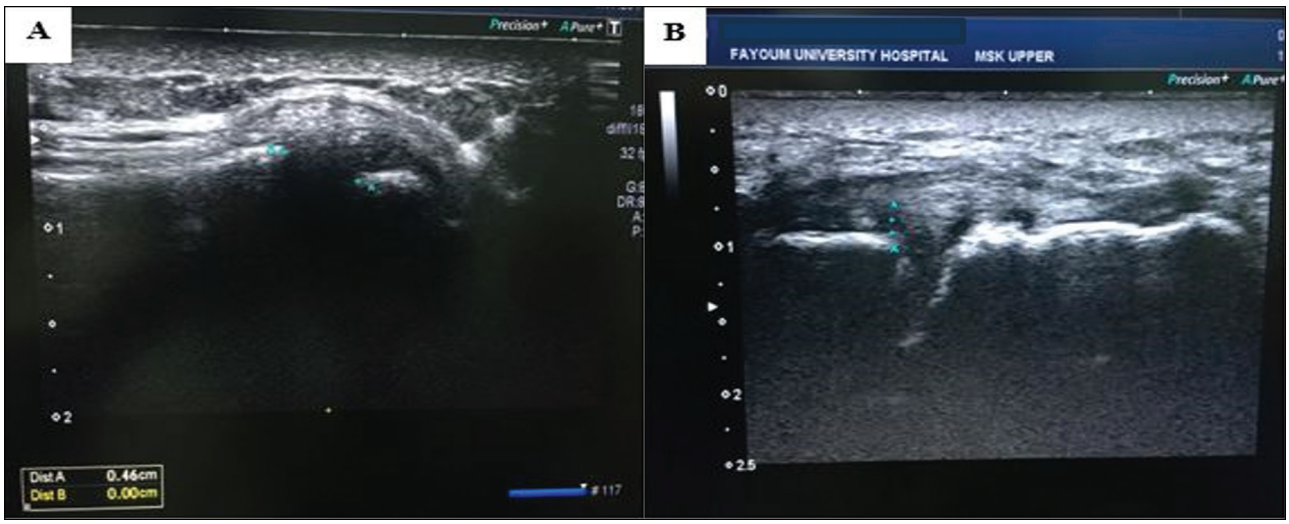
Intraoperative arthroscopic view showing the undersurface of the coracoid process of the right shoulder with the placement of the button of the tightrope.

Fig. 2



Anterior ultrasound approach with A) resting position of the arm (a) and cross-body adduction position of the arm (b). Posterior US approach with resting position of the arm (c) and cross-body adduction position of the arm (d).

Fig. 3



Ultrasound view showing side-to-side acromioclavicular joint distance (a). and anteroposterior translation of acromioclavicular joint (b).

images in the axial plane were taken and the best images were selected for measurements. Measuring was done in frozen frame using a line extending from a point at the far edge of the acromion whether anterior or posterior according to the examination approach to another point at the opposite far edge point of the lateral end clavicle. Distance in between was calculated by ultrasound software in centimeters. Multiple measurements were taken by two ultrasound practitioner and mean measurements were obtained for each position. Offset changes were recorded for each patient during position one, which was cross-arm position, and position two which was the resting position. The change in AC offset was measured by subtraction of offset during full adduction and offset during resting position. The change of offset was measured once during the anterior ultrasound approach and again during the posterior ultrasound approach. Both were measured for operated and normal shoulders.

Patients' records, operative details, and immediate postoperative radiography were reviewed. Patient factors such as sex, age, height, weight, and BMI at the time of operation were noted. Injury factors such as injured side, dominance, and Rockwood type were noted. Operative factors such as trauma-surgery interval, and if simple suturing of torn coracoclavicular ligaments was done with the usage of the open technique were noted. Follow-up factors such as whole follow-up 3 duration, final visual analog scale, final constant-Murley score, and cross-body adduction test results were noted.

Classification of patients was done into two groups based on the operative technique of Tightrope application. All previous factors were reviewed to assess if any factors would affect cross-body adduction test results and would diminish the expected dynamic horizontal instability of the acromioclavicular joint after single Tightrope usage.

Data was entered into a Microsoft Excel data sheet and analyzed using SPSS 22 version software [15]. Average values were considered, and categorical data was represented in the form of frequencies and proportions. The chi-square test or Fischer's exact test (for 2×2 tables only) was used as a 'test of significance' for qualitative data. Continuous data were represented as mean and standard deviation. An Independent *t*-test was used as a 'test of significance' to identify the mean difference between the normal and operated sides. Paired *t*-test was used to compare the difference between preoperative and follow-up means values. In all cases, a *P*-value of less than 0.05 was considered significant.

Results

Our study groups were divided into group A and group B. Group A included patients who had arthroscopic technique and group B included patients who had open technique reinforced by trans articular k-wires for 6 weeks in all group cases. Group A had 17 cases (16 males and one female) while group B had 10 cases (10 males) with 27 patients as total study participants. The mean age of all study participants in the last follow-up visit was 34.2 years (32.4 years for group A patients and 37.8 years for group B patients). The mean height, weight, and BMI of group A patients at the time of surgery were 173.1 cm, 81.9 kgs, and 27.3 kg/m^2, respectively, while the mean height, weight, and BMI of group B patients at the time of surgery was 176.9 cm, 88.2 kgs, and 28.2 kg/m^2, respectively as shown in Table 1.

Group A patients had 13 right-sided operated shoulders and four left-sided operated shoulders, while group B had nine right-sided operated shoulders and only one left-sided operated shoulder. Dominant limb in group A patients included 14 patients, while group B included nine patients. Regarding the Rockwood type of injury, group A had three patients with grade III and 14 patients with grade V dislocations. Group B had

Table 1 Demographic and basic factors

	Group A (*N*=17)	Group B (*N*=10)	*P* value
	Mean±SD	Mean±SD	
Age (years)	32.1±7.4	37.8±5.3	0.061
Height (cm)	173.1±5.3	176.9±4	0.060
Weight (kg)	81.9±9.1	88.2±10.7	0.117
Body mass index (kg/m^2)	27.3±2.5	28.2±3.1	0.459
Injury to surgery interval (days)	6.8±3.6	8.2±5.5	0.420
	Number (%)	**Number (%)**	
Sex			
Male	16 (94.1)	10 (100.0)	1.000
Female	1 (5.9)	0	
Simple suturing of torn CCL			
Not	17 (100)	7 (70.0)	**0.041***
Achieved	0	3 (30.0)	
Side			
Right	13 (76.5)	9 (90.0)	0.621
Left	4 (23.5)	1 (10.0)	
Dominant side			
Affected	14 (82.4)	9 (90.0)	1.000
Not	3 (17.6)	1 (10.0)	
Rockwood Type			
III	3 (17.6)	4 (40.0)	0.365
V	14 (82.4)	6 (60.0)	

CCL, coracoclavicular ligaments; **SD**, standard deviation.
t-test, χ^2, Chi-square test.
* Significant.

four patients with grade III and six patients with grade V. Mean injury-surgery interval was 6.8 days in group A and 8.2 days in group B. Seven patients out of group B patients underwent extra simple suturing of torn coracoclavicular ligaments. There was no significant difference between all variables of both groups except that group B had additional simple coracoclavicular ligament suturing in 70% of its patients as shown in Table 1. Group B patients had one patient with postoperative wound infection who responded well to local debridement, antibiotic therapy, and regular dressing. Another patient presented with pin tract infection who responded well also to the previous measures. All previous data were obtained from patients' records.

The clinical cross-body adduction test done during the follow-up visits gave positive results in 14 patients out of group A patients with localized pain over the ACJ. Three patients out of them also had gross distal clavicle posterior subluxation deformity while performing the test during follow-ups which was a sure sign of horizontal instability due to anterior overhanging of acromion leaving the clavicle to protrude posteriorly. Group A patients with negative results were three, two of them had grade III that were subjected to operative repair due to performing high-contact sports, and the third case had a BMI greater than 30. For group B, six patients gave positive results with localized pain over the ACJ. Two patients out of the positive 6 patients also had gross distal posterior clavicular subluxation deformity while performing the test. Group B patients with negative results were 4, two of them had grade III, one had a BMI greater than 30, and the fourth case had grade V which was unusual as the logic is to have postoperative horizontal instability due to his high injury grade as per shown in Table 2.

Offset change of ultrasound done at 24 months postoperative follow-up visit by anterior and posterior approaches was significant between operated and normal sides. Moreover, changes of offset with the posterior ultrasound approach were more evident than anterior ultrasound in both normal (*P* value=0.005) and operated (*P* value < 0.0001) sides as shown in Table 3.

Table 2 Outcome

	Group A (*N*=17)		Group B (*N*=10)		*P* value
	Mean±SD		Mean±SD		
Duration of follow-up (months)	26.9±4.7		24.5±3.3		0.168
Final constant Murley	91.4±6.4		95.3±4.7		0.084
	Median	**Range**	**Median**	**Range**	
Final Visual analog scale	1	0–2	0	0–2	0.170
	Number (Percentage)		Number (Percentage)		
Cross body adduction pain					
–ve	3 (17.6)		4 (40.0)		0.365
+ve	14 (82.4)		6 (60.0)		
Cross-body adduction gross deformity					
–ve	14 (82.4)		8 (80.0)		1.000
+ve	3 (17.6)		2 (20.0)		

t-test, χ^2, Chi-square test.
SD, standard deviation.

Table 3 Comparison between offset changes between operated and normal shoulders

	Operated side	Normal side	*P* value
	Mean±SD (Range)	Mean±SD (Range)	
Offset change anterior US approach	0.06±0.04 (0.02–0.17)	0.04±0.01 (0.01–0.07)	0.006 *
Offset change posterior US approach	0.2±0.02 (0.16–0.23)	0.05±0.02 (0.01–0.09)	<0.0001 *
P value	<0.0001 *	0.005 *	

SD, standard deviation; *t*-test, US, ultrasound.
*; Significant.

Discussion

AC ligaments and joint capsule's main role is to maintain horizontal congruency of distal clavicular end to acromial end during a shoulder-wide range of motion besides, the triangular orientation of conoid and trapezoid components of coracoclavicular ligaments adds to this stability [16]. So, addressing ACJ dislocations with indirect coracoclavicular repair techniques especially nonrigid forms such as cerclage [17], suspensory systems [18], and anchors [19] could efficiently maintain distal clavicular end vertical orientation within the ACJ but has a very limited role to maintain its horizontal orientation within the joint which can be observed as distal end clavicular subluxation during shoulder adduction/abduction and scapular protraction/retraction. On applying suspensory devices like Tightrope, the clavicle is fixed on a single point which acts as a pivot around which the distal clavicular end rotates and gives rise to horizontal instability. Cadaveric studies confirmed that by just dividing AC ligaments and capsule while observing this instability [20]. Also, Morikawa and colleagues compared the effect of different techniques of repair of AC ligaments with the addition of coracoclavicular button repair on cadavers. They concluded that all forms failed to restore native stability and coracoclavicular repair leading to minimal additional effect on posterior rotational stability [13]. Furthermore, Pastor and colleagues studied the biomechanical influence of the delto-trapezial fascia on the ACJ and concluded that delto-trapezial fascia has a synergistic stabilizing effect

with AC ligaments [3]. On the other hand, applying two Tightropes or three buttons in an inverted triangular manner as an augment for a single construct could not maintain horizontal stability, however theoretically it could, and the cause might be lacking the AC ligamentous point of fixation [21,22].

Our results showed that not all cases observed gave horizontal instability and seven out of twenty-seven patients had this horizontal stability. It could be explained by some factors that might add extra stabilization. Four patients had grade III injuries indicating intact delto-trapezius fascia. One patient had no horizontal instability however, having grade V injury which was unusual, but it could be explained by performing the open technique, anatomical reduction, usage of trans-acromial wires for 6 weeks, and additional simple suturing of the coracoclavicular ligament which could give extra horizontal stabilization. Two patients observed had BMI greater than 30, which could be explained by either masked distal clavicular end horizontal ballottement and instability or less mobility of shoulder joints due to increased BMI. Also, the painless examination could be explained by limb weight that could drive acromial and clavicular ends away from each other rendering the examination results negative.

About the use of ultrasound in assessment of horizontal instability in ACJ, Hobusch and colleagues concluded that ultrasound-based assessment of horizontal instability dynamics is cost-efficient tool with high precision. It also avoids radiation exposure. They stated that dynamic US is a safe and readily available imaging technique for the precise assessment of the horizontal instability of the ACJ [23].

Patients with apparent horizontal stability need more biomechanical analysis and more workup to define the exact causes of stability. We did not make any correlation between examination results and radiological findings of the last follow-ups whether there were any changes in the coracoclavicular distance or any radiological signs of failure. This might be an additional cause of giving positive examination results in the remaining 20 patients. In addition, we had no appropriate radiological method to assess dynamic horizontal stability. Dissimilarities between the incidence of pain and degree of deformity between the two groups can be attributed to the subjectivity of pain, the objectivity of observing deformity, or due to masking of deformity by other factors e.g. increased BMI.

Mean offset changes were more evident in all operated shoulders than in normal shoulders indicating inevitable horizontal instability in our study. Moreover, offset changes with the posterior ultrasound approach were more evident than the anterior ultrasound approach. This was noted to be significant in both operated and normal sides with more significance in the operated one and might point to more accurate results and superiority of the posterior approach. It could be explained also by the complex movements of acromion over the clavicle and the ACJ orientation which is not just a simple axial movement in the anteroposterior direction [24,25].

The usage of ultrasound evaluation which is highly operator-dependent might be one of the weak points and limitations of our study besides, relatively small study groups. In addition, no correlation between examination results and radiological findings of the last follow-ups might be another limitation to our study.

Conclusion

The less the Rockwood grading, the more potential to secure more horizontal stability. The open approach also gives more horizontal stability that could be explained by precise anatomical reduction of the ACJ plus the add-on k-wire fixation. With increased BMI, horizontal instability is usually masked. So, some factors may diminish, or mask clinical dynamic horizontal instability not controlled by a single Tightrope.

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Conflicts of interest

There are no conflicts of interest.

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