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Current trends in surgical treatment of the acromioclavicular joint injuries in 2023: a review of the literature

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Background: This article examines the wide range of surgical reconstruction options available for acromioclavicular (AC) joint injuries. However, the lack of consensus regarding the most suitable surgical techniques is attributed to the high and variable failure rates observed with current approaches.
Methods: This article presents a comprehensive overview of the current surgical principles and techniques used by renowned experts in the field of AC shoulder injury management.
Results: It emphasizes the significance of addressing horizontal and rotational instability in AC injuries and highlights the impact of impaired scapular biomechanics.
Conclusion: By exploring these emerging concepts and strategies, the article aims to lay the foundation for future studies aimed at improving treatment outcomes and patient management.

Surgical reconstruction options for acromioclavicular (AC) joint injuries involve a wide range of approaches, techniques, and methods. The primary objective when treating these high grade injuries is to restore the disrupted vertical and horizontal stability in an anatomically and biomechanically optimized manner. Unfortunately, there is currently no consensus on the most appropriate surgical technique(s) to achieve this goal given the high and variable rates of failure of current techniques.[5,30,33,42]

This article aims to present a summary of the current surgical principles and techniques used by leading experts in managing AC shoulder injuries. Additionally, we will highlight the significance of horizontal and rotational instability in AC injuries and the impact of dysfunctional scapular biomechanics. Ultimately, this will shed light on future direction for studies that focus on these emerging concepts and strategies to offer the best possible treatment and management for patients.

Acromioclavicular (AC) joint anatomy and biomechanics

The biomechanics of the AC joint involve a close interplay between the clavicle, scapula, and their respective soft tissues. The biomechanics of the AC joint are affected by not only the bony structure but also the soft tissue components of the AC joint capsule and the coracoclavicular (CC) ligaments: the trapezoid and conoid. However, the AC joint only makes up a component of the entire shoulder. Shoulder girdle motion is a complex process involving multiple joints, including the glenohumeral, sternoclavicular (SC), scapulothoracic, and AC joints. In a study by Ludewig et al, the researchers found that scapulothoracic motion occurs simultaneously with motion in the SC and AC joints during shoulder elevation. They described the AC joint motion in relation to the movement of the scapula relative to the clavicle. During humeral elevation, the reported AC joint motion included scapular internal rotation of 8°, upward rotation of 11°, and posterior tilting of 19°. The research findings demonstrate that the natural movement and forces experienced by the AC joint involve not only vertical and horizontal motion but also rotational motions.[13]

When evaluating and treating patients with AC injuries, it is important to consider the complexity of the shoulder girdle motion and all the forces at play.[2,7] Cadaveric sectioning studies have shown that cutting the AC joint in isolation results in greater anterior-posterior translation compared to cutting the CC ligaments in isolation. However, sectioning of the CC ligaments in isolation resulted in greater superior-inferior translation.[49] These soft tissues act synergistically and studies have demonstrated that transecting the AC joint capsule results in the CC joint experiencing twice the load horizontally but not vertically.[27] The bony architecture of the AC joint is also crucial in maintaining horizontal stability. Distal clavicle excision not only increases the horizontal instability but doing so concomitantly during AC reconstruction

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may be counterproductive and put undue stress on the recent reconstruction.[38]

Scapular dysfunction

Over the last few decades, the surgical management of AC injuries has primarily centered on the clavicular side of the joint. The focus has been on reconnecting the "displaced" clavicle to the scapula through reconstruction or repair of the injured CC ligaments. However, recent research has brought new insights into the biomechanics of the scapula and its relationship to the clavicle in AC pathology.[2,8,38,39] In AC injuries, the separation of the scapula from the supportive clavicular strut causes the scapula to move downward, accompanied by protraction and internal rotation, which shifts the scapula medially relative to the AC joint.[38,39]

This displacement of the scapula has significant functional consequences on shoulder biomechanics. It disrupts the scapulohumeral complex, preventing the scapular stabilizing muscles from maintaining the proper positioning of the glenohumeral and acromiohumeral joints.[38] As a result, the scapular-humeral rhythm is altered, leading to subsequent loss of rotator cuff strength and function. To restore rotator cuff strength and function, it becomes necessary to address the retraction of the scapula and the pivot point of the AC joint.

Furthermore, Gumina et al conducted a study showing that scapular dyskinesis is present in a significant percentage of patients with chronic type III injuries. Among them, a subset demonstrated scapular malposition, inferior medial border prominence, coracoid pain, and scapular dyskinesis (SICK scapula), which is associated with inferior shoulder function and pain. These findings challenge the conventional belief of focusing solely on "reducing" the clavicle in AC joint injuries. Instead, they suggest that the displaced portion is actually the scapula, shifting the focus toward reducing the scapula back to the clavicle.

This perspective is further supported by newer biomechanical studies,[13,17,27] emphasizing the goal of reconstructing the scapular-clavicle relationship. The ultimate aim is to enable these structures to move synchronously for optimal shoulder function.[13,17,27,38,39]

Surgical management of AC joint injuries: current understanding

There are a multitude of described procedures to address an injury to the AC joint, totaling more than 150.[5] This in itself shows how we as an orthopedic community are still striving to find a definitive answer on appropriate management of the injury. It also highlights the challenging nature of these injuries and the high failure rates postoperatively corroborate that sentiment.[17]

The consensus for Rockwood Types I-II is nonsurgical management and Types IV-VI necessitates surgical treatment.[5,11,17,21,23,24,30,37] The challenging Type III injuries, however, remain a point of debate. Over the years, the severity of type III AC joint injuries has been recognized to vary significantly, leading to the publication of a consensus statement by the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine in 2014. This statement recommended further subclassifying type III injuries to accurately identify patients who may benefit from surgery. Type IIIA injuries are considered stable without clavicle over-riding on the cross-body adduction view and without significant scapular dysfunction. Type IIIB injuries exhibit horizontal instability and therapy-resistant scapular dysfunction.[6] Signifying Type IIIA is managed nonsurgically and vice versa for IIIB injuries.

Current principles on how to manage AC injuries are based on repairing or reconstructing the injured structures, the CC ligaments and AC joint capsule with surrounding soft tissue. However, the majority of the modern techniques include addressing the CC ligaments in isolation with constructs using suture suspensory construct, synthetic devices, hardware, and/or graft tissue.[5,13,15-17,21,24,27,30] Additionally, nonanatomic CC reconstruction options utilizing a hook plate and transfer of the CA ligament (Weaver-Dunn procedure) and modifications thereof have also been used. Over time, anatomic versus nonanatomic reconstruction options of the CC ligaments have been evaluated biomechanically.

These have shown that anatomic CC reconstruction has similar biomechanical properties to the native CC ligament and vastly improved from nonanatomic constructs of the past.

However, there has not been a consensus of a single anatomic reconstruction method that is superior to others.

Additional surgical decision factors include the acuity of the injury. Flint et al performed a systematic review and found AC injuries are consistently deemed acute as 3 weeks or less and chronic as 6 weeks or more.[20] Additionally, the histologic regenerative properties of the AC ligament complex were studied and found that surgical management within the first week has the highest biologic healing potential. Furthermore, by the 2nd-3rd week, the healing potential had plateaued.[28] Ideally when managing acute high grade injuries, these should be addressed within that 1-3−week window. Unfortunately, because of the trial of nonsurgical management with Type I-III and chronic high grade injuries, this can cause confusion in the terminology.

The advent of arthroscopic surgery and the benefits of such techniques have shifted a majority of surgeons to now performing modifications of the older open techniques via arthroscopic assistance or completely arthroscopic. This in theory reduces some of the wound complications with large open incisions. However, complication rates with surgical management are still reported to range anywhere from 5%-30%.[37] Commonly reported surgical complications depend on fixation method but include loss of fixation, graft failure, fractures of the coracoid and clavicle, hardware prominence/irritation and subsequent removal, infection, wound healing, subacromial impingement, and hardware migration.[33]

Surgical techniques

Coracoclavicular ligament reconstruction

At this time, the majority of the surgical techniques toward addressing AC injuries involve trying to recreate the native CC ligaments whether it is from autograft, allograft, suture, synthetic materials, or any combination therein.[1] This is especially true in the acute injury setting and has historically been the traditional approach to addressing Rockwood III-VI injuries. These different techniques and variations are presented throughout the literature and well studied.[2,5,13,14,17,21,24,29-31,33]

The literature and biomechanical studies over the last few decades have convincingly shown that anatomic reconstruction of the CC ligaments and their attachment on the clavicle/coracoid are superior to nonanatomic.[14,29-31] Anatomic Coracoclavicular Reconstruction (ACCR) is able to resist peak loads to failure equivalent to that of native CC ligaments.[14,29-31] Additionally, proper tunnel placement in the clavicle is crucial for optimal strength and reducing the risk of failures. Research indicates that tunnel placement corresponding to the attachment of the CC ligaments in the clavicle results in placement of the graft into higher bone marrow density and correlates with higher loads to failure in experimental settings.[10]

Going into the intricacies of every variation of ACCR exceeds the scope and intention of this review. Nevertheless, it remains a matter of concern that performing isolated CC reconstruction in cases of higher grade AC injuries with horizontal instability may lead to suboptimal results. The nonanatomic restoration of native biomechanics and the absence of both anterior-to-posterior and rotational control at the AC joint can result in unfavorable outcomes, including residual deformity, impingement, restricted range of motion, and persistent pain.[8,18]

Acromioclavicular joint reconstruction/repair

Increased awareness of the importance of recreating the AC joint has now led to newer techniques and evolving strategies on how to repair it after an injury.[8,17,19,22,24,26,40,41,50,55,56] Similarly to the isolated CC ligament reconstruction, techniques reconstructing the AC joint capsule involve using suture, anchors, grafts, and/or hardware. Repairing the AC capsule enhances both horizontal and rotational stability, as studies suggest that an intact superior-posterior capsuloligamentous complex contributes to nearly 80% of the horizontal stability.[8,17-19] This principle is important in restoring the translational and rotational stability afforded by an intact AC joint capsule, soft tissue, and surrounding bony architecture.

There is now a heightened awareness on the importance of reconstructing the AC anatomy and biomechanics whether in acutely or chronically injured AC joint.[8,18,22,32,36] With that in mind, there has been an advent of newer techniques implementing constructs with bone tunnels, suture anchors, or combination. The ideal construct for AC repair/reconstruction is yet to be delineated. Currently described techniques include box-shaped configurations and figure of 8. At this time, the box-shaped configuration seems biomechanically superior to figure-8 configuration.[19] However, these box-shaped and figure-8 constructs can lead to suture cut out of the bone. Tape like suture could potentially mitigate this but further biomechanical and clinical data are needed. Additionally, Peeters et al performed a biomechanical study looking at compressional and translational stability after multiple knot combination repairs of AC joint using bone tunnels and suture anchors. They found a Nice knot in combination with titanium suture anchors or bone tunnels both provided adequate translational stability in all planes in comparison to previously described methods of isolated CC repair/reconstruction or combination of AC/CC.

Further research is required to determine the optimal technique as each approach carries its own potential complications.[17] AC reconstruction offers the advantage of enhancing stability in multiple planes, particularly horizontally. Addressing horizontal instability is crucial, as it is often a contributing factor to failed AC reconstruction, resulting in persistent pain, instability, and reduced shoulder function.[18,19] Despite the growing recognition of this surgical principle, there is currently limited literature available on clinical implementation and patient-reported outcomes of these techniques. Therefore, future studies and research papers are necessary to provide more guidance on the specific techniques and their effectiveness.

Combined acromioclavicular and coracoclavicular reconstruction

Over the last few decades, the CC ligaments were addressed via isolated ACCR with or without graft augmentation in the setting of high grade AC joint injuries. This was effective in controlling vertical stability, but as previously mentioned, this does not control the dynamic horizontal instability created by these higher grade AC injuries.[8,18,19] More recent methods have recently been described addressing both AC horizontal/translational stability by combining both CC and AC reconstructions. These include mainly arthroscopic or arthroscopic-assisted procedures to address the pathology.

Differing techniques have been described in the literature; however, their main goal is the same: reconstruct the injured CC and AC structures. Schiebel describes his technique for high grade acute AC injury with horizontal instability in which a combination of CC and AC reconstructions are performed.[4] His described technique involves arthroscopic assistance with incision over distal clavicle. A self-tensioning pulley type of implant using a low-profile double button is drilled and placed to recreate the CC ligaments. For the AC joint, 2 bone tunnels are created in the distal clavicle and the acromion and a nonabsorbable suture tape is passed through each and tied through the same clavicular incision posteriorly creating a cerclage construct. The reported advantages of this type of construct are the lower profile nature with self-tensioning that would reduce potential residual deformity and prominence of hardware and/or knot stack.[4]

Goodine et al during their biomechanical study used a suture construct consisting of a double-loaded Polyether ether ketone (PEEK) suture anchor placed on posterior aspect of the acromial side of the AC joint and with 1 limb passed posterior to anterior in the previously addressed Weaver-Dunn like CA ligament transfer and the second limb passed via bone tunnel to the anterior acromial and then the 2 limbs tied together. This construct reconstructed the anterior capsule. Then the posterior capsule was then repaired using the remaining limbs and tied over the posterior clavicle button from the previous W-D transfer.[8]

Similar dual reconstruction techniques have also been recently described by Ardebol et al. Their described procedure includes a coracoid and AC tensionable cerclage construct.[34] The AC joint reconstruction is addressed in a figure of 8 transosseous configuration. The CC joint is interestingly addressed via a tensionable construct with a semitendinosus allograft and tensionable suture in both the acute and chronic settings. They cite the poor outcomes associated with single-suture coracoid cerclage techniques in comparison to graft reconstruction of the CC ligaments. The authors cited benefits of this arthroscopic technique include addressing concomitant pathology, improved reduction with tensioner, anatomic AC joint reconstruction, and avoidance of drill tunnels in coracoid. Cons include difficulty with coracoid exposure in addition to potential neurovascular injury.[34]

The advent of arthroscopy has dominated the literature and surgical techniques but open/mini-open procedures still are present in the landscape. Kim et al describes an open AC and CC ligament reconstruction technique using racking hitch tensionable suture cerclage construct of the CC ligament; this does use drill holes in the anatomic insertion sites of trapezoid and conoid ligaments. The AC reconstruction is addressed using an allograft passed through reamed 4.0 mm holes in the distal clavicle and acromion and tied via a surgeons knot and reinforced with a 2-0 FiberWire (Arthrex, Naples, FL, USA) suture. The final tensioning is performed on the CC sutures using a tensionable device. Author reported advantages to this approach include precise reduction of AC joint, anatomic CC reconstruction, no metal implants or hardware, and no graft passage around coracoid. Disadvantages are the technically challenging nature of the procedure, risk of iatrogenic or postoperative fracture of clavicle/acromion, graft failure, and risk to neurovascular structures.[3]

It is evident that there is no singular construct that trumps others but the concept of hybrid reconstruction of the CC and the AC joint are critical in chronic injuries.[46-48] Tauber et al showed that combined AC and CC ligament reconstruction better restored horizontal stability compared to isolated reconstruction. Additionally, they found that patients undergoing hybrid construct reconstruction showed improved radiologic and patient-reported outcomes.[25] Acute hybrid construct research is scarce but additional clinical studies are needed to validate the idea of superior biomechanical construct to isolated ACCR.[17] However, with newer biomechanical data and the elevated complication rates of older techniques, the importance of creating a hybrid construct has grown more evident.[8,9,17,56,57]

Complications and outcomes

As with any surgery or technique, they are not without their own inherent risks and complications. Due to the vast amount of procedures described in the literature, the number of complications for each one is beyond the scope of this article. However, we will focus on the common complications associated with these newer techniques.

In constructs using bone tunnels and suspensory/graft reconstruction, the risk of fracture is a major concern. This is especially true as you create increasingly larger diameter holes in the coracoid, clavicle, and acromion.[3,4,8,17,18,34] Creating anatomically accurate ligament footprints during reconstruction carries a notable risk of cortical breach and fracture.[51,54] Additionally, the size of the tunnels, particularly in the clavicle, is crucial, as larger tunnels can increase the risk of fractures. A recent study demonstrated that using hamstring tendon grafts through 6 mm tunnels significantly weakens the clavicle compared to using a cortical button and suture through 2.4 mm tunnels.[51,54]

Residual horizontal instability and radiographic failure are another commonly described complication. Radiographic failure rates based on vertical displacement (defined as more than fifty percent change in position) measured on anterior-posterior radiographs vary widely, ranging from 0-47%.[24,43] Early failures often occur within the first 6 weeks after surgery, and overcorrection compared to the unaffected extremity has been observed.[8,12] Fewer studies have examined postoperative AC joint stability in the horizontal plane. Some studies have identified posterior displacement of the distal clavicle on axillary X-rays and signs of dynamic posterior instability on Alexander view X-rays.[8,12,49] Different surgical techniques, such as arthroscopic CC reconstruction with a 2-suture button technique or hook plate fixation, have been associated with varying rates of posterior instability as well.[42,45,49] Horizontal instability rates have been reported in patients undergoing both acute and chronic treatment, varying from 16%-43%.[8,12,24,33,42-45,49] These findings suggest that residual horizontal instability is a common complication that has often been overlooked in previous studies that did not assess dynamic radiographic parameters in this plane.[8,12,42,45,49]

AC joint reconstruction using the aforementioned techniques has shown favorable clinical outcomes and the ability to return to preinjury activity levels with reported success rates ranging from 83% to 90%, even at 2 years.[17,43,44] Younger patients have shown even higher outcome values in these procedures.[44] Even with these outcomes, the unrecognized postoperative horizontal and rotational instability cannot be overlooked and if missed can lead to chronic pain and clinical failures.[17,19,22,35] It has been found in a recent study that combining AC and CC ligament reconstruction better restores horizontal stability and results in improved patient-reported and radiographic outcomes.[52] However, additional studies including clinical outcomes are needed to validate these recent findings.

Discussion

This article has delved into the diverse surgical approaches to AC joint reconstruction presented by orthopedic experts. While a consensus on the optimal approach is still lacking, there is growing recognition that a hybrid approach, addressing both the CC ligaments and the AC joint, offers the most biomechanical advantage in achieving near-anatomic stability.[8,17,19,22,53] As our understanding of AC joint biomechanics and surrounding anatomy improves, we can strive to provide more effective treatment for our patients.

In light of this, the authors advocate for a shift in future studies, moving away from solely clavicle-centered reconstructions (such as isolated CC reconstruction) and toward a hybrid approach involving both AC and CC reconstruction in the majority of cases, whether chronic or potentially acute. Despite the current limited clinical data on this topic, we underscore the significance of this hybrid concept and encourage further studies on clinical outcomes.[8,17,19,22,24,53] By broadening our perspective to consider the scapula and its relationship to the extremity, we can guide the orthopedic community toward adopting innovative strategies, techniques, and future trials aimed at developing the most suitable AC reconstruction options for patients in the future.

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References

1. Alexander OM. Radiography of the acromioclavicular articulation. Med Radiogr Photogr 1954;30:34-9. 13202745.
2. Allman FL. Fractures and ligamentous injuries of the clavicle and its articulation. J Bone Joint Surg 1967;49:774-84.
3. Ardebol J, Hwang S, Horinek JL, Parsons BO, Denard PJ. Arthroscopically assisted tensionable cerclage reconstruction of an acromioclavicular separation with combined fixation of the coracoclavicular and acromioclavicular ligaments. Arthrosc Tech 2023;12:e321-7. https://doi.org/10.1016/j.eats.2022.11.010.
4. Barth J, Duparc F, Andrieu K, Duport M, Toussaint B, Bertiaux S, et al. Is coracoclavicular stabilisation alone sufficient for the endoscopic treatment of severe acromioclavicular joint dislocation (Rockwood types III, IV, and V)? J Orthop Traumatol Surg Res 2015;101:S297-303. https://doi.org/10.1016/j.otsr.2015.09.003.
5. Beitzel K, Cote MP, Apostolakos J, Solovyova O, Judson CH, Ziegler CG, et al. Current concepts in the treatment of acromioclavicular joint dislocations. Arthrosc J Arthrosc Relat Surg 2013;29:387-97. https://doi.org/10.1016/j.arthro.2012.11.023.
6. 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. Arthrosc J Arthrosc Relat Surg 2014;30:271-8. https://doi.org/10.1016/j.arthro.2013.11.005.
7. Beitzel K, Obopilwe E, Apostolakos J, Cote MP, Russell RP, Charette R, et al. Rotational and translational stability of different methods for Direct acromioclavicular ligament repair in anatomic acromioclavicular joint reconstruction. Am J Sports Med 2014;42:2141-8. https://doi.org/10.1177/0363546514538947.
8. Beitzel K, Sablan N, Chowaniec DM, Obopilwe E, Cote MP, Arciero RA, et al. Sequential resection of the distal clavicle and its effects on horizontal acromioclavicular joint translation. Am J Sports Med 2012;40:681-5. https://doi.org/10.1177/0363546511428880.
9. Berthold DP, Muench LN, Dyrna F, Mazzocca AD, Garvin P, Voss A, et al. Current concepts in acromioclavicular joint (AC) instability – a proposed treatment algorithm for acute and chronic AC-joint surgery. BMC Muscoskel Disord 2022;23:1078. https://doi.org/10.1186/s12891-022-05935-0.
10. Braun S, Martetschläger F, Imhoff AB. Arthroskopisch assistierte Stabilisierung bei akuter und chronischer Akromioklavikulargelenksprengung. Operat Orthop Traumatol 2014;26:228-36. https://doi.org/10.1007/s00064-013-0276-x.
11. Chronopoulos E, Kim TK, Park HB, Ashenbrenner D, McFarland EG. Diagnostic value of physical tests for isolated chronic acromioclavicular lesions. Am J Sports Med 2004;32:655-61. https://doi.org/10.1177/0363546503261723.
12. Clavert P, Meyer A, Boyer P, Gastaud O, Barth J, Duparc F. Complication rates and types of failure after arthroscopic acute acromioclavicular dislocation fixation. Prospective multicenter study of 116 cases. J Orthop Traumatol Surg Res 2015;101:S313-6. https://doi.org/10.1016/j.otsr.2015.09.012.
13. Cook JB, Krul KP. Challenges in treating acromioclavicular separations: current concepts. J Am Acad Orthop Surg 2018;26:669-77. https://doi.org/10.5435/JAAOS-D-16-00776.
14. Costic RS, Labriola JE, Rodosky MW, Debski RE. Biomechanical rationale for development of anatomical reconstructions of coracoclavicular ligaments after

Complete acromioclavicular joint dislocations. Am J Sports Med 2004;32:1929-36. https://doi.org/10.1177/0363546504264637.
15. De Groot C, Verstift DE, Heisen J, Van Deurzen DF, Van Den Bekerom MP. Management of acromioclavicular injuries – current concepts. Orthop Res Rev 2023;15:1-12. https://doi.org/10.2147/ORR.S340531.
16. Deans CF, Gentile JM, Tao MA. Acromioclavicular joint injuries in overhead athletes: a concise review of injury mechanisms, treatment options, and outcomes. Curr Rev Musculosk Med 2019;12:80-6. https://doi.org/10.1007/s12178-019-09542-w.
17. Debski RE, Parsons IM, Woo SL-Y, Fu FH. Effect of capsular injury on acromioclavicular joint Mechanics. J Bone Joint Surg Am 2001;83:1344-51.
18. Dyrna F, De Oliveira CCT, Nowak M, Voss A, Obopilwe E, Braun S, et al. Risk of fracture of the acromion depends on size and orientation of acromial bone tunnels when performing acromioclavicular reconstruction. Knee Surg Sports Traumatol Arthrosc 2018;26:275-84. https://doi.org/10.1007/s00167-017-4728-y.
19. Dyrna F, Imhoff FB, Haller B, Braun S, Obopilwe E, Apostolakos JM, et al. Primary stability of an acromioclavicular joint repair is affected by the type of additional reconstruction of the acromioclavicular capsule. Am J Sports Med 2018;46:3471-9. https://doi.org/10.1177/0363546518807908.
20. Flint JH, Wade AM, Giuliani J, Rue J-P. Defining the terms *acute* and *chronic* in orthopaedic sports injuries: a systematic review. Am J Sports Med 2014;42:235-41. https://doi.org/10.1177/0363546513490656.
21. Frank RM, Cotter EJ, Leroux TS, Romeo AA. Acromioclavicular joint injuries: evidence-based treatment. J Am Acad Orthop Surg 2019;27:e775-88. https://doi.org/10.5435/JAAOS-D-17-00105.
22. Geaney LE, Beitzel K, Chowaniec DM, Cote MP, Apostolakos J, Arciero RA, et al. Graft fixation is highest with anatomic tunnel positioning in acromioclavicular reconstruction. Arthrosc J Arthrosc Relat Surg 2013;29:434-9. https://doi.org/10.1016/j.arthro.2012.10.010.
23. Goodine T, Celik H, Flores-Hernandez C, D'Lima D, Hoenecke H. Combination of surgical techniques restores Multidirectional biomechanical stability of acromioclavicular joint. Arthrosc J Arthrosc Relat Surg 2022;38:1774-83. https://doi.org/10.1016/j.arthro.2021.11.051.
24. Ibrahim DK, Lam PH, Aveledo Anzola RJ, Murrell GA. Biomechanical evaluation of an independent acromioclavicular ligament repair for acromioclavicular joint reconstruction. Shoulder Elbow 2020;12:184-92. https://doi.org/10.1177/1758573219857685.
25. Kim JY, Park H-Y, Bryant S, Gardner B, Chakrabarti M, McGahan P, et al. Combined coracoclavicular and acromioclavicular joint reconstruction with allograft using a cerclage tensioning system. Arthroscopy Techniques 2021;10:e317-23. https://doi.org/10.1016/j.eats.2020.10.013.
26. Lee SJ, Nicholas SJ, Akizuki KH, McHugh MP, Kremenic IJ, Ben-Avi S. Reconstruction of the coracoclavicular ligaments with tendon grafts. Am J Sports Med 2003;31:648-54. https://doi.org/10.1177/03635465030310050301.
27. Ludewig PM, Phadke V, Braman JP, Hassett DR, Cieminski CJ, LaPrade RF. Motion of the shoulder complex during Multiplanar humeral elevation. J Bone Joint Surg Am 2009;91:378-89. https://doi.org/10.2106/JBJS.G.01483.
28. Maier D, Tuecking L-R, Bernstein A, Lang G, Wagner FC, Jaeger M, et al. The acromioclavicular ligament shows an early and dynamic healing response following acute traumatic rupture. BMC Muscoskel Disord 2020;21:593. https://doi.org/10.1186/s12891-020-03614-6.
29. Martetschläger F, Horan MP, Warth RJ, Millett PJ. Complications after anatomic fixation and reconstruction of the coracoclavicular ligaments. Am J Sports Med 2013;41:2896-903. https://doi.org/10.1177/0363546513502459.
30. Mazzocca AD, Arciero RA, Bicos J. Evaluation and treatment of acromioclavicular joint injuries. Am J Sports Med 2007;35:316-29. https://doi.org/10.1177/0363546506298022.
31. Mazzocca AD, Conway JE, Johnson S, Rios CG, Dumonski ML, Santangelo SA, et al. The anatomic coracoclavicular ligament reconstruction. Operat Tech Sports Med 2004;12:56-61. https://doi.org/10.1053/j.otsm.2004.04.001.
32. Mazzocca AD, Santangelo SA, Johnson ST, Rios CG, Dumonski ML, Arciero RA. A biomechanical evaluation of an anatomical coracoclavicular ligament reconstruction. Am J Sports Med 2006;34:236-46. https://doi.org/10.1177/0363546505281795.
33. Mehrberg RD, Lobel SM, Gibson WK. Disorders of the acromioclavicular joint. Phys Med Rehabil Clin N Am 2004;15:537-55. https://doi.org/10.1016/j.pmr.2003.12.003.
34. 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.
35. Minkus M, Kraus N, Hann C, Scheibel M. Arthroscopic reconstruction after acute acromioclavicular separation injuries. JBJS Essential Surg Tech 2017;7:e7. https://doi.org/10.2106/JBJS.ST.16.00063.
36. Morikawa D, Dyrna F, Cote MP, Johnson JD, Obopilwe E, Imhoff FB, et al. Repair of the entire superior acromioclavicular ligament complex best restores posterior translation and rotational stability. Knee Surg Sports Traumatol Arthrosc 2019;27:3764-70. https://doi.org/10.1007/s00167-018-5205-y.
37. Nelson A, Woodmass J, Esposito J, Ono Y, Lo I, Boorman R, et al. Complications following arthroscopic fixation of acromioclavicular separations: a systematic review of the literature. Open Access J Sports Med 2015;97. https://doi.org/10.2147/OAJSM.S73211.
38. Oki S, Matsumura N, Iwamoto W, Ikegami H, Kiriyama Y, Nakamura T, et al. Acromioclavicular joint ligamentous system contributing to clavicular strut function: a cadaveric study. J Shoulder Elbow Surg 2013;22:1433-9. https://doi.org/10.1016/j.jse.2013.01.004.
39. Peeters I, Herregodts S, De Wilde L, Van Tongel A. Biomechanical evaluation of a new technique for acromioclavicular stabilization. J Orthop Traumatol Surg Res 2020;106:247-54. https://doi.org/10.1016/j.otsr.2019.11.016.
40. Petri M, Warth RJ, Greenspoon JA, Horan MP, Millett PJ. Clinical results following non-operative management for Grade III acromioclavicular joint injuries: does eventual surgery affect overall outcomes? Orthop J Sports Med 2015;3:2325967115S0007. https://doi.org/10.1177/2325967115S00079.
41. Richards DP, Howard A. Distal clavicle fracture mimicking type IV acromioclavicular joint injury in the skeletally immature athlete. Clin J Sport Med 2001;11:57-9.
42. Rios CG, Arciero RA, Mazzocca AD. Anatomy of the clavicle and coracoid process for reconstruction of the coracoclavicular ligaments. Am J Sports Med 2007;35:811-7. https://doi.org/10.1177/0363546506297536.
43. Rosslenbroich SB, Schliemann B, Schneider KN, Metzlaff SL, Koesters CA, Weimann A, et al. Minimally invasive coracoclavicular ligament reconstruction with a Flip-button technique (MINAR): clinical and radiological Midterm results. Am J Sports Med 2015;43:1751-7. https://doi.org/10.1177/0363546515579179.
44. Rylander LS, Baldini T, Mitchell JJ, Messina M, Justl Ellis IA, McCarty EC. Coracoclavicular ligament reconstruction: coracoid tunnel diameter correlates with failure risk. Orthopedics 2014;37:e531. https://doi.org/10.3928/01477447-20140528-52.
45. Salzmann GM, Walz L, Buchmann S, Glabgly P, Venjakob A, Imhoff AB. Arthroscopically assisted 2-Bundle anatomical reduction of acute acromioclavicular joint separations. Am J Sports Med 2010;38:1179-87. https://doi.org/10.1177/0363546509355645.
46. 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.
47. Sciascia A, Bois AJ, Kibler WB. Nonoperative management of traumatic acromioclavicular joint injury: a clinical commentary with clinical practice considerations. Int J Sports Phys Ther 2022;17:519-40. https://doi.org/10.26603/001c.32545.
48. Shah RR, Kinder J, Peelman J, Moen TC, Sarwark J. Pediatric clavicle and acromioclavicular injuries. J Pediatr Orthop 2010;30:S69-72. https://doi.org/10.1097/BPO.0b013e3181ba9e94.
49. Simovitch R, Sanders B, Ozbaydar M, Lavery K, Warner JJP. Acromioclavicular joint injuries: diagnosis and management. J Am Acad Orthop Surg 2009;17:207-19. https://doi.org/10.5435/00124635-200904000-00002.
50. Spencer HT, Hsu L, Sodl J, Arianjam A, Yian EH. Radiographic failure and rates of re-operation after acromioclavicular joint reconstruction: a comparison of surgical techniques. Bone Joint J 2016;98-B:512-8. https://doi.org/10.1302/0301-620X.98B4.35935.
51. Spiegl UJ, Smith SD, Euler SA, Dornan GJ, Millett PJ, Wijdicks CA. Biomechanical consequences of coracoclavicular reconstruction techniques on clavicle strength. Am J Sports Med 2014;42:1724-30. https://doi.org/10.1177/0363546514524159.
52. Stine IA, Vangsness CT. Analysis of the capsule and ligament insertions about the acromioclavicular joint: a cadaveric study. Arthrosc J Arthrosc Relat Surg 2009;25:968-74. https://doi.org/10.1016/j.arthro.2009.04.072.
53. Tauber M, Koller H, Hitzl W, Resch H. Dynamic radiologic evaluation of horizontal instability in acute acromioclavicular joint dislocations. Am J Sports Med 2010;38:1188-95. https://doi.org/10.1177/0363546510361951.
54. Tauber M, Valler D, Lichtenberg S, Magosch P, Moroder P, Habermeyer P. Arthroscopic stabilization of chronic acromioclavicular joint dislocations: triple- versus single-Bundle reconstruction. Am J Sports Med 2016;44:482-9. https://doi.org/10.1177/0363546515615583.
55. Tossy JD, Mead NC, Sigmond HM. 11 acromioclavicular separations: useful and practical classification for treatment. Clin Orthop Relat Res 1963;28:111-9.
56. Venjakob AJ, Salzmann GM, Gabel F, Buchmann S, Walz L, Spang JT, et al. Arthroscopically assisted 2-Bundle anatomic reduction of acute acromioclavicular joint separations: 58-Month findings. Am J Sports Med 2013;41:615-21. https://doi.org/10.1177/0363546512473438.
57. Zanca P. Shoulder pain: involvement of the acromioclavicular joint: (ANALYSIS OF 1,000 cases). Am J Roentgenol 1971;112:493-506.