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Chronic anterior sternoclavicular instability: technique and results of corrective clavicular osteotomy

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Background: Chronic anterior sternoclavicular (SC) instability is a rare but potentially disabling condition. It can arise in conjunction with trauma or hyperlaxity, or both. Numerous surgical techniques have been described, but no gold standard exists. SC instability is often position-dependent and can be reduced with the arm in a specific position.

Methods: To directly address this issue, we used a technique of corrective osteotomy of the clavicle with the goal to reorient the articular portion of the medial end of the clavicle so that it remains stable in all functional positions of the arm. To illustrate the technique and the correction in space, we performed postoperative 3-dimensional computed tomography analyses of the shoulder girdle of 4 patients. Clinical scores were obtained at the final follow-up and compared with preoperative scores.

Results: Mean follow-up was 64 months (range, 19-191 months). The mean Constant score improved from 58 (range, 45-68) preoperatively to 73 (range, 69-84) postoperatively and the Subjective Shoulder Value from 42 (range, 15-80) to 79 (range, 50-100). All patients reported good or very good stability of the SC joint at the last follow-up. We recorded no intraoperative or direct postoperative complications. During follow-up, 3 patients underwent removal of the plate, 1 of them for plate breakage. The mean postoperative correction for combined rotations is given as a 3-dimensional angle and averaged 28.0° (range, 8.6°-39.7°).

Conclusion: In this pilot study, medial corrective clavicular osteotomy using the described technique treated anterior SC instability with improvement of clinical shoulder function scores and good patient satisfaction. The technique appears simple and safe and deserves further evaluation.

Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Sternoclavicular joint; sternoclavicular instability; corrective osteotomy; clavicle osteotomy; 3-D CT analysis ; anterior subluxation

Disorders of the sternoclavicular (SC) joint are rare, and it has therefore been called the "forgotten articulation of the shoulder girdle."[17,34] It is difficult to evaluate using conventional radiography, even when using specialized plain film projections.[10] This difficulty can be overcome by cross-sectional

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imaging, such as computed tomography (CT) or magnetic resonance imaging, which are recommended for evaluation of the osseous and soft tissue alterations of the SC joint.[13,34] SC instability can be secondary to trauma or hyperlaxity, or both.[21,37,45]

Because the clavicular epiphysis is the last to ossify, subluxation should not be mistaken for a physeal fracture-dislocation with articular disruptions in patients up to 25 years.[12] Posterior dislocation constitutes a different entity and will not be addressed in this study. For acute, chronic, and recurrent anterior instability, nonoperative treatment has been recommended and can yield favorable results.[11,36,45] Nevertheless, anterior instability of the joint does not always follow a benign course when treated conservatively, and some patients experience painful restriction of shoulder function despite adequate conservative treatment.[1,4,28,43] Although pathologies of the SC joint have been the subject of scientific research for decades, no consensus concerning the preferred treatment or a gold standard exists due to the scarcity of the pathology.[17,35]

Resection arthroplasty has been recommended for osteoarthritis with good results, but poor outcomes are described for instability.[24,31,34,35] Studies directly comparing the different techniques are rare, but favor stabilization.[14,30] To prevent persistent or recurrent secondary instability after resection arthroplasty and to preserve the joint, a number of reconstructive and stabilizing techniques have been described.[35] Deleterious complications have been reported for the use of unstable implants, such as Kirschner wires and pins, so that their use is contraindicated.[27,44] Local tissue transposition, autografts, or allografts can be used to reconstruct the SC and costoclavicular ligaments.[1,4,8,15,18,42] Techniques using artificial materials like LARS bands (Corin, Cirencester, UK) and FiberWire (Arthrex, Naples, FL, USA) have been described recently.[2,32] Best biomechanical stability is obtained by using a figure-of-8 reconstruction.[40] Clinical case studies and series show that stability and function can be improved in most adult and adolescent patients.[6,18,25,39] The procedure is recommended for chronic instability in a systematic review.[43] An alternative approach by restricting joint motion with a hook plate required implant removal in 29 of 32 patients, but showed no recurrence of instability.[46]

Anatomy

The SC joint is a diarthrodial joint located at the aperture of the thorax. The head of the clavicle lies in a shallow groove of the sternum. Less than half of the medial clavicular surface articulates with the corresponding articular facet on the manubrium sterni. This incongruence of the bony structures explains the need of rigid ligamentous stabilization.[38] This stabilizing apparatus consists of the costoclavicular ligament, the interclavicular ligament, and the posterior and anterior SC and capsular ligaments. In addition, the SC joint contains an intra-articular disc built of fibrocartilage, which resists medial displacement of the clavicle.

Bearn[7] demonstrated that the capsular ligaments were the most important structures. In a cadaveric study, posterior sectioning resulted in a greater increase of anterior translation than sectioning the anterior capsule.[41] The SC joint allows a large range of motion. Every 10° of flexion of the arm result in rotation of the clavicle of 4°.[23] With combined movements, the clavicle can rotate up to 35° along its longitudinal axis. In the anteroposterior plane, it has a range of movement of 70° around neutral and 50° of rotation around the longitudinal axis.[26,33,36]

We observed that SC instability is often position dependent and thus dynamic. Our goal was to improve shoulder function by omitting the painful positional dislocation of the clavicle by using a technique that preserves the SC joint. Clavicular osteotomy was described as early 1967 to aid irreducible acute anterior SC dislocation. The 2 clavicular fragments were tethered with suture and left to heal.[29] Another group described a clavicular osteotomy for the treatment of symptomatic fracture malunion.[19] We adapted the latter to treat SC instability and describe the detailed technique and preliminary results. CT scans at last follow-up were used to quantify the correction by using the contralateral clavicle as a template, as described before.[20]

Materials and methods

Indications and contraindications

In the rare case that conservative treatment fails and symptomatic anterior instability of the SC joint persists, surgical treatment may be indicated. Instability had to be objective, the limited shoulder function disabling, and conservative treatment for at least 6 months must have failed. Patients with chronic anterior SC joint dislocations or severe concomitant osteoarthritis of the SC joint were excluded.

We treated patients who continued to experience painfully disabling dynamic anterior subluxation of the clavicle during arm movement by rotational corrective osteotomy. Inclusion criteria were the ability to give informed consent to participate in the study. We excluded patients with posterior instability or pain due to ossification around the SC joint or simple osteoarthritis without objective instability. Pregnant women were excluded because the surgery is elective.

Data acquisition

The study included 4 patients who were treated in our facility between 2003 and 2013 for SC instability by a clavicle osteotomy. All patients were seen for a clinical follow-up and CT scan of the shoulder girdle. Clinical examination was performed, including scoring using the minimal data set of swiss orthopaedics, Subjective Shoulder Value (SSV), and the Constant Score.[16] Demographic and clinical data are descriptive.

Surgical technique

Setup

The patient was placed in the beach chair position with standard surgical preparation. The arm was draped free. Under anesthesia,

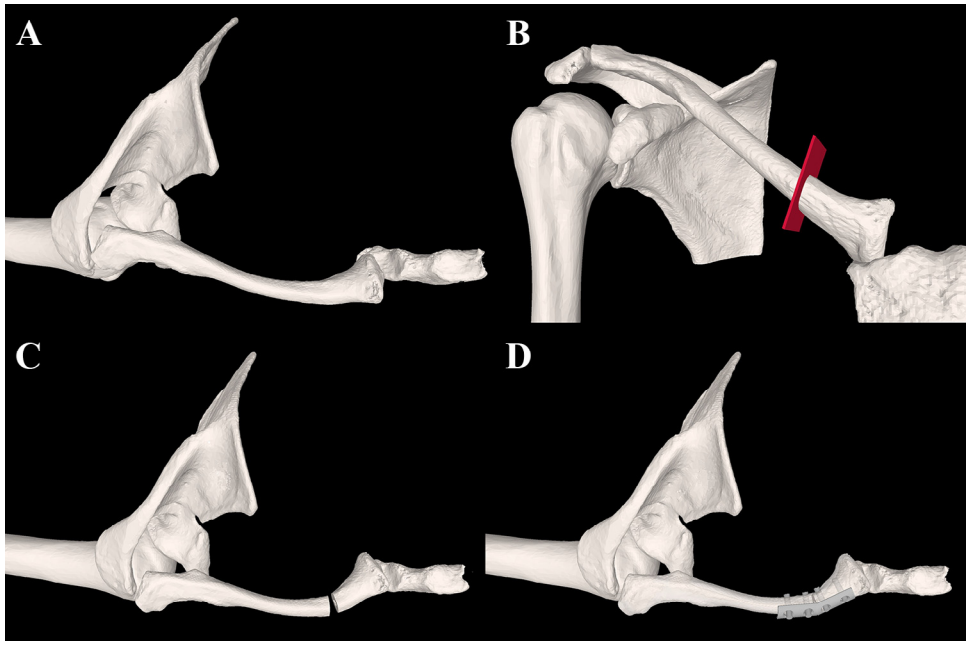

Figure 1 Illustration of the surgical technique: (**A**) Preoperative positional anterior dislocation of the sternoclavicular (SC) joint when the arm is brought in abduction/external rotation. (**B**) Performance of a perpendicular osteotomy of the clavicle 4 to 5 cm lateral to the SC. (**C**) Provocation of the unstable position and leaving the now free sternal part of the clavicle reduced in respect to the sternum. (**D**) Temporary application of a 3.5-mm 4-hole one-third tubular plate, which was manually bent to be adapted to the position of the 2 clavicular fragments to the bone with 2 pointed reduction forceps. Testing stability by moving the arm through the full range of motion while palpating and visually controlling the SC joint. If the joint remained stable, fixation of the plate to the 2 clavicular fragments was achieved using 3.5-mm bicortical screws.

the arm was flexed until the subluxation was provoked and then brought back to neutral position.

Surgical procedure

The line of the incision was marked over the medial third of the clavicle in line of Langer's lines ("necklace approach"). The skin and platysma muscle were incised, and subcutaneous dissection was advanced down to the periosteum. The joint capsule and the SC articulation were left untouched. The osteotomy was planned 4 to 5 cm lateral to the SC joint. The periosteum was incised directly over the future osteotomy site. The clavicle was osteotomized, and 2 blunt-tipped Hohmann retractors were used to protect the deep structures. Subsequently, the arm was brought in the flexion angle previously provoking instability, thereby leaving the now free sternal part of the clavicle reduced in respect to the sternum. The resulting position of the 2 clavicular portions was then stabilized using a 3.5-mm 4-hole one-third tubular plate, which was manually bent to be adapted to the position of the 2 clavicular fragments and applied to the bone with 2 pointed reduction forceps.

Before definitive osteosynthesis, stability was tested by moving the arm through the full range of motion while palpating and visually controlling the SC joint. If the joint remained stable, fixation of the plate to the 2 clavicular fragments was achieved using 3.5-mm bicortical screws. If the joint subluxated in a particular position during range of motion testing, the plate was removed, the joint was relocated in this position, the plate was readapted, and the 2 clavicular fragments were fixed in the respective position. By this maneuver, the medial part of the clavicle is rotated so that it tends to move posteriorly in neutral arm position. Because the posterior stabilizing complex remains competent, the clavicle stays reduced in neutral position of the arm. When moving the arm into elevation, the medial clavicle moves toward a neutral position in the joint and therefore no longer subluxates (Fig. 1).

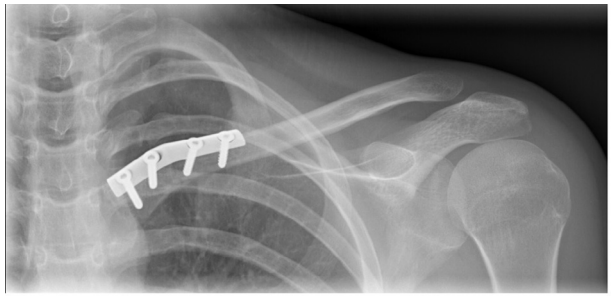

Figure 2 Postoperative x-ray image after a left-side clavicle osteotomy in a 19-year-old woman.

The soft tissue was closed by adapting the subcutaneous and subcuticular layers with Maxon 4-0 sutures (Covidien, Dublin, Ireland) and Steri-Strips (3M, St. Paul, MN, USA). The arm was placed in a simple sling. Postoperative radiographs were taken to confirm correct plate position. (Fig. 2)

Rehabilitation

Patients received instructions during their hospital stay from our physiotherapists on how to perform pendulum exercises. These were performed for the first 6 weeks, and then full movement was allowed.

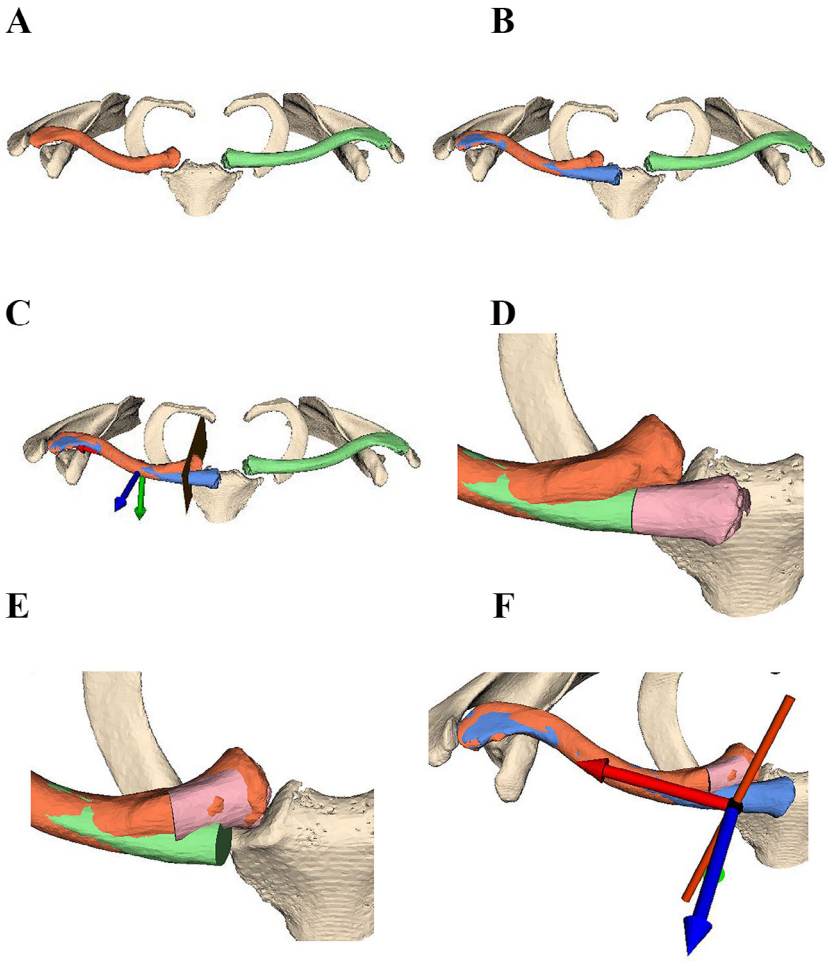

Figure 3 (**A**) Postoperative 3-dimensional model of a shoulder girdle with the clavicle after osteotomy (*orange*) and the contralateral clavicle as a reference (*green*). (**B**) The contralateral healthy bone is mirrored and laterally aligned to use it as a template (*blue*).[5,9] Note that the medial end of the clavicle now appears medially displaced, but the whole clavicle will be lateralized during the operation. (**C** and **D**) An anatomic coordinate system is implemented and the osteotomy plane defined orthogonal to the longitudinal axis of the clavicle (*x*-axis). (**E**) The medial part (*pink*) is subsequently aligned to the pathologic bone. (**F**) The correction is quantified by measuring the relative displacement from the medial osteotomized part (*pink*) to the mirrored reference (*blue*).

Maximal load of the extremity, including contact sports, was allowed after 3 months.

CT deformity evaluation

CT data were acquired using a Philips Brilliance 40 CT scanner (Philips, Bothell, WA, USA) with an axial resolution of 0.67 mm. Segmentation and quantification of the correction by the osteotomy using the healthy contralateral clavicle were performed as described before (Fig. 3, *A*).[20,22] The mirrored healthy reference bone is aligned to the lateral segment of the pathologic clavicle (Fig. 3, *B*). Subsequently, the osteotomy of the reference model is performed virtually (Fig. 3, *C* and *D*), and the medial segment is aligned to the pathologic counterpart (Fig. 3, *E*). The anatomic coordinate system was defined such that the *x*-axis corresponds to the longitudinal axis of the clavicular bone, pointing to the acromioclavicular joint, and the *y*-axis to the cranial-caudal orientation of the body, pointing to the feet. The translation and rotation of the medial segment based on an anatomic coordinate system is measured and describes the difference between the reference and pathologic bones (Fig. 3, *F*).

Results

Demographic data of the 4 patients (2 men and 2 women) are reported in Table I. Mean follow-up was 64 months (range, 19-191 months). The mean age at surgery was 24 years (range, 18-33 years). The patients showed no sign of physeal injury in preoperative CT scans. The interval from trauma to the index surgery averaged 27 months (range, 6-34 months).

No intraoperative or direct postoperative complications were encountered. Plate breakage occurred in 1 patient during follow-up, but the osteotomy had healed. Two other patients desired plate removal. There were no vascular complications or infections and no nonunions of the osteotomy.

Table I Demographic data

Patient	Sex	Age (yr)	Side/ dominance	Trauma	Injury or diagnosis to surgery (mo)	Occupation	Follow-up (mo)	Revision surgery	Pain medication
1	M	27	Left/D	Fall from height	6	Nonmanual	23	Plate removal	No
2	F	18	Left/D	Snowboard accident	34	Nonmanual	19	No	No
3	M	19	Right/D	No trauma	6	Manual	24	Plate removal for plate breakage	No
4	F	33	Left/ND	Fall from height	8	Nonmanual	191	Plate removal	Yes

M, male; *F*, female; *D*, dominant; *ND*, nondominant.

Table II Clinical scores

Patient	CS	Contralateral	VAS	Contralateral	SSV	Contralateral	Satisfaction
1*							
	69	80	5	15	80	100	3
2	61	65	10	12	30	70	1
	70	77	8	13	50	70	2
3	68	75	12	15	80	100	1
	84	85	15	15	100	100	2
4	45	80	6	15	15	80	0
	69	60	14	4	85	70	3

CS, Constant score; *VAS*, visual analog scale; *SSV*, Subjective Shoulder Value.
Gray shaded, postoperative scores.
CS: max = 100. VAS: 0 = extreme pain, 15 = no pain. SSV: 0%-100%. Satisfaction: 0 = not satisfied, 3 = very satisfied.
* Preoperative scores were missing for this patient.

Table III Clinical findings

Patient	Instability			Pain on palpation		Crepitation
	Subjective stability	Manual	Dynamic	SC	AC	
1	2	No	No	Yes	No	Yes
2	2	Yes	No	Yes	No	No
3	3	No	Yes	No	No	No
4	3	No	Yes	Yes	No	Yes

SC, sternoclavicular; *AC*, acromioclavicular.
Subjective instability: 0 = unstable, 3 = very good stability.

Clinical preoperative and postoperative scores are summarized in Table II. Preoperative scores were missing for patient 1. The mean Constant score improved from 58 (range, 45-68) preoperatively to 73 (range, 69-84) postoperatively, and the Subjective Shoulder Value (SSV) improved from 42 (range, 15-80) to 79 (range, 50-100). The subscore for pain improved slightly, from 9.3 (range, 6-12) preoperatively to 10.5 (range, 5-15) postoperatively.

Clinical findings are described in Table III. All patients reported good or very good subjective stability of the SC joint after clavicle osteotomy. Clinical examination showed possible manual subluxation in neutral arm position in 1 patient, and slight palpable subluxation in 2 patients when performing dynamic examination. Crepitation was palpable in 2 patients. The evaluation of the performed correction is given for the 3 axes of the anatomic coordinate system. The mean postoperative correction for combined rotation is given as the 3-dimensional (3-D) angle and was a mean of 28.0° (range, 8.6°-39.7°; Table IV).

Discussion

Substantial improvement of stability and overall symptoms without restoring fully normal shoulder function was observed in 4 patients with disabling, recurrent anterior SC subluxations using corrective osteotomy of the medial clavicle. The obtained mean Constant scores were comparable with

Table IV Postoperative correction in 3-dimensional angle

Patient	Correction	*x*-axis	*y*-axis	*z*-axis	3-D angle
1	Rotation	4.2	26.8	−30.2	39.7
	Translation	0.1	−1.2	1.3	
2	Rotation	−13.6	18.8	−15.3	29.0
	Translation	−0.1	0.1	−0.1	
3	Rotation	−11.2	−27.2	−21.6	34.7
	Translation	−0.5	−2.3	−1.5	
4	Rotation	−3.0	7.6	−2.3	8.6
	Translation	0.6	−1.4	0.4	

3-D, 3-dimensional.
All values in degrees.

results described for other stabilizing interventions.[1,3,30] Although all patients showed improved shoulder function and good satisfaction, restoring normal contralateral shoulder function was not possible in almost all patients. With only 4 patients, we could not document a correlation between the amount of correction and the subjective and objective instability. The presented technique could correct anterior SC instability without articular stabilization, permanent foreign material, or graft harvesting. It leaves the SC joint untouched, thus avoiding further articular damage, and avoids potential risks of tracheal and iatrogenic vascular injury. The intervention does eradicate the painful clunk of clavicular displacement during arm movement and thereby improves subjective and objective shoulder function.

Conclusion

Corrective clavicle osteotomy is a potential alternative to direct stabilization of the SC joint for disabling, recurrent anterior instability. In the future, 3-D planning will be conducted preoperatively, and the correction will be performed according to the 3-D preoperative planning. A prospective protocol is hoped to determine whether more quantitative corrections improve the results further.

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Disclaimer

Philipp Fürnstahl is a shareholder of Balgrist CARD AG, a company developing preoperative planning software. The other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Abiddin Z, Sinopidis C, Grocock CJ, Yin Q, Frostick SP. Suture anchors for treatment of sternoclavicular joint instability. J Shoulder Elbow Surg 2006;15:315-8. http://dx.doi.org/10.1016/j.jse.2005.07.005
2. Adamcik S, Ahler M, Gioutsos K, Schmid RA, Kocher GJ. Repair of sternoclavicular joint dislocations with FiberWire((R)). Arch Orthop Trauma Surg 2017;137:341-5. http://dx.doi.org/10.1007/s00402-017-2632-z
3. Al-Yassari G, Hetzenauer M, Tauber M, Resch H. Novel method to treat sterno-clavicular joint instability and medial clavicle fracture symptomatic nonunion. J Shoulder Elbow Surg 2009;18:553-5. http://dx.doi.org/10.1016/j.jse.2008.11.011
4. Armstrong AL, Dias JJ. Reconstruction for instability of the sternoclavicular joint using the tendon of the sternocleidomastoid muscle. J Bone Joint Surg Br 2008;90:610-3. http://dx.doi.org/10.1302/0301-620X.90B5.20293
5. Audette MA, Ferrie FP, Peters TM. An algorithmic overview of surface registration techniques for medical imaging. Med Image Anal 2000;4:201-17.
6. Bae DS, Kocher MS, Waters PM, Micheli LM, Griffey M, Dichtel L. Chronic recurrent anterior sternoclavicular joint instability: results of surgical management. J Pediatr Orthop 2006;26:71-4. http://dx.doi.org/10.1097/01.bpo.0000187998.91837.b2
7. Bearn JG. Direct observations on the function of the capsule of the sternoclavicular joint in clavicular support. J Anat 1967;101:159-70.
8. Castropil W, Ramadan LB, Bitar AC, Schor B, de Oliveira D, Elia C. Sternoclavicular dislocation—reconstruction with semitendinosus tendon autograft: a case report. Knee Surg Sports Traumatol Arthrosc 2008;16:865-8. http://dx.doi.org/10.1007/s00167-008-0527-9
9. Chen YM, Medioni G. Object modeling by registration of multiple range images. Proceedings of the 1991 IEEE, Intematiod Conference on Robotics and Automation, Sacramento, California—April 1991.
10. Cope R. Dislocations of the sternoclavicular joint. Skeletal Radiol 1993;22:233-8.
11. de Jong KP, Sukul DM. Anterior sternoclavicular dislocation: a long-term follow-up study. J Orthop Trauma 1990;4:420-3.
12. Denham RH, Dingley RF. Epiphysesal separation of the medial end of the clavicle. J Bone Joint Surg 1967;49-A:1179-83.
13. Destouet JM, Gilula LA, Murphy WA, Sagel SS. Computed tomography of the sternoclavicular joint and sternum. Radiology 1981;138:123-8.
14. Eskola A, Vainionpaa S, Vastamaki M, Slatis P, Rokkanen P. Operation for old sternoclavicular dislocation. Results in 12 cases. J Bone Joint Surg Br 1989;71:63-5.
15. Gaines RJ, Liporace FA, Yoon RS, DeMaio M. A novel technique for ligamentous reconstruction of the sternoclavicular joint. J Orthop Trauma 2014;28:e65-9. http://dx.doi.org/10.1097/BOT.0b013e31829aa9c5
16. Gilbart MK, Gerber C. Comparison of the subjective shoulder value and the Constant score. J Shoulder Elbow Surg 2007;16:717-21. http://dx.doi.org/10.1016/j.jse.2007.02.123
17. Glass ER, Thompson JD, Cole PA, Gause TM 2nd, Altman GT. Treatment of sternoclavicular joint dislocations: a systematic review of 251 dislocations in 24 case series. J Trauma 2011;70:1294-8. http://dx.doi.org/10.1097/TA.0b013e3182092c7b
18. Guan JJ, Wolf BR. Reconstruction for anterior sternoclavicular joint dislocation and instability. J Shoulder Elbow Surg 2013;22:775-81. http://dx.doi.org/10.1016/j.jse.2012.07.009
19. Hillen RJ, Eygendaal D. Corrective osteotomy after malunion of mid shaft fractures of the clavicle. Strategies Trauma Limb Reconstr 2007;2:59-61. http://dx.doi.org/10.1007/s11751-007-0024-6
20. Hingsammer AM, Lazaros V, Dominik MC, Furnstahl P. Three-dimensional corrective osteotomies of mal-united clavicles—is the contralateral anatomy a reliable template for reconstruction? Clin Anat 2015;28:865-71. http://dx.doi.org/10.1002/ca.22572

21. Hiramuro-Shoji F, Wirth MA, Rockwood CA Jr. Atraumatic conditions of the sternoclavicular joint. J Shoulder Elbow Surg 2003;12:79-88. http://dx.doi.org/10.1067/mse.2003.128566
22. Hirsiger S, Schweizer A, Miyake J, Nagy L, Furnstahl P. Corrective osteotomies of phalangeal and metacarpal malunions using patient-specific guides: CT-based evaluation of the reduction accuracy. Hand (N Y) 2017;1558944717726135. http://dx.doi.org/10.1177/1558944717726135
23. Inman VT, Saunders JB, Abbott LC. Observations on the function of the shoulder joint. J Bone Joint Surg 1944;26:1-30.
24. Katthagen JC, Tahal DS, Menge TJ, Horan MP, Millett PJ. Minimum 2-year outcomes and return to sport following resection arthroplasty for the treatment of sternoclavicular osteoarthritis. J Shoulder Elbow Surg 2017;26:e37-43. http://dx.doi.org/10.1016/j.jse.2016.07.008
25. Kawaguchi K, Tanaka S, Yoshitomi H, Nagai I, Sato W, Karita T, et al. Double figure-of-eight reconstruction technique for chronic anterior sternoclavicular joint dislocation. Knee Surg Sports Traumatol Arthrosc 2015;23:1559-62. http://dx.doi.org/10.1007/s00167-014-2979-4
26. Kent BE. Functional anatomy of the shoulder complex. A review. Phys Ther 1971;51:947.
27. Lyons FA, Rockwood CA Jr. Migration of pins used in operations on the shoulder. J Bone Joint Surg Am 1990;72:1262-7.
28. Martetschläger F, Warth RJ, Millett PJ. Instability and degenerative arthritis of the sternoclavicular joint: a current concepts review. Am J Sports Med 2014;42:999-1007. http://dx.doi.org/10.1177/0363546513498990
29. Omer GE Jr. Osteotomy of the clavicle in surgical reduction of anterior sternoclavicular dislocation. J Trauma 1967;7:584-90.
30. Panzica M, Zeichen J, Hankemeier S, Gaulke R, Krettek C, Jagodzinski M. Long-term outcome after joint reconstruction or medial resection arthroplasty for anterior SCJ instability. Arch Orthop Trauma Surg 2010;130:657-65. http://dx.doi.org/10.1007/s00402-009-0911-z
31. Pingsmann A, Patsalis T, Michiels I. Resection arthroplasty of the sternoclavicular joint for the treatment of primary degenerative sternoclavicular arthritis. J Bone Joint Surg Br 2002;84:513-7.
32. Quayle JM, Arnander MW, Pennington RG, Rosell LP. Artificial ligament reconstruction of sternoclavicular joint instability: report of a novel surgical technique with early results. Tech Hand Up Extrem Surg 2014;18:31-5. http://dx.doi.org/10.1097/BTH.0000000000000027
33. Renfree KJ, Wright TW. Anatomy and biomechanics of the acromioclavicular and sternoclavicular joints. Clin Sports Med 2003;22:219-37.
34. Robinson CM, Jenkins PJ, Markham PE, Beggs I. Disorders of the sternoclavicular joint. J Bone Joint Surg Br 2008;90:685-96. http://dx.doi.org/10.1302/0301-620X.90B6.20391
35. Rockwood CA Jr, Groh GI, Wirth MA, Grassi FA. Resection arthroplasty of the sternoclavicular joint. J Bone Joint Surg Am 1997;79:387-93.
36. Rockwood CA Jr, Odor JM. Spontaneous atraumatic anterior subluxation of the sternoclavicular joint. J Bone Joint Surg Am 1989;71:1280-8.
37. Sadr B, Swann M. Spontaneous dislocation of the sterno-clavicular joint. Acta Orthop Scand 1979;50:269-74.
38. Sewell MD, Al-Hadithy N, Le Leu A, Lambert SM. Instability of the sternoclavicular joint: current concepts in classification, treatment and outcomes. Bone Joint J 2013;95-B:721-31. http://dx.doi.org/10.1302/0301-620X.95B6.31064
39. Singer G, Ferlic P, Kraus T, Eberl R. Reconstruction of the sternoclavicular joint in active patients with the figure-of-eight technique using hamstrings. J Shoulder Elbow Surg 2013;22:64-9. http://dx.doi.org/10.1016/j.jse.2012.02.009
40. Spencer EE Jr, Kuhn JE. Biomechanical analysis of reconstructions for sternoclavicular joint instability. J Bone Joint Surg Am 2004;86-A:98-105.
41. Spencer EE, Kuhn JE, Huston LJ, Carpenter JE, Hughes RE. Ligamentous restraints to anterior and posterior translation of the sternoclavicular joint. J Shoulder Elbow Surg 2002;11:43-7. http://dx.doi.org/10.1067/mse.2002.119394
42. Thomas DP, Williams PR, Hoddinott HC. A “safe” surgical technique for stabilisation of the sternoclavicular joint: a cadaveric and clinical study. Ann R Coll Surg Engl 2000;82:432-5.
43. Thut D, Hergan D, Dukas A, Day M, Sherman OH. Sternoclavicular joint reconstruction—a systematic review. Bull NYU Hosp Jt Dis 2011;69:128-35.
44. Wada S, Noguchi T, Hashimoto T, Uchida Y, Kawahara K. Successful treatment of a patient with penetrating injury of the esophagus and brachiocephalic artery due to migration of Kirschner wires. Ann Thorac Cardiovasc Surg 2005;11:313-5.
45. Wirth MA, Rockwood CA Jr. Acute and chronic traumatic injuries of the sternoclavicular joint. J Am Acad Orthop Surg 1996;4:268-78.
46. Zhang C, Lin L, Liang J, Wang B, Chen G, Chen H. Efficacy analysis of a novel sternoclavicular hook plate for treatment of unstable sternoclavicular joint dislocation or fracture. J Orthop Surg (Hong Kong) 2017;25:2309499016684488. http://dx.doi.org/10.1177/2309499016684488