

1 **Acromioclavicular Joint Augmentation at the Time of Coracoclavicular Ligament**
2 **Reconstruction Fails to Improve Functional Outcomes Despite Significantly Improved**
3 **Horizontal Stability**

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5

6 **Abstract**

7 Purpose

8 Acromioclavicular joint reconstruction is a well-established and frequently performed
9 procedure. Recent scientific and commercial interest has led to a drive to develop and
10 perform surgical techniques that more reliably restore horizontal stability in order to improve
11 patient outcomes. The aim of this systematic review was to evaluate the biomechanical
12 evidence for procedures directed at restoring horizontal stability and determine whether they
13 are associated with superior clinical results when compared to well-established procedures.

14 Methods

15 A review of the online databases Medline and EMBASE was conducted in accordance with
16 the PRISMA guidelines on the 23rd December 2017. Biomechanical and clinical studies
17 reporting either static or dynamic horizontal displacement following acromioclavicular joint
18 reconstruction (Coracoclavicular reconstruction or Weaver-Dunn) were included. In addition,
19 biomechanical and clinical studies reporting outcomes after additional augmentation of the
20 acromioclavicular joint were included. The studies were appraised using the Methodological
21 index for non-randomised studies tool.

22 Results

23 The search strategy identified 18 studies eligible for inclusion; six biomechanical and 12
24 clinical studies. Comparative biomechanical studies demonstrated that acromioclavicular
25 augmentation provided significantly increased horizontal stability compared to the
26 coracoclavicular reconstruction and Weaver Dunn procedure. Comparative clinical studies
27 demonstrated no significant differences between coracoclavicular reconstruction with and
28 without acromioclavicular augmentation in terms of functional outcomes (American Shoulder
29 and Elbow Surgeon and Constant score), complication or revision rates. However, one
30 comparative study did demonstrate an improvement in Taft ($p=0.018$) and Acromioclavicular
31 Joint Instability scores ($p=0.0001$) after acromioclavicular augmentation.

32 Conclusion

33 In conclusion, coracoclavicular reconstruction with augmentation of the acromioclavicular
34 joint has been shown to provide improved horizontal stability in both biomechanical and
35 clinical studies compared to isolated coracoclavicular reconstruction. However, comparative
36 studies have shown no clinical advantage with respect to American Shoulder and Elbow
37 Surgeon or Constant scores and therefore the results of this systematic review do not support
38 acromioclavicular augmentation in routine clinical practice.

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41 **This systematic review provides level IV evidence**

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43 **Key Terms:**

44 Acromioclavicular joint dislocation

45 Acromioclavicular stabilisation

46 Horizontal stability

47 Coracoclavicular ligament

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61 **Introduction**

62 Acromioclavicular (AC) joint reconstruction is a well-established and frequently performed
63 procedure for high Rockwood grade injuries [28] (IV and above) and those with grade III
64 injuries that fail non-operative treatment. The aim of surgical treatment is to reduce and fix
65 the AC joint, and repair or reconstruct the coracoclavicular (CC) ligaments. The most
66 frequently performed procedures are the modified Weaver Dunn procedure and anatomic
67 reconstruction of the CC ligaments, which can include a single or double bundle repair
68 technique, using an autograft, allograft or synthetic ligament.

69 The wide range of surgical procedures reported for the management of AC joint dislocations
70 reflects that each is associated with limitations and that none have been demonstrated to be
71 superior to the others with respect to clinical outcomes [22, 23]. An emerging concept in the
72 quest for improved results is to address not only vertical instability but also persistent
73 horizontal AC joint instability. Several authors have reported that persistent horizontal
74 instability after surgical reconstruction is associated with inferior outcomes; Minkus et al.
75 demonstrated that dynamic posterior translation was significantly correlated to clinical
76 instability scores [25] whereas Blazar et al. [6] demonstrated that the amount of
77 anteroposterior translation was correlated to increasing pain after AC joint excision. Previous
78 biomechanical studies have suggested that CC ligament reconstruction alone may not provide
79 sufficient horizontal stability [3, 9, 31, 32].

80 Several studies have shown the importance of the capsule of the AC joint for horizontal
81 stability even in the presence of intact CC ligaments [9, 11, 17, 20]. The superior and
82 posterior acromioclavicular ligaments are the major structures responsible for limiting the
83 posterior translation of the distal clavicle, whereas the inferior AC ligament is the main
84 structure limiting anterior translation [4, 17, 20]. Techniques that augment or reconstruct the

85 AC ligaments have been developed. Recent scientific and commercial interest has led to a
86 trend towards some surgeons performing AC augmentation procedures in addition to CC
87 ligament repair or reconstruction. However, the effectiveness of these procedures at restoring
88 horizontal instability and improving clinical results has yet to be proven. A systematic review
89 of the literature is indicated to both guide clinical practice and future research. The aim of
90 this study is to review the literature to evaluate the strength of evidence from biomechanical
91 and clinical studies that investigate the effectiveness of AC ligament augmentation at the time
92 of AC joint stabilisation.

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94 **Materials and Methods**

95 A systematic review of the literature was conducted in accordance with the PRISMA guidelines
96 using the online databases Medline and EMBASE. The review was registered on the
97 PROSPERO database on 8th January 2018 (Reference number CRD42018084923). The
98 searches were performed independently by two authors on the 23rd of December 2017 and
99 repeated on the 5th of January 2018 to ensure accuracy. Any discrepancies were resolved
100 through discussion between these two authors, with the senior author resolving any residual
101 differences. The Medline search strategy is illustrated in Appendix 1.

102 Biomechanical and clinical studies published in English were considered for eligibility.
103 Biomechanical studies must have reported either static or dynamic horizontal displacement
104 following surgical reconstructions that included the Weaver Dunn procedure, CC ligament
105 reconstruction and AC augmentation. Clinical studies could be either cases series or
106 comparative studies and were required to have reported a minimum follow-up of 12 months.
107 Studies reporting results after either CC ligament reconstruction or the Weaver Dunn procedure

108 must have specifically recorded static or dynamic horizontal instability or a specific instability
109 score, Acromioclavicular joint instability (ACJI) or Taft Scores. In addition, any studies
110 reporting surgical intervention for AC joint instability which included augmentation of the AC
111 joint were included. Only primary research was considered for review with any abstracts,
112 comments, review articles and technique articles excluded. The clinical studies were appraised
113 independently by two authors using the Methodological index for non-randomised studies
114 (MINORS) tool [35].

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117 **Results**

118 The search strategy identified 18 studies eligible for inclusion [1, 2, 7, 8, 10, 12, 13, 15, 16, 19,
119 21, 24, 31, 34, 37, 40, 42, 43]. Six biomechanical studies [2, 10, 13, 24, 31, 43]; two reporting
120 on horizontal stability following CC ligament reconstruction (n=24) and four after AC ligament
121 reconstruction (n=117). The remaining 12 studies were clinical [1, 7, 8, 12, 15, 16, 19, 21, 34,
122 37, 40, 42]; six reporting horizontal stability after CC ligament reconstruction (n=138), five
123 after AC ligament augmentation (n=147) and the final study reporting results after a
124 combination of AC joint reconstruction procedures (n=116). A flow chart of the search strategy
125 is shown in Figure 1. Concise details of the biomechanical studies are given in Table 1 and the
126 clinical studies in Tables 2 to 4.

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128 **Biomechanical Studies**

129 Four of the biomechanical studies compared horizontal stability after different reconstructive
130 procedures of the AC joint. Gonzalez-Lomas et al. [13] and Saier et al. [31] compared CC

131 ligament reconstruction alone against CC ligament reconstruction with AC augmentation.
132 Gonzalez-Lomas et al. [13] performed a single tunnel CC ligament reconstruction and free
133 intramedullary graft for AC augmentation which was secured by suture buttons. Translational
134 loads of 10N and then 15N were applied with 3 different compression loads (10N, 20N and
135 30N) across the AC joint. The authors reported that the mean anterior-posterior translation after
136 additional AC augmentation was 50% or less than that of CC ligament reconstruction in all
137 loading conditions ($p<0.05$) although no difference in vertical translation was demonstrated.
138 Whereas Saier et al. [31] compared a double tunnel CC ligament reconstruction using the
139 TightRope device (Arthrex) against additional AC augmentation with FiberTape (Arthrex).
140 Cadaveric samples underwent 5000 cycles of anteroposterior directed 70N load and
141 displacement pre and post loading was recorded. The authors demonstrated that only
142 reconstruction of both CC and AC ligaments gave comparable horizontal translation to the
143 native joint.

144 Michlitsch et al. [24] compared the stability of the AC joint after CC ligament reconstruction
145 with AC augmentation using a free tendon graft against the Weaver Dunn procedure.
146 Translational loads of 10N and then 15N were applied in 4 directions (anterior, posterior,
147 superior and inferior) with 3 different compression loads (10N, 20N and 30N) applied across
148 the AC joint. The study demonstrated that CC ligament and AC augmentation had significantly
149 lower horizontal and vertical translation ($p<0.001$) compared to the Weaver Dunn procedure.

150 Beitzel et al. [2] used cadaveric specimens to analyse if horizontal stability was improved
151 following single or double tunnel CC ligament reconstruction when compared to the Modified
152 Weaver Dunn procedure. After reconstruction, specimens were preconditioned from 0 to 25N
153 for 10 cycles in each direction and then tested to 70N in three directions (anterior, posterior
154 and superior). The authors report that both single and double tunnel CC ligament reconstruction
155 provided significantly higher horizontal stability with less anterior and posterior translation

156 (p=0.005) than the Weaver Dunn procedure. Comparisons between the two techniques for CC
157 ligament reconstruction revealed no significant difference in horizontal stability.

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159 **Clinical Studies**

160 **Horizontal Instability**

161 Tauber et al. performed a prospective cohort study (Level of evidence 2) of chronic AC joint
162 injuries (grade III and above) treated at two centres with either single bundle CC ligament
163 reconstruction or triple bundle technique, which involved reconstruction of both CC
164 ligaments individually as well as AC augmentation. The authors measured static horizontal
165 stability at follow up on the axillary view and reported it as stable, subluxated, or dislocated if
166 the lateral clavicle showed anteroposterior translation compared with the uninjured side of
167 less than 50%, between 50% and 100%, and more than 100%, respectively. The study
168 demonstrated that horizontal stability was significantly higher (p =0.011) after the triple
169 bundle technique (75% stable) compared to the single bundle CC ligament reconstruction
170 (29% stable) [42].

171 Comparison of CC ligament reconstruction to the Weaver Dunn procedure showed a higher
172 rate of persistent posterior subluxation after the Weaver Dunn procedure (8.3% versus 0%) at
173 a mean 37 months follow up, although this did not reach statistical significance [40]. Studies
174 reporting on horizontal instability after double tunnel CC ligament reconstruction
175 demonstrated this was present in between 0% and 53% of cases [1, 7, 8, 19]. The range of
176 horizontal instability after CC ligament reconstruction with AC augmentation ranged from
177 5.8% to 13% [15, 16].

178 **Functional Outcomes**

179 Five studies reported either the Constant or American Shoulder and Elbow Surgeons (ASES)
180 scores following CC ligament reconstruction using a double tunnel technique [7, 8, 12, 19,
181 34], see Table 2. The Constant score was reported in all five studies with the mean values
182 ranging from 90.2 to 95.5. Glanzmann et al. demonstrated that 95% of patients returned to
183 sporting activities [12]. Tauber et al. [40] compared a Modified Weaver Dunn and double
184 tunnel CC ligament reconstruction using autogenous semitendinosus graft. At a mean 37
185 months follow up the functional scores after double tunnel CC ligament reconstruction were
186 significantly better than after the modified Weaver Dunn procedure ($p < 0.001$); ASES 96
187 versus 74 and Constant score 93 versus 81.

188 Four studies reported either the Constant or ASES score following CC ligament
189 reconstruction using a double tunnel technique with AC augmentation [15, 16, 21, 37]. The
190 Constant score was reported in all four studies with the mean values ranging from 84 to 92.4.
191 Tauber et al. prospectively compared single bundle CC ligament reconstruction against triple
192 bundle reconstruction that included AC augmentation. At two years there was no significant
193 difference in functional scores; Constant Score 88.8 versus 82.6 and ASES 95.3 versus 88
194 [42].

195 Five clinical studies reported specific instability functional scores for the AC joint, see Table
196 2. These were the Taft score [38] and the Acromioclavicular Joint Instability Score (ACJI
197 score) [32]. The Taft score was first described in 1987 and measures three criteria each with a
198 maximum score of 4 (maximum 12): 1) Subjective rating of pain and stiffness 2) Objective
199 rating of abduction strength and range of motion 3) Radiological outcome. In addition, 1
200 point was subtracted from the objective rating for joint tenderness, crepitus or a poor
201 cosmetic appearance. The ACJI score (maximum, 100 points) was described in 2011 by

202 Scheibel et al. and evaluates 5 items: 1) Pain (20 points) 2) Activities of Daily Living (10
203 points) 3) Cosmesis (10 points) 4) Function (25 points) 5) Radiological Assessment (35
204 points). It is important to note that neither the Taft or ACJI score have been validated in the
205 assessment of AC joint instability.

206 Tauber et al. demonstrated that triple tunnel reconstruction (combined CC ligament
207 reconstruction and AC augmentation) was associated with a significantly improved Taft score
208 (10.9 versus 9, $p=0.018$) and ACJI score (84.7 versus 58.4, $p=0.0001$) when compared to
209 single bundle CC ligament reconstruction [42]. Two case series reported instability scores
210 after double tunnel CC ligament reconstruction; ACJI score 75.9-87.3 and Taft score 10.5 [7,
211 19] which were comparable to the two case series that reported instability scores after double
212 tunnel CC ligament reconstruction with AC augmentation; ACJI score 87 and Taft score 9 to
213 11 [15, 16].

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216 **Complications and Revision Surgery**

217 The complication rate was reported in 9 of the 12 studies, including in all the comparative
218 studies (Table 4). 4 of the 12 studies failed to report the rate of revision [8, 37, 40, 42] which
219 included two comparative studies (Table 4) [40, 42]. The mean follow-up ranged from 12 to
220 37 months with 9 studies having a mean follow up of over two years.

221 The comparative study conducted by Tauber et al. [42], demonstrated that AC augmentation
222 using a triple bundle technique was associated with a lower complication rate (16.7% versus
223 35.7%) than single bundle repair. The triple bundle repair group had a lower rate of vertical

224 redislocation (8.3% vs 21.4%) and persistent hypesthesia (8.3% vs 14.3%). Tauber et al. [40]
225 demonstrated an equal complication rate between the Weaver Dunn procedure and double
226 tunnel reconstructions (8.3% in both groups). Case series reporting the outcome of double
227 tunnel CC ligament reconstruction reported a complication rate ranging from 2.5% to 70.7%
228 and revision rate from 3% and 15.8% [7, 12, 19, 34]. Case series reporting CC ligament
229 reconstruction with AC augmentation reported a complication rate ranging of 18.75% and
230 revision rate from 11.6% and 12.5% [15, 16, 21]. The most common reasons for
231 complications including the need for revision surgery, were implant related irritation,
232 infection, stiffness and loss of reduction. None of the authors reported complications
233 specifically attributable to the additional AC joint augmentation procedures.

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236 **Discussion**

237 The most important finding of the present study was that additional AC augmentation failed
238 to improve functional outcomes, as determined by the ASES and Constant scores, when
239 compared to CC ligament reconstruction alone, despite biomechanical studies reporting
240 improved horizontal stability. The included biomechanical studies clearly demonstrate that
241 CC ligament reconstruction with additional AC augmentation is associated with a statistically
242 significant improvement in horizontal stability when compared to CC ligament reconstruction
243 alone [13, 31]. Tauber et al. [42] also demonstrated in their clinical study that 75% of cases
244 repaired using the triple bundle techniques (including AC augmentation) were horizontally
245 stable compared to 29% in the single bundled repair group.

246 Clinical studies have shown CC ligament reconstruction, whether it is performed in
247 conjunction with augmentation of the AC joint or not, is associated with good functional
248 scores. The only comparative study included in this review, from Tauber et al. demonstrated
249 no statistically significant difference in Constant and ASES scores between the techniques
250 [42] but it should be noted that these functional scores have not been validated for
251 acromioclavicular joint instability and therefore may not be sensitive enough to capture any
252 clinical differences. In contrast, Tauber et al. did report an improvement in specific ACJ
253 instability scores after combined CC ligament reconstruction and AC augmentation [42] but it
254 is imperative to understand the limitations of these findings. Although the Taft [38] and ACJI
255 scores [32] have been designed to measure AC joint instability, neither has been validated for
256 this purpose. Furthermore it should be highlighted that even if a statistically significant
257 difference is demonstrated, the lack of validation, specifically the failure to establish a
258 threshold of minimal clinically important difference, limits the clinical relevance of the
259 findings related to the Taft and ACJI scores. Additionally, it should be noted that the study
260 from Tauber et al, included only 26 patients, a sample size calculation was not performed,
261 and the allocation of patients to each type of procedure was not stated thus raising concerns
262 about potential selection bias. In view of these weaknesses in study design and reporting, the
263 strength of evidence and clinical relevance of the reported improvement in the Taft and ACJI
264 scores must be considered to be very low.

265 The clinical studies failed to demonstrate a clear difference in complication or revision rate
266 between those undergoing CC ligament reconstructions and those having additional AC
267 augmentation but lack of explicit reporting, small overall numbers and short term follow up
268 limit the confidence in this specific evaluation. One of the main concerns of drilling
269 additional tunnels or placing implants within the acromion is fracture. This was not reported
270 in any of the studies, and may not have occurred, but it is important to highlight that future

271 studies should explicitly report acromial fracture and any other procedure specific
272 complications. Revision rates reported in the case series of the two techniques, 3% to 15.8%
273 after double tunnel CC ligament reconstruction [7, 12, 19, 34] and 11.6% to 12.5% after CC
274 ligament reconstruction with AC augmentation [15, 16, 21], were comparable to a recent
275 systematic review of various AC joint stabilisation procedures; suspensory device 6.2%, free
276 tendon graft 10.3% and modified Weaver Dunn procedures 12.5% [26].

277 Appraisal of the non-randomised clinical studies using the Methodological index for non-
278 randomised studies (MINORS) tool [35] demonstrated a variety of limitations which are
279 summarised in Table 5. Common limitations included the lack of a control group and low
280 patient numbers in the majority of the studies. Variation in inclusion criteria (acute, chronic
281 or revision surgery), surgical technique (Weaver Dunn, single tunnel, double tunnel, triple
282 tunnel CC ligament reconstruction and intramedullary augmentation), open or arthroscopic
283 procedures, choice of outcome measurements and threshold for reporting
284 complications/revision were present in most studies.

285 A further limitation of this systematic review is the confounding effect of the broad spectrum
286 of Rockwood grades of AC joint instability included. Of the clinical studies, six included
287 patients with Grades III to V injuries, three included only grade V injuries and the remaining
288 three studies included either Grade III and IV, Grade III and V or Grade IV and V injuries.
289 Previous work by Tauber et al. has demonstrated that the incidence of horizontal instability
290 varies between injury grade, being 57.1%, 80% and 100% in Grades II, III and V respectively
291 [42]. Only two studies commented on the effect of the Rockwood grading on functional
292 outcome [1, 40] and none of the included studies reported on correlation between grading and
293 the residual horizontal instability. Therefore future research needs to more clearly define the
294 type of instability being studied and correlate different types of instability with outcomes.

295 The findings of this review are directly applicable to the recent trend towards performing AC
296 augmentation procedures in addition to CC ligament reconstruction in an attempt to improve
297 functional outcomes. The main clinical relevance of this study is that a lack of significant
298 improvement in ASES and Constant scores is demonstrated. This should prompt a cautious
299 approach to adding AC augmentation procedures to CC ligament reconstruction.

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303 **Conclusion**

304 CC ligament reconstruction with augmentation of the AC joint has been shown to provide
305 improved horizontal stability in both biomechanical and clinical studies compared to isolated
306 CC reconstruction. However, comparative studies have shown no clinical advantage with
307 respect to ASES or Constant scores and therefore the results of this SR do not support AC
308 augmentation in routine clinical practice.

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472 **Figure 1: Flow diagram of review process**

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474 **Table 1 – Summary of Biomechanical studies**

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476 **Table 2 – Summary of clinical studies and functional outcomes**

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478 **Table 3 – Radiological outcomes in clinical studies**

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480 **Table 4 – Complications in clinical studies**

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482 **Table 5: Methodological items for non-randomised studies (MINORS) Scores for**
483 **clinical studies**

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485 **Appendix 1: Search strategy for Medline**

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