In vivo analysis of the circles measurement supports its use in evaluating acromioclavicular joint dislocations

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Background: Classification and treatment of acromioclavicular joint (ACJ) dislocations according to the Rockwood classification is controversial. The "circles measurement" on Alexander views was proposed to enable a clear assessment of displacement in ACJ dislocations. However, the method and its ABC classification were introduced on a Sawbones model based on exemplary Rockwood scenarios without soft tissue. This is the first in vivo study to investigate the circles measurement. We aimed to compare this new measurement method with the Rockwood classification and the previously described semiquantitative degree of dynamic horizontal translation (DHT).
Methods: A total of 100 consecutive patients (87 men and 13 women) with acute ACJ dislocations between 2017 and 2020 were included retrospectively. The mean age was 41 years (range, 18-71 years). ACJ dislocations on panoramic stress views were classified according to Rockwood type (type II, n = 8; type IIIA, n = 9; type IIIB, n = 24; type IV, n = 7; and type V, n = 52). On Alexander views, where the hand of the affected arm rested on the contralateral shoulder, the circles measurement and the semiquantitative degree of DHT (none, n = 6; partial, n = 15; or complete, n = 79) were assessed. Convergent and discriminant validity of the circles measurement (including its ABC classification according to displacement) with the coracoclavicular distance and Rockwood types, as well as the semiquantitative degree of DHT, was tested.
Results: The circles measurement showed a strong correlation with the coracoclavicular distance according to the Rockwood classification ($r = 0.66$, $P < .001$) and differentiated between Rockwood types according to the ABC classification, including types IIIA and IIIB. The circles measurement correlated with the semiquantitative method of assessing DHT ($r = 0.61$, $P < .001$). Measurement values were smaller in cases without DHT than in cases with partial DHT ($P = .008$). Cases with complete DHT had respectively larger measurement values ($P < .001$).
Conclusion: In this first in vivo study, the circles measurement allowed differentiation between Rockwood types according to the ABC classification in acute ACJ dislocations with a single measurement and correlated with the semiquantitative degree of DHT. On the basis of these validations of the circles measurement, its use for evaluating ACJ dislocations is recommended.
Level of evidence: Basic Science Study; Validation of Classification System
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Keywords: Shoulder; acromioclavicular joint dislocation; circles; Rockwood; coracoclavicular; Alexander view; dynamic horizontal translation

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Acromioclavicular joint (ACJ) dislocation is a common injury of the shoulder girdle. Progressive soft-tissue disruption is classified according to the radiologic classification of Rockwood.[20] The classification and, therefore, the treatment options revolve mainly around vertical instability. However, classification reliability is only fair,[4,9,17] and measurements of vertical instability are prone to projectional variation.[20]

Horizontal ACJ displacement is not adequately addressed on plain radiographs[7] despite its possible association with inferior clinical outcomes.[10,13,22] Horizontal ACJ displacement is preferably assessed on the Alexander view,[1,6,13,18,22] representing a stressed lateral radiograph, where the hand of the affected arm rests on the contralateral shoulder. This view was found to take into account vertical and horizontal displacement in a single view,[7,13,15,23] as shown by Zumstein et al[23] and Murphy et al.[15] In their respective Sawbones models (Vashon Island, WA, USA), progressive vertical and horizontal displacement was simulated and considered by the respective measurement method in vitro.

In a semiquantitative analysis using Alexander views, Kraus et al[10] found that patients with complete dynamic horizontal translation (DHT) showed worse ACJ-specific scores after an acute injury. Zumstein et al[23] proposed the acromial midline–to–dorsal clavicle (AC-DC) measurement for ACJ displacement, also using Alexander views.[7] Despite the realistic appreciation of displacement, the AC-DC measurement is complex and bound to the acromial line.

To solve the limitations in assessment of ACJ dislocations, the radiologic "circles measurement" was introduced by Murphy et al.[15] This measurement represents the side-comparative distance between the anteromedial acromion and the lateral clavicle. In the aforementioned Sawbones model based on exemplary Rockwood scenarios with progressive displacement, excellent reliability along with convergent and discriminant validity was found,[15] enabling the development of an ABC classification. However, in vitro Sawbones models and the exemplary scenarios in the absence of soft-tissue disruption have not yet been investigated clinically.

We aimed to subject the circles measurement and its ABC classification to validation. Furthermore, we intended to compare this measurement method with the previously described semiquantitative degree of DHT.[10]

Methods

In this retrospective diagnostic study, the radiographs of the last 100 consecutive patients (87 men and 13 women) who underwent treatment of acute ACJ dislocations between 2017 and 2020 at a single institution were evaluated. The mean age was 41 years (range, 18-71 years).

Panoramic stress views (10-kg axial load per hand) and bilateral Alexander views were used for radiographic assessment.[1] Patients with a previous injury to the contralateral ACJ, polytrauma, or incomplete or mediocre radiographs were excluded.

On panoramic stress views, for each side, the coracoclavicular (CC) distance was measured from the top of the coracoid process to the lower border of the distal clavicle, 3 cm medial to its lateral end.[2] The CC difference, as a percentage, was defined as follows: (CC distance on injured side [in millimeters] − CC distance on uninjured side [in millimeters])/CC distance on uninjured side × 100.[20] This percentage was used to grade dislocations according to the Rockwood classification[20]: 10% to 25% indicates type II; greater than 25% to 100%, type III; and greater than 100%, type V. Type IV was characterized by the combination of a variable amount of vertical dislocation with a radiologic posterior dislocation[7] and showed clinical subluxation of the clavicle through the trapezius fascia.[3] Type III was subdivided into stable (IIIA) and unstable (IIIB) injuries according to the International Society of Arthroscopy, Knee Surgery & Orthopaedic Sports Medicine (ISAKOS),[3] with the unstable type IIIB characterized clinically by therapy-resistant scapular dysfunction and radiologically by overriding of the clavicle on Alexander views. Owing to the objective and timely accessibility, we focused on the radiologic aspect for differentiation. The study comprised 8 patients with a Rockwood type II injury, 9 with type IIIA,[3] 24 with type IIIB,[3] 7 with type IV, and 52 with type V.

For Alexander views,[1] the standing patient was positioned at a 45° angle toward the detector, similar to positioning for a Y-view. The hand of the injured side was adducted across the body and rested on the contralateral shoulder. Alexander views were used to measure the circles distance, representing the side-comparative distance between the anteromedial acromion and the lateral clavicle[15] (Fig. 1).

For measurement purposes, a circle enclosing the lateral extent of the clavicle with its superior, inferior, and posterolateral cortical borders is drawn. A second circle, enclosing the anteromedial acromion congruent to the superior, inferior, and anteromedial cortices, is then drawn. Next, the center-to-center distance is measured, defining the measurement for a single side. Ultimately, the circles measurement is reported as the side-comparative difference (Injured side − Uninjured side).

Measurements were performed independently by 2 observers (P.V. and L.E.) using digital calipers on an image archiving system (JiveX; VISUS Health IT, Bochum, Germany) and were recorded to the nearest 0.1 mm. All measurements describe the differences between the injured and uninjured sides. The image order was random and blinded. One observer (P.V.) assessed all measurement again after 2 weeks.

According to the previous in vitro study of the circles measurement in a Sawbones model with simulation of Rockwood scenarios by means of progressive vertical and horizontal displacement,[15] an ABC classification was proposed: minimally displaced cases (group A, equivalent to Rockwood types II and IIIA with ≤100% vertical clavicular displacement without horizontal displacement), moderately displaced cases (group B,
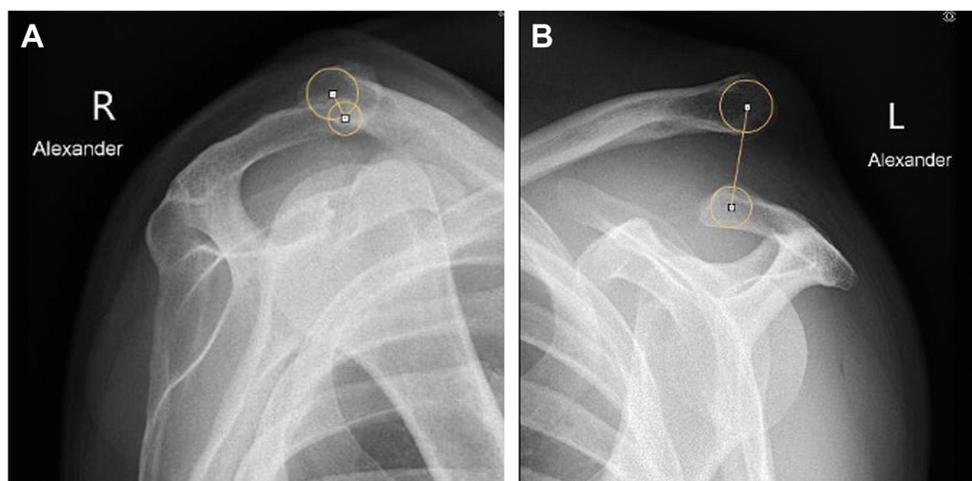
Figure 1 Circles measurement on Alexander views with all required annotations: radiographs of healthy side (**A**) and affected side (**B**). For measurement purposes, a circle enclosing the lateral extent of the clavicle with its superior, inferior, and posterolateral cortical borders is drawn (*larger circle*). A second circle, enclosing the anteromedial acromion congruent to the superior, inferior, and anteromedial cortices, is then drawn (*smaller circle*). Next, the center-to-center distance (*line*) is measured, defining the measurement for a single side. Ultimately, the circles measurement is reported as the side-comparative difference (Injured side − Uninjured side). The more *en face* view of the glenoid on the radiograph on the injured side should be noted. *R*, right; *L*, left.

equivalent to Rockwood type IIIB with 100% vertical clavicular displacement and 50% horizontal displacement), and significantly displaced cases (group C, equivalent to Rockwood types IV and V with 200% vertical clavicular displacement and 100%-200% of horizontal displacement).

The semiquantitative assessment of DHT (none, partial, or complete), described by Kraus et al,[10] was also performed using Alexander views. The absence of DHT is depicted by a clavicle in line with the acromion and includes a possible crossing over between the 2 bones equal to the healthy side. A partially unstable ACJ is characterized by a posterosuperior translation < 1 clavicle width. Complete translation is defined by posterosuperior translation ≥ 1 clavicle width. For the aspects of Rockwood type and DHT in each case, a consensus agreement was met to avoid referencing variability.

Statistical analysis

Statistical analysis was performed using SPSS software (version 25.0; IBM, Armonk, NY, USA). Intraobserver reliability and interobserver reliability of the circles measurement were calculated using a 2-way random intraclass correlation coefficient (ICC) with single measurement and absolute agreement (ICC [2,1]), presented with a 95% confidence interval (CI).

The correlation between the circles measurement and the CC distance was determined by calculating the Pearson correlation coefficient (convergent validity). A coefficient value < 0.2 was rated as poor; 0.2-0.4, low; 0.4-0.6, moderate; 0.6-0.8, good; and >0.8, excellent.[8] Bland-Altman analysis was performed to compare the measurement differences between the circles measurement and the CC distance. Limits of agreement were calculated.

Intergroup analysis to differentiate between Rockwood types was assessed by 1-way analysis of variance following Kolmogorov-Smirnov normality testing for the evaluation of discriminant validity. For multiple comparisons, Bonferroni

correction was used. If discrimination between Rockwood types undergoing different treatment pathways (ABC) was noted, a receiver operating characteristic analysis was performed to obtain the threshold values (predictor values) between classification groups A and B, as well as groups B and C.

We calculated the Spearman correlation coefficient to analyze the correlation between the circles measurement and the semi-quantitative degree of DHT. The Mann-Whitney U test was used to compare the circles measurement value between pairs of the 3 groups according to the degree of DHT (none, partial, or complete). The level of significance was set at $P < .05$.

Results

According to the ICC[2,1] (95% CI, with 2 observers), both intraobserver reliability and interobserver reliability were excellent. Intraobserver reliability was 0.98 (95% CI, 0.96-0.98), and interobserver reliability was 0.93 (95% CI, 0.85-0.96).

Circles measurement and CC distance

There was a positive correlation between the circles measurement and the CC distance ($r = 0.66$, $P < .001$) (Fig. 2). The mean difference between the injured and uninjured shoulders was 10.2 ± 4.3 mm for the CC distance and 22.3 ± 6.3 mm for the circles measurement, indicating that the circles measurement captured a larger vector of ACJ displacement between the injured and uninjured sides ($P < .001$).

The absolute differences between measurement methods were compared using a Bland-Altman plot (Fig. 3). The mean difference between the CC distance and the circles
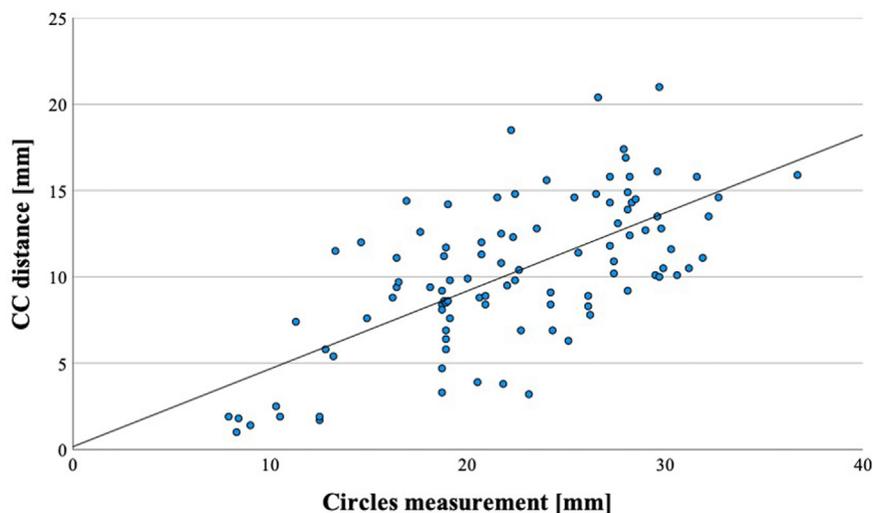
Figure 2 Scatter plot of correlation between circles measurement and coracoclavicular (*CC*) distance. A positive correlation was observed between the measurement methods ($r = 0.66$, $P < .001$), as represented by the *black line*.

measurement was −12.1 mm, denoting substantially lower values for the CC distance. Limits of agreement ranged from −2.7 to −21.4 mm, and the critical difference was ±10.1 mm. The negative correlation between the mean and difference of the 2 values ($r = -0.457$, $P < .001$) implies that higher measurement values were associated with higher discrepancy between the measurement methods.

CC distance and circles measurement by Rockwood type

Mean values of the CC distance and the circles measurement according to Rockwood type are displayed in Figure 4. For each Rockwood type, there was a difference between the circles measurement and the CC distance ($P < .001$).

The circles measurement values for type II injuries (9.9 mm; 95% CI, 8.4-11.5 mm) were smaller than those for type IIIA (15.5 mm; 95% CI, 13.4-17.5 mm; $P = .001$), type IIIB (19.8 mm; 95% CI, 18.7-21 mm; $P < .001$), type IV (24.1 mm; 95% CI, 21.5-26.6 mm; $P < .001$), and type V (26.3 mm; 95% CI, 25-27.5 mm; $P < .001$) injuries. Type IIIA injuries showed lower values than the higher types of injuries: type IIIB ($P = .007$), type IV ($P < .001$), and type V ($P < .001$). Type IIIB injuries showed smaller values than type IV ($P = .036$) and type V ($P < .001$) injuries. There was no difference in the circles measurement between type IV and type V injuries ($P = .418$).

Receiver operating characteristic analysis

The lower limit of the 95% CI for Rockwood type IIIB injuries was 18 mm, differentiating between groups A and B. The area under the curve was 0.92, sensitivity was 91.7%, and specificity was 88.2% (positive predictive value, 95.7%; negative predictive value, 80%).

The lower limit of the 95% CI for Rockwood type IV injuries was 21.4 mm, denoting the threshold between groups B and C. The area under the curve was 0.88, whereas sensitivity and specificity were 88.1% and 83.3%, respectively (positive predictive value, 92.9%; negative predictive value, 71.4%). The ABC classification based on threshold values is displayed in Figure 5.

Circles measurement and semiquantitative degree of DHT

The ACJ was graded as horizontally stable in 6 patients, partially translated in 15, and completely translated in 79. Cases with a horizontally stable ACJ had smaller measurement values (10.8 mm; 95% CI, 7.4-14.2 mm) than cases with partial translation (16.1 mm; 95% CI, 13.9-18.2 mm; $P = .008$) (Fig. 6). Cases with complete horizontal ACJ translation had higher measurement values (24.3 mm; 95% CI, 23.2-25.5 mm) than cases with no horizontal ACJ translation ($P < .001$) or only partial horizontal ACJ translation ($P < .001$).

Discussion

In this first in vivo study, we investigated the diagnostic value of the new circles measurement method to assess the severity of acute ACJ dislocations. The main finding of our study is that the circles measurement allowed differentiation between Rockwood types according to the ABC classification and correlated with the semiquantitative method of assessing DHT.

The circles measurement detected a higher vector of displacement in ACJ dislocations compared with the CC distance. The difference between the 2 measurement methods was higher for each Rockwood type, with
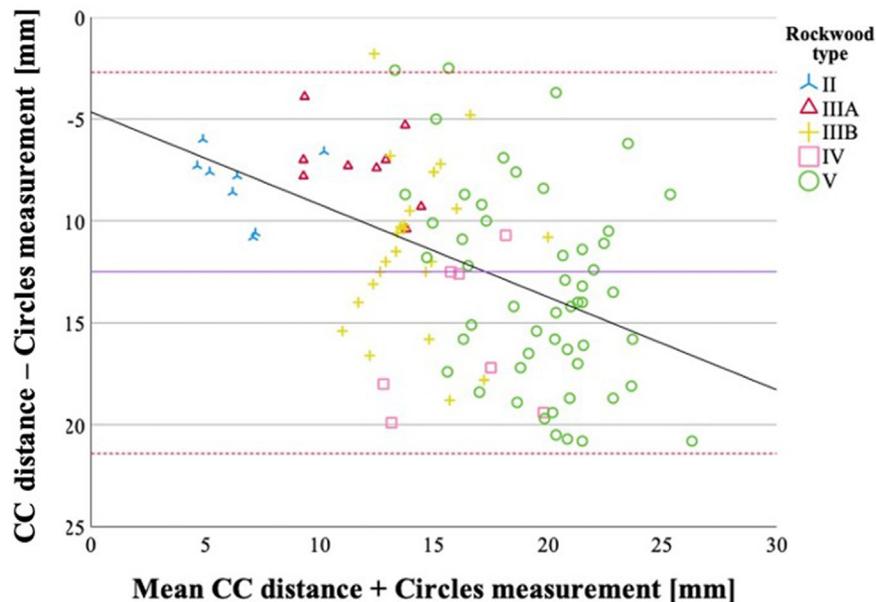
Figure 3 Bland-Altman plot displaying mean values (*dots*) for circles measurement and coracoclavicular (*CC*) distance vs. difference between these 2 values. The Rockwood types are presented as *scatter points*. The *black line* resembles the negative correlation (r = −0.457, $P < .001$) between the mean and the difference of the 2 measurement methods.
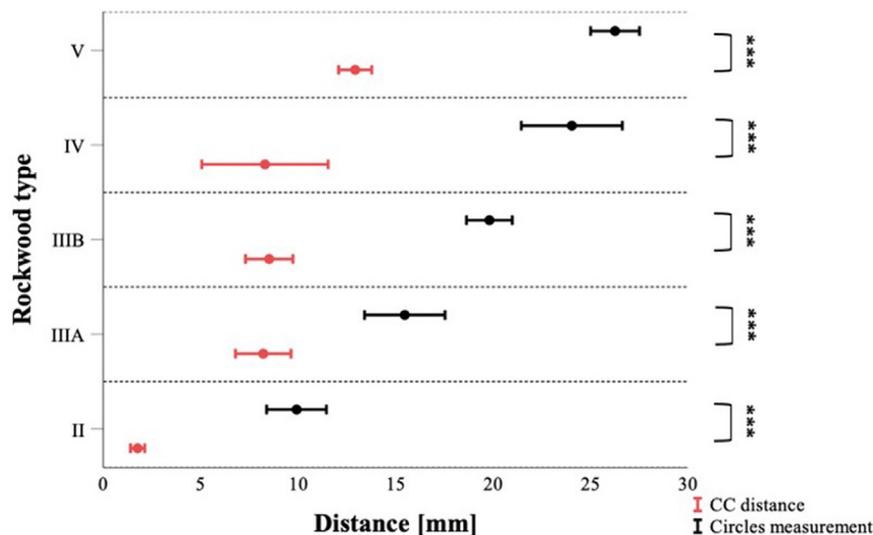

Figure 4 Mean values (*dots*) of coracoclavicular (*CC*) distance (*red*) and circles measurement (*black*) with 95% confidence intervals (*whiskers*), listed according to Rockwood type. ***$P < .001$.

increasing measuring discrepancies for higher ACJ displacement. This aspect probably relates to a higher degree of injury allowing more motion of the scapula as inferior, medial, and anterior translation as the arm is moved across the body.

The classification of Rockwood types is mainly based on vertical displacement, but plain radiographs are prone to projectional variation.[20,21] Horizontal displacement is not respected adequately in these radiographic images[7] despite its clinical relevance.[10,12,22] Assessment of soft-tissue disruption according to the Rockwood classification may be complicated in an acute clinical setting and is further

compromised by the fair reliability.[6,9,17] Magnetic resonance imaging is technically useful to assess ligament status but is also limited by its moderate reliability.[14] The AC-DC method was found to be more accurate than the CC distance for assessing vertical displacement[7,23] and demonstrated that the CC distance underestimates ACJ displacement in Rockwood type IV injuries. Despite these advantages, it has methodologic limitations. The reference to the acromial axis narrows flexibility in capturing total displacement. Additionally, the missing ability to discriminate between Rockwood types IIIA and IIIB[7] questions its ability to assess horizontal displacement.
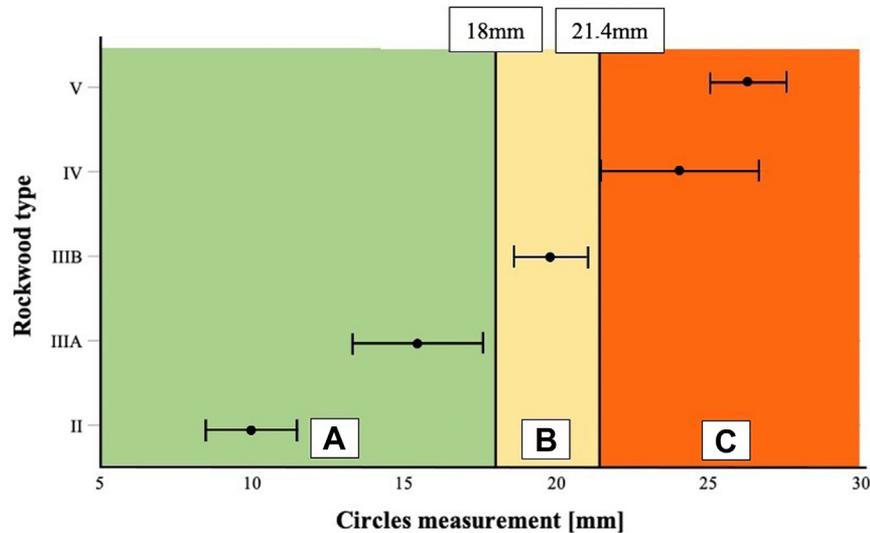
Figure 5 Mean circles measurements (*dots*) per Rockwood type with 95% confidence intervals (*whiskers*). The initially proposed ABC classification has been updated as follows: values < 18 mm are allocated to group A (*green*) (minimally displaced, equivalent to Rockwood types II and IIIA), whereas values of 18-21.4 mm are assigned to group B (*yellow*) (moderately displaced, equivalent to Rockwood type IIIB). Group C (*orange*) includes values > 21.4 mm (significantly displaced, equivalent to Rockwood types IV and V).
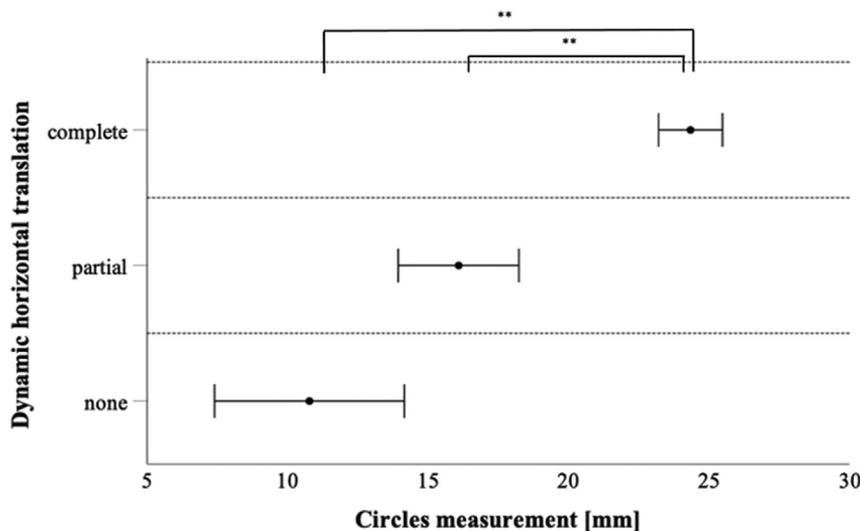

Figure 6 Circles measurement (mean shown in *dots*, 95% confidence intervals shown in *whiskers*) according to degree of dynamic horizontal translation. **, $P < .01$.

For the circles measurement, we found excellent intra-rater and inter-rater reliability and increasing ACJ displacement by Rockwood type, making this a sound parameter in evaluating ACJ dislocations. The new measurement method is not bound to the acromial axis and allows judgment of vertical and horizontal ACJ displacement, as shown by the preceding in vivo study.[15] This ability is critical because the magnitude of displacement is the main indicator of an unstable joint and is therefore relevant, albeit not the primary deciding factor, for treatment.[3]

ACJ displacement was higher in our in vivo study compared with the in vitro results. This finding can be explained by the absence of soft tissue in the in vitro study, preventing progressive vertical and horizontal ACJ displacement found in biomechanical studies.[5,11,16,19] In vitro measurements and biomechanical studies have the limitation of a mechanically fixed scapula or clavicle, preventing the simultaneous displacement found in vivo.[2] Therefore, we observed the higher displacement values in our in vivo study as a result of soft-tissue disruption with simultaneous displacement of the scapula and clavicle, accentuated by stressed Alexander views. For example, an anterior scapular motion can be noted by a more *en face* view of the glenoid on the injured side, as displayed in Figure 1.

A correlation of the circles measurement with the semiquantitative method of Kraus et al[10] was found. In vivo circles measurement values were higher in cases with complete DHT than in cases with no or only partial DHT. Because complete DHT led to inferior outcomes in terms of ACJ-specific scores,[10] our findings suggest that a side-comparative circles value of approximately 24 mm might be associated with decreased clinical outcomes. However, further studies are needed to confirm this assumption.

The in vivo results allowed discrimination between the Rockwood types according to the ABC classification based on the circles measurement, providing an algorithm for classification. Such differentiation enables initial triage during the first examination and facilitates decision making by use of a standardized protocol, especially in multidisciplinary emergency departments. Possible benefits include better comparability and higher logistic and financial efficiency, as well as lower radiation exposure thanks to a single, narrower projection. The primary focus of this study was to perform a radiologic analysis, although patient factors and clinical examination findings must be considered for a holistic assessment and are essential in deciding on the respective therapy.

There are several limitations to this study, including its retrospective design. Patients with lower injury types may be under-represented, either because they did not seek consultations or because the radiographic imaging required for study inclusion was not performed. The data presented do not allow a precise quantification of ACJ displacement as measured by 3-dimensional imaging, and the respective share of vertical and horizontal displacement is unknown. Correlations to clinical parameters were not assessed, thereby inhibiting the treatment implications of this study. Future studies should set out to assess ACJ displacement as quantified by the circles measurement in relation to clinical parameters, enabling a clearer distinction for the diagnosis of ACJ dislocations.

Conclusion

In this first in vivo study, the circles measurement allowed differentiation between Rockwood types according to the ABC classification in acute ACJ dislocations with a single measurement and correlated with the semiquantitative degree of DHT. On the basis of these validations, the use of the circles measurement for evaluating ACJ dislocations is recommended.

Disclaimer:

References

1. Alexander OM. Radiography of the acromioclavicular articulation. Med Radiogr Photogr 1954;30:34-9.
2. Azar F, Pfeifer C, Alt V, Pregler B, Weiss I, Mayr A, et al. Clavicle elevation or shoulder girdle depression in acromioclavicular joint dislocation: a radiological investigation. Orthop J Sports Med 2019;7:2325967119879927. https://doi.org/10.1177/2325967119879927
3. Beitzel K, Mazzocca AD, Bak K, Itoi E, Kibler WB, Mirzayan R, et al. ISAKOS upper extremity committee consensus statement on the need for diversification of the Rockwood classification for acromioclavicular joint injuries. Arthroscopy 2014;30:271-8. https://doi.org/10.1016/j.arthro.2013.11.005
4. Cho CH, Hwang I, Seo JS, Choi CH, Ko SH, Park HB, et al. Reliability of the classification and treatment of dislocations of the acromioclavicular joint. J Shoulder Elbow Surg 2014;23:665-70. https://doi.org/10.1016/j.jse.2014.02.005
5. Eschler A, Rösler K, Rotter R, Gradl G, Mittlmeier T, Gierer P. Acromioclavicular joint dislocations: radiological correlation between Rockwood classification system and injury patterns in human cadaver species. Arch Orthop Trauma Surg 2014;134:1193-8. https://doi.org/10.1007/s00402-014-2045-1
6. Gastaud O, Raynier JL, Duparc F, Baverel L, Andrieu K, Tarissi N, et al. Reliability of radiographic measurements for acromioclavicular joint separations. Orthop Traumatol Surg Res 2015;101:S291-5. https://doi.org/10.1016/j.otsr.2015.09.010
7. Karargyris O, Murphy RJ, Arenas A, Bolliger L, Zumstein MA. Improved identification of unstable acromioclavicular joint injuries in a clinical population using the acromial center line to dorsal clavicle radiographic measurement. J Shoulder Elbow Surg 2020;29:1599-605. https://doi.org/10.1016/j.jse.2019.12.014
8. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med 2016; 15:155-63. https://doi.org/10.1016/j.jcm.2016.02.012
9. Kraeutler MJ, Williams GR Jr, Cohen SB, Ciccotti MG, Tucker BS, Dines JS, et al. Inter- and intraobserver reliability of the radiographic diagnosis and treatment of acromioclavicular joint separations. Orthopedics 2012;35:e1483-7. https://doi.org/10.3928/01477447-20120919-16
10. Kraus N, Hann C, Gerhardt C, Scheibel M. Dynamic instability of the acromioclavicular joint: a new classification for acute AC joint separation. Obere Extrem 2018;13:279-85. https://doi.org/10.1007/s11678-018-0469-x
11. Kurata S, Inoue K, Hasegawa H, Shimizu T, Iida A, Kawamura K, et al. The role of the acromioclavicular ligament in acromioclavicular joint stability: a cadaveric biomechanical study. Orthop J Sports Med 2021; 9:2325967120982947. https://doi.org/10.1177/2325967120982947
12. Metzlaff S, Rosslenbroich S, Forkel PH, Schliemann B, Arshad H, Raschke M, et al. Surgical treatment of acute acromioclavicular joint dislocations: hook plate versus minimally invasive reconstruction. Knee Surg Sports Traumatol Arthrosc 2016;24:1972-8. https://doi.org/10.1007/s00167-014-3294-9
13. Minkus M, Hann C, Scheibel M, Kraus N. Quantification of dynamic posterior translation in modified bilateral Alexander views and correlation with clinical and radiological parameters in patients with acute acromioclavicular joint instability. Arch Orthop Trauma Surg 2017;137:845-52. https://doi.org/10.1007/s00402-017-2691-1
14. Minkus M, Wieners G, Maziak N, Plachel F, Scheibel M, Kraus N. The ligamentous injury pattern in acute acromioclavicular dislocations

and its impact on clinical and radiographic parameters. J Shoulder Elbow Surg 2021;30:795-805. https://doi.org/10.1016/j.jse.2020.10.026

15. Murphy RJ, Moor BK, Lesniewski PJ, Hayoz A, Alcantara W, Zumstein MA. Evaluation of the circles measurement and the ABC classification of acromioclavicular joint injuries. Am J Sports Med 2021;49:1619-25. https://doi.org/10.1177/03635465211003300

16. Oki S, Matsumura N, Iwamoto W, Ikegami H, Kiriyama Y, Nakamura T, et al. The function of the acromioclavicular and coracoclavicular ligaments in shoulder motion: a whole-cadaver study. Am J Sports Med 2012;40:2617-26. https://doi.org/10.1177/0363546512458571

17. Pifer M, Ashfaq K, Maerz T, Jackson A, Baker K, Anderson K. Intra- and interdisciplinary agreement in the rating of acromioclavicular joint dislocations. Phys Sportsmed 2013;41:25-32. https://doi.org/10.3810/psm.2013.11.2033

18. Rahm S, Wieser K, Spross C, Vich M, Gerber C, Meyer DC. Standard axillary radiographs of the shoulder may mimic posterior subluxation of the lateral end of the clavicle. J Orthop Trauma 2013;27:622-6. https://doi.org/10.1097/BOT.0b013e31828f912c

19. Rochcongar G, Emily S, Lebel B, Pineau V, Burdin G, Hulet C. Measure of horizontal and vertical displacement of the acromioclavicular joint after cutting ligament using X-ray and opto-electronic system. Surg Radiol Anat 2012;34:639-43. https://doi.org/10.1007/s00276-012-0953-8

20. Rockwood CA Jr. Fractures and dislocations of the shoulder. In: Rockwood CA Jr, Green DP, editors. Fractures in adults. Philadelphia: Lippincott; 1984. p. 860-910.

21. Schaefer FK, Schaefer PJ, Brossmann J, Hilgert RE, Heller M, Jahnke T. Experimental and clinical evaluation of acromioclavicular joint structures with new scan orientations in MRI. Eur Radiol 2006; 16:1488-93. https://doi.org/10.1007/s00276-012-0953-8

22. Scheibel M, Dröschel S, Gerhardt C, Kraus N. Arthroscopically assisted stabilization of acute high-grade acromioclavicular joint separations. Am J Sports Med 2011;39:1507-16. https://doi.org/10.1177/0363546511399379

23. Zumstein MA, Schiessl P, Ambuehl B, Bolliger L, Weihs J, Maurer MH, et al. New quantitative radiographic parameters for vertical and horizontal instability in acromioclavicular joint dislocations. Knee Surg Sports Traumatol Arthrosc 2018;26:125-35. https://doi.org/10.1007/s00167-017-4579-6