Acta Orthop. Belg., 2013, **79**, 36-41

ORIGINAL STUDY

Biomechanical comparison of indirect and direct arthroscopic excision of the distal clavicle

Francois HARDEMAN, Karin VAN ROOYEN, Jan SOMERS, Stefan DOLL, Robert PAGE, Joe DE BEER

From the University of Stellenbosch, South Africa

The purpose of this study was to compare the stability and force of ultimate failure of the acromioclavicular joint (ACJ) after direct arthroscopic distal clavicle excision (DCE) through superior portals and indirect arthroscopic DCE through inferior portals in paired cadaveric shoulders.
Ten paired saline-embalmed cadaveric shoulders were operated alternatively using the indirect and direct technique. Biomechanical testing was performed in the horizontal plane, testing displacement at 15N and 30N and finally failure strength was measured testing the constructs until failure occurred.
There was a significant difference in failure strength with the direct DCE being stronger : 766.6 N (SD 233.5) against 540.3 N (SD 239.1) for the indirect DCE, p = 0.01334). There was no statistical difference for the displacement measured at 15N and 30N.
A direct DCE will result in a postoperative ACJ with greater ultimate failure strength compared to indirect DCE because the inferior ACJ capsule can be better preserved.

Keywords : distal clavicle excision ; acromioclavicular joint ; shoulder arthroscopy ; surgical technique.

INTRODUCTION

Acromioclavicular joint (ACJ) pathology is a common cause of shoulder pain. The technique of open distal clavicle excision (DCE) was first described in 1941, independently by Gurd *(18)* and Mumford *(23)*. The main complications of the open techniques were distal clavicle instability (caused by excessive resection or capsular injury) and dehiscence of the deltotrapezial fascia.

With the advent of arthroscopic surgery, techniques have evolved to treat this painful condition through a minimally invasive approach. The critical role of the superior AC ligament in stabilising the ACJ has been demonstrated in previous studies *(6,25)*). The advantages of arthroscopic techniques are a better visualisation, improved cosmesis, decreased postoperative activity limitations, increased ACJ stability through retention of the

■ Francois Hardeman, MD, Orthopaedic Surgeon.
■ Jan Somers, MD Orthopaedic Surgeon.
Jan Yperman Hospital, Ieper, Belgium.
■ Karin Van Rooyen, MD, General Medicine.
■ Joe De Beer, MD Orthopaedic Surgeon.
The Cape Shoulder Institute, Cape Town, South Africa.
■ Stefan Doll, BEng, MScEng, Biomechanical Engineer
Biomechanical Engineering Research Group (BERG), University of Stellenbosch, South Africa.
■ Robert Page, MD, PhD, Head of Department of Anatomy and Histology.
Department of Anatomy and Histology, University of Stellenbosch, South Africa.
Correspondence : Francois Hardeman, Jan Yperman Hospital, Ieper, Belgium. E-mail : francois.hardeman@gmail.com

No benefits or funds were received in support of this study. The authors report no conflict of interests.

Fig. 1. — Drawing of an indirect DCE, where the entire inferior, anterior and posterior ACJ capsule is resected.

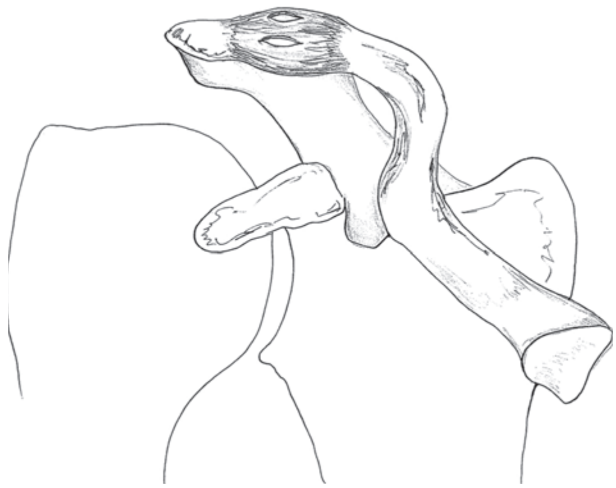

Fig. 2. — Drawing of a direct DCE, where the damage on the ACJ capsule is limited to the anterosuperior and posterio-superior portal.

superior AC ligament, swifter return to sports and decreased narcotic requirement, the preservation of the superior AC ligament intact and the possibility to address concomitant shoulder pathology found in up to 50% of cases (*2,7,8,9,15*).

Several studies have investigated the clinical outcome after open versus arthroscopic DCE. Freedman *et al* (*15*) demonstrated the superiority of the arthroscopic procedure over the open procedure by a better VAS score after one year. Disadvantages of the arthroscopic technique are cost and learning curve.

The indirect (or subacromial) technique (*17,19,30*) was first described : the ACJ is excised using an inferior bursal view. The disadvantage of this technique is that the entire inferior capsule and parts of the anterior and posterior capsule have to be excised to achieve a good access to the joint (Fig. 1).

The direct (or superior) technique (*1,2,28,31*) allows excision of the ACJ through 2 small superior portals, leaving most of the capsule intact (Fig. 2). In this technique the capsule and ligaments are subperiosteally elevated to expose the distal clavicle. The direct DCE leads to earlier pain relief and shorter hospital stay compared to the open procedure (*13*) and permitted a faster return to athletic activity compared to the indirect approach (*5*). A disadvantage of this technique is that it is technically more demanding.

Instability of the ACJ after DCE is a known complication causing continuing pain after resection. Previous biomechanical studies have shown that AC ligaments and capsule control antero-posterior (AP) mobility, whereas supero-inferior (SI) translation is controlled by the coraco-clavicular ligaments (*5,8-10,16,20,22,27*). Excessive resection of the ACJ capsule results in increased AP mobility of the ACJ.

The two different arthroscopic techniques are commonly used in daily practice to treat ACJ arthritis. To achieve a good visualisation of the ACJ in the indirect DCE the entire inferior and parts of the anterior and posterior part of the ACJ capsule have to be removed. In the direct approach only two small portals are made through the capsule. The purpose of this study was to compare the stability of the ACJ after direct arthroscopic DCE through superior portals and indirect arthroscopic DCE through inferior view in paired cadaveric shoulders. Our hypothesis was that horizontal AC stability would be less affected when more of the ACJ capsule was left intact.

MATERIALS AND METHODS

Ten paired saline-embalmed cadaveric shoulders were available for this study. Only specimens without previous surgery in the proximity of both shoulder joints were used. On one shoulder an indirect arthroscopic DCE was performed, on the contralateral shoulder a direct arthroscopic DCE.

Surgical technique

Based on previous anatomical studies of the ACJ capsule a 5 mm clavicular and a 2 mm acromial resection were undertaken (3,4,24,29), using a ClearCut Oval Burr (Arthrex, Naples, FL). For both techniques a 4 mm 30° arthroscope was used. The amount of resection was controlled using a 4.85 mm ClearCut Oval Burr (Arthrex, Naples, FL) as a reference.

For the indirect DCE the ACJ was visualised and excised through 3 portals : posterior, lateral and anterosuperior underneath the ACJ. The accuracy of the lateral and anterosuperior portal placement was augmented using a spinal needle. The ACJ was opened with a shaver and a suction electrode, only removing the inferior ACJ ligament and capsule, and the most inferior parts of the anterior and posterior capsule. Visualisation of the ACJ was performed through the posterior, lateral and anterior portal alternatively.

For the direct DCE the orientation of the ACJ and the edges of the clavicula and acromion were determined using 2 intramuscular needles. The ACJ was first visualised through a posterosuperior portal, made 5 mm posterior to the posterior edge of the ACJ and in line with the ACJ, penetrating the posterior capsule. The joint was entered with the arthroscope using serial dilatation : first with a 4 mm obturator, than with the 4.5 mm obturator and canula and finally with the 4.5 mm canula and 4 mm 30° arthroscope. Using a spinal needle the correct entry point of the anterosuperior portal was determined. From this portal resection was started using a shaver, suction electrode and oval burr. Viewing and working portal were switched to achieve a complete 5 mm resection on the clavicle and a 2 mm resection on the acromion, as in the direct approach.

Measurement setup

All tests were done in the Department of Anatomy in controlled conditions. After completion of the chosen procedure the entire scapula, clavicle, ACJ capsule and coracoclavicular ligaments were resected “en-bloc”. To control the translation of the clavicle in relation to the scapula in the horizontal plane a custom-made set-up was created. The scapula was fastened to the system with 3 large screws. Rubber mats ensured that the scapula sat secure in the clamp and prevented the bone from fracturing under compression. After fastening the scapula, the clavicle was inserted into the custom-designed clavicle clamp, where the clavicle was fixed in a tube with 2 screws. The force was generated with a 12V DC motor driving the lead screw, which in turn activated the linear drive, giving the ACJ a forwards and backwards motion in the horizontal plane.

Edwards (11) showed that typical tissue hysteresis occurred with a load of 30 N across the ACJ and that at least 3 cycles of preconditioning at the 30-N level were required to show reproducible cycles in all tested specimens. Therefore a preconditioning loading level (0 to 30 N, 1 Hz, 3 cycles) was chosen to simulate a small amount of force transmission across the joint (12).

Before starting measurements, the Linear Variable Differential Transformer (LVDT) displacement sensor and the force transducer were zeroed at their current position and force at full relaxation of the ACJ. Following this, the clavicle was put under a cyclic loading of 30 N for 3 repetitions at 1 Hz to ensure the tissue to be relaxed and to establish a baseline displacement. At this point force and displacement measurements were zeroed again. For the measurements, the force on the joint was increased to 15 N and a displacement reading was taken. After this the force was zeroed and increased again to 30 N, another displacement reading was done. The final test involved the force on the joint being increased gradually at a speed of 15 mm/s until the construct failed. Both a force and displacement reading were continuously taken. Failure of the ACJ, clavicle or scapula concluded the testing. To not confuse the reader, the measurements were taken continuously at a sample rate of 200 Hz. The data were read off from a graph and analysed.

After failure point was reached the ACJ itself was evaluated for adequacy of resection : the inclination of the excised surfaces was measured and the presence of bony bumps or holes was recorded.

Statistical evaluation

Statistica 10 (Statsoft) was used to calculate significance. Statistical evaluation was performed by mixed model repeated measures analysis of variance (ANOVA). For the evaluation of the displacement at 15 N and 30 N logarithmic values were used. P-values of < 0.05 were considered significant.

RESULTS

Mean age of the specimens was 57.6 y (range 41-76 y). All specimens in the direct group had preservation of the inferior capsule. The anterior and posterior capsule were damaged by the insertion of the instruments. In the indirect group the inferior capsule was completely removed, together with the inferior third of the anterior and posterior capsule.

Mean displacement at 15 N was 1.46 mm (SD 0.78). The displacement in the direct group averaged 0.77 mm (SD 0.55) and in the indirect group 2.14 mm (SD 2.74) with the difference being non-significant ($p = 0.09664$). Similar findings were noted for the displacement measured at 30 N, with a mean displacement of 2.36 mm (SD 0.95) and a respective displacement for the direct and indirect group of 1.53 mm (SD 0.66) and 3.20 mm (SD 2.92), $p = 0.07997$.

Nine out of 10 claviculo-scapular constructs failed in the ACJ. One clavicular fracture occurred in the direct group. Mean end point failure for all 10 constructs was 653.4 N (SD 252.7). The direct DCE were significantly stronger than the indirect (respective mean failure values of 766.6 (SD 233.5) and 540.3 (SD 239.1), $p = 0.01334$). After failure all ACJ's were evaluated. No inadequate resections were identified.

DISCUSSION

The purpose of this study was to compare the horizontal stability of the ACJ after direct arthroscopic DCE through superior portals and indirect arthroscopic DCE through an inferior view in paired cadaveric shoulders. The hypothesis was that horizontal AC mobility after DCE would be less when more of the capsule was left intact. This was not confirmed in this study, as there was no statistical difference in the horizontal displacement between both groups. The ACJ's were stronger after direct DCE compared to indirect DCE, when tested in the horizontal plane. This confirms findings of previous studies that the joint capsule is important for the strength of the ACJ (*15*).

To our knowledge no previous study investigated biomechanical strength after direct and indirect DCE. This study clearly demonstrated that ACJ's were stronger after direct DCE compared to indirect DCE. Displacement at 15 and 30 N showed nearly significant differences between both groups in favour of the direct group.

Instability of the ACJ is a common source of pain after DCE. In order to maintain sufficient ACJ stability after DCE the preservation of the ACJ capsule is important. The 2 incisions in the anterior and posterior capsule in the direct DCE certainly violate the ACJ capsule, but the preservation of the inferior capsule seems important for the joint strength.

Vertical instability after excision should not be a problem since the distances from the lateral edge of the clavicle to the attachment tuberosities of the trapezoid and conoid ligaments have been measured at 25 mm and 47 mm (*26*). Overzealous resection of the distal clavicle is possible in either technique and should be avoided. Nevertheless a spontaneous vertical AC dislocation after indirect DCE has recently been published in a case report (*21*), where the CCL's were probably harmed during surgery by an anterior portal placed too medially. The higher failure strength of the direct excisions diminishes the risk for traumatic AC dislocations.

The direct approach safeguards most of the ACJ capsule. Our study underlines the role of this capsule by showing that the joint is stronger when more of the capsule is maintained. A better proprioception of the intact joint capsule may be an additional factor contributing to a swifter return to athletic activities (*5*). The direct DCE is therefore recommended as an isolated procedure in the young and athletic patient. Since it is more time-consuming than the indirect DCE the decision to perform a direct or indirect DCE in conjunction with another procedure is left to the discretion of the treating surgeon.

Direct exposure of the pathology of the ACJ is another advantage of the direct technique. At this point a final decision concerning the procedure being indicated can still be made. When the DCE is resected in the indirect way, the inferior capsule has to be removed and surgical excision of the ACJ may have been started before the cartilaginous surfaces can be evaluated. Both techniques can easily be performed with a standard 4 mm 30° scope. Since associated pathology is frequent, the authors recommend an evaluation of the glenohumeral and subacromial space before entering the ACJ, irrespective of the technique used.

This study has some limitations. DCE was performed on shoulders that were not known to have ACJ arthritis. Joint properties might change in the arthritic ACJ, thereby changing the biomechanical behaviour. There was neither control group of untreated shoulders nor a control group of open DCE's. It would be interesting to know whether there is a difference between arthroscopic and open DCE. Finally, as all studies of this nature, this is a "Time Zero" study, evaluating biomechanics at the time of surgery only. The capacity of clinically relevant capsular/ligamentous healing cannot be examined, and thus the persistence of these biomechanical changes is unknown.

To conclude, the treatment of arthroscopic DCE's through a direct approach resulted in superior horizontal ACJ ultimate failure strength compared to the indirect approach in a cadaver model, with a tendency to better horizontal ACJ stability. The direct arthroscopic DCE may offer advantages, early in the postoperative period, in the young and athletic patient where the ACJ is subject to heavier loads.

REFERENCES

1. **Auge WK II, Fischer RA.** Arthroscopic distal clavicle resection for isolated atraumatic osteolysis in weight lifters. *Am J Sports Med* 1998 ; 26 : 189-192.
2. **Bigliani LU, Nicholson GP, Flatow EL.** Arthroscopic resection of the distal clavicle. *Orthop Clin North Am* 1993 ; 24 : 133-141.
3. **Boehm TD, Kirschner S, Fischer A, Gohlke F.** The relation of the coracoclavicular ligament insertion to the acromioclavicular joint. A cadaver study of relevance to lateral clavicle resection. *Acta Orthop Scand* 2003 ; 74 : 718-721.
4. **Branch TP, Burdette HL, Shahriari AS, Carter FM, Hutton WC.** The role of the acromioclavicular ligaments and the effect of distal clavicle resection. *Am J Sports Med* 1996 ; 24 : 293-297.
5. **Charron KM, Schepsis AA, Voloshin I.** Arthroscopic distal clavicle resection in athletes : A prospective comparison of the direct and indirect approach. *Am J Sports Med* 2007 ; 35 : 53-58.
6. **Chronopoulos E, Gill HS, Freehill MT, Petersen SA, McFarland EG.** Complications after open distal clavicle excision. *Clin Orthop Relat Res* 2008 ; 466 : 646-651.
7. **Cook FF, Tibone JE.** The Mumford procedure in athletes. An objective analysis of function. *Am J Sports Med* 1988 ; 16 : 97-100.
8. **Dawson PA, Adamson GJ, Pink MM *et al.*** Relative contribution of acromioclavicular joint capsule and coracoclavicular ligaments to acromioclavicular stability. *J Shoulder Elbow Surg* 2009 ; 18 : 237-244.
9. **Debski RE, Parsons IM 3rd, Fenwick J, Vangura A.** Ligament mechanics during three degree-of-freedom motion at the acromioclavicular joint. *Ann Biomed Eng* 2000 ; 28 : 612-618.
10. **Debski RE, Parsons IM 4th, Woo SL, Fu FH.** Effect of capsular injury on acromioclavicular joint mechanics. *J Bone Joint Surg* 2001 ; 83-A : 1344-1351.
11. **Edwards SG.** Acromioclavicular stability : A biomechanical comparison of acromioplasty to acromioplasty with coplaning of the distal clavicle. *Arthroscopy* 2003 ; 19 : 1079-1084.
12. **Edwards SL, Wilson NA, Flores SE, Koh JL, Zhang L.** Arthroscopic distal clavicle resection : a biomechanical analysis of resection length and joint compliance in a cadaveric model. *Arthroscopy* 2007 ; 23 : 1278-1284.
13. **Flatow EL, Cordasco FA, Bigliani LU.** Arthroscopic resection of the outer end of the clavicle from a superior approach : a critical, quantitative, radiographic assessment of bone removal. *Arthroscopy* 1992 ; 8 : 55-64.
14. **Flatow EL, Duralde XA, Nicholson GP, Pollock RG, Bigliani LU.** Arthroscopic resection of the distal clavicle with a superior approach. *J Shoulder Elbow Surg* 1995 ; 4 : 41-50.
15. **Freedman BA, Javernick MA, O'Brien FP, Ross AE, Doukas WC.** Arthroscopic versus open distal clavicle excision : Comparative results at six months and one year from a randomized, prospective clinical trial. *J Shoulder Elbow Surg* 2007 ; 16 : 413-418.
16. **Fukuda K, Craig EV, An KN, Cofield RH, Chao EY.** Biomechanical study of the ligamentous system of the acromioclavicular joint. *J Bone Joint Surg* 1986 ; 68-A : 434-440.
17. **Gartsman GM.** Arthroscopic resection of the acromioclavicular joint. *Am J Sports Med* 1993 ; 21 : 71-77.
18. **Gurd FB.** The treatment of complete dislocation of the outer end of the clavicle : a hitherto undescribed operation. *Ann Surg* 1941 ; 216 : 80-88.
19. **Kay SP, Ellman H, Harris E.** Arthroscopic distal clavicle excision. Technique and early results. *Clin Orthop Relat Res* 1994 ; 301 : 181-184.
20. **Klimkiewicz JJ, Williams GR, Sher JS *et al.*** The acromioclavicular capsule as a restraint to posterior translation of the clavicle : a biomechanical analysis. *J Shoulder Elbow Surg* 1999 ; 8 : 119-124.
21. **Labson J, Anderson K, Marder R.** Acromioclavicular dislocation after arthroscopic distal clavicle resection : a case report. *J Shoulder Elbow Surg* 2011 ; 20 : e10-e12.
22. **Lee KW, Debski RE, Chen CH, Woo SL, Fu FH.** Functional evaluation of the ligaments at the acromioclavicular joint during anteroposterior and superoinferior translation. *Am J Sports Med* 1997 ; 25 : 858-862.
23. **Mumford EB.** Acromioclavicular dislocations. A new operative treatment. *J Bone Joint Surg* 1941 ; 23-A : 799-802.

24. **Renfree K, Riley M, Wheeler D, Hentz J, Wright T.** Ligamentous anatomy of the distal clavicle. *J Shoulder Elbow Surg* 2003 ; 12 : 355-359.
25. **Renfree KJ, Wright TW.** Anatomy and biomechanics of the acromioclavicular and sternoclavicular joints. *Clin Sports Med* 2003 ; 22 : 219-237.
26. **Rios CG, Arciero RA, Mazzocca AD.** Anatomy of the clavicle and coracoid process for reconstruction of the coracoclavicular ligaments. *Am J Sports Med* 2007 ; 35 : 811-817.
27. **Salter EG Jr, Nasca RJ, Shelley BS.** Anatomical observations on the acromioclavicular joint and supporting ligaments. *Am J Sports Med* 1987 ; 15 : 199-206.
28. **Sellards R, Nicholson GP.** Arthroscopic distal clavicle resection. *Oper Tech Sports Med* 2004 ; 12 : 18-26.
29. **Stine IA, Vangsness Jr CT.** Analysis of the capsule and ligament insertions about the acromioclaovicular joint : a cadaveric study. *Arthroscopy* 2009 ; 25 : 968-974
30. **Tolin BS, Snyder SJ.** Our technique for the arthroscopic Mumford procedure. *Orthop Clin North Am* 1993 ; 24 : 143-151.
31. **Zawadsky M, Marra G, Wiater JM *et al.*** Osteolysis of the distal clavicle : Long-term results of arthroscopic resection. *Arthroscopy* 2000 ; 16 : 600-605.