



Original article

Anatomical study of the position and orientation of the coracoclavicular ligaments: Differences in bone tunnel position by gender



Terufumi Shibata^{a,*}, Teruaki Izaki^a, Satoshi Miyake^a, Nobunao Doi^a, Yozo Shibata^b, Yutaka Irie^c, Katsuro Tachibana^c, Takuaki Yamamoto^a

^a Department of Orthopaedic Surgery, Fukuoka University Faculty of Medicine, 7-45-1 Nanakuma, Jonan-ku, Fukuoka 814-0180, Japan

^b Department of Orthopaedic Surgery, Fukuoka University Chikushi Hospital, 1-1-1 Zokumyoin, Chikushino, Fukuoka 818-8502, Japan

^c Department of Anatomy, Fukuoka University Faculty of Medicine, 7-45-1 Nanakuma, Jonan-ku, Fukuoka 814-0180, Japan

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ABSTRACT

Background: Reconstructing both coracoclavicular ligaments following acromioclavicular dislocation has recently been reported to restore the function of the acromioclavicular joint better than traditional procedures. Knowing the appropriate position and orientation of the bone tunnels and the potential risks of neurovascular injuries leads to safe reconstruction. We aimed to answer the following questions: what is the difference in the accurate clavicular bone tunnel positions (BTPs) during coracoclavicular ligament reconstruction between sex, and what are the potential risks for neurovascular injuries?

Hypothesis: The BTPs differ by sex at the site of coracoclavicular ligament reconstruction.

Patients and methods: We introduced two Kirschner wires into 25 cadaver shoulders (17 male, 8 female), one through the insertion center of the trapezoid ligament and one through the conoid ligament, and measured the distance from the respective Kirschner wire insertion points to the bony landmarks of the clavicle and the oblique angle of each Kirschner wire. The shortest distance from the insertion point of each Kirschner wire to the suprascapular nerve and artery was also measured.

Results: While the distance from the acromioclavicular joint to the respective Kirschner wire insertion points tended to be longer in males, the ratio of these insertion points to total clavicle length was constant. Other measurements for respective Kirschner wire insertions to the bony landmarks and neurovascular structures were comparable, as were abduction and retroversion angles. The distance from the suprascapular nerve to the insertion point of the conoid ligament at the coracoid process was 13.8 ± 4.0 mm, while the distance from the suprascapular artery was 7.1 ± 3.3 mm.

Discussion: Appropriate position and orientation of the bone tunnels, and the ratio of the BTPs to the total clavicular length, aid surgeons in performing the reconstruction. The conoid ligament insertion on the coracoid was just proximal to the suprascapular artery, so surgeons should be careful with conoid insertion.

Level of evidence: V, cadaver study.

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1. Introduction

Reconstruction of the coracoclavicular ligaments as separate anatomical structures has been investigated to correct acromioclavicular dislocation because of their distinct function. The conoid ligament is responsible for the restraint against anterior and

superior loading, whereas the trapezoid ligament provides resistance to posterior loading [1]. Two-bundle stabilization of the acromioclavicular joint is biomechanically superior and better restores joint function compared with single-bundle stabilization [2–4]. Inappropriate tunnel positioning in both the clavicle and coracoid process increases fracture risk [5]. Therefore, correct tunnel position and orientation is important to obtain better clinical results. Several authors reported that a malpositioned insertion point during bone tunnel drilling increases the risk of damaging the suprascapular nerve and artery around the coracoid process; [6,7]

* Corresponding author.

E-mail address: teru-sky-ideal@lion.ocn.ne.jp (T. Shibata).

however, the distance from the exit point has not been investigated. Because the suprascapular artery and nerve pass just medial to the coracoid process, the exit point of the drill on the coracoid process is crucial.

Zhu et al. [8] studied the location and orientation of the coracoclavicular ligaments by drilling through the center of the trapezoid and the conoid tuberosities. Although these tuberosities are bony landmarks that are easily verified, the center of each tuberosity does not necessarily match the center of the coracoclavicular ligament attachment. The trapezoid ligament's attachment extends medial to this tuberosity [9]. The center of the conoid ligament is not also located on the most prominent aspect of the conoid tuberosity, and the conoid tuberosity is broad and the exact center is not always distinct [10]. Therefore, additional data on the bone tunnel position (BTP) and orientation that passes through the insertion center of these ligaments are needed. The differences between sex in the coracoclavicular ligament attachment on the clavicular undersurface have been previously reported [10,11]. Thus, a difference in the BTP on the clavicular surface between sex has been suspected. However, Zhu et al. [8] did not report the sex of the cadavers. For these reasons, a more accurate position and orientation of the coracoclavicular ligament is needed.

The purpose of this study was to answer the following questions:

- what is the difference in the accurate clavicular BTPs for coracoclavicular ligament reconstruction between sex?;
- what are the potential risks of neurovascular injuries during coracoclavicular ligament reconstruction?

We hypothesized that accurate BTPs for anatomical reconstruction of the acromioclavicular joint differ by sex.

2. Patients and methods

2.1. Specimen demographics

This study included 25 shoulders from 17 male and 8 female cadavers donated to our institution. We obtained a single shoulder from each cadaver, and the remainder of each body was used for medical education. This study was approved by our Institutional Review Board. Donors were preserved in formalin-based dilution, and none of the cadavers had obvious congenital abnormalities, findings of trauma, or previous surgery to the shoulder.

2.2. Specimen preparation

To expose the lateral clavicle, coracoid process, and coracoclavicular ligament, we carefully removed all periscapular and clavicular muscles. To disconnect the glenohumeral joint, we resected the rotator cuff and capsule at the proximal humerus.

Before each specimen was disarticulated at the scapulothoracic joint, the proximal clavicle and scapular spine were fixed using a metal plate and screws to maintain the position between the clavicle and the coracoid process. The screws did not damage the area of interest. After dissection, the scapula was fixed using a bench vise, which we mounted on a freestanding camera platform so that the specimen's alignment could be freely changed. We positioned the scapular body vertically and the upper surface of the clavicle

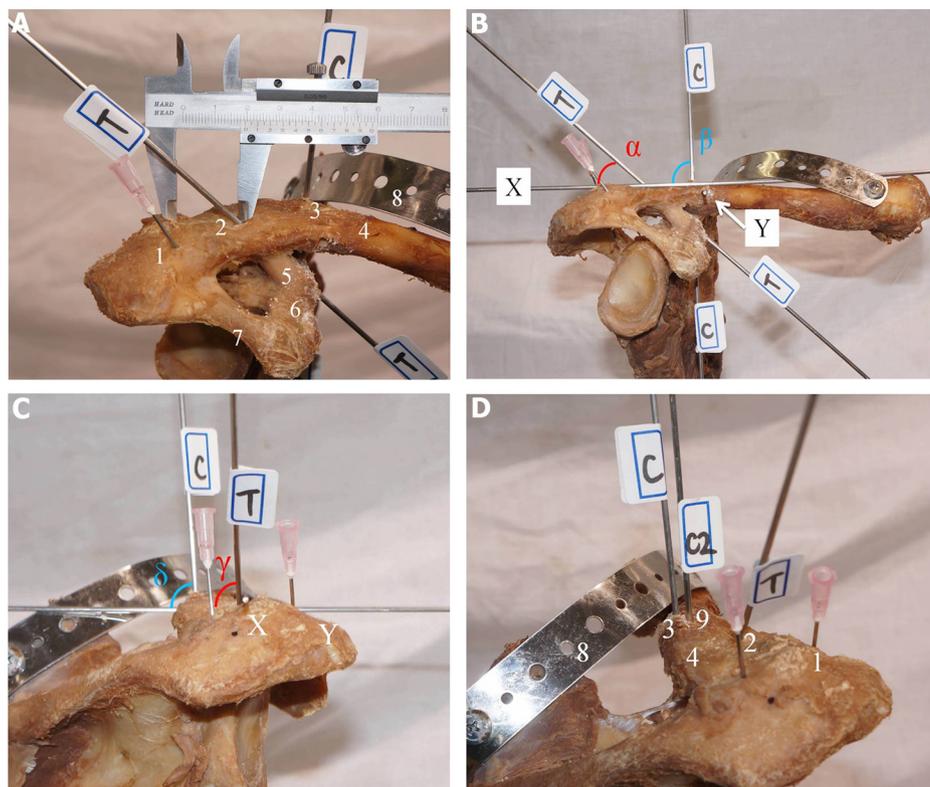


Fig. 1. A. Distance from the lateral edge of the clavicle to the K-wire insertion in the trapezoid ligament. An 18-G needle is placed within the acromioclavicular joint to mark the lateral edge of the clavicle. 1. Lateral edge of the clavicle; 2. Insertion point of the K-wire in the trapezoid ligament; 3. Insertion point of the K-wire in the conoid ligament; 4. Clavicle; 5. Trapezoid ligament; 6. Coracoid process; 7. Coracoacromial ligament; 8. Metal plate fixing the proximal clavicle and the scapular spine; T: K-wire drilled through the trapezoid ligament; C: K-wire drilled through the conoid ligament. B. Coronal view of the right shoulder. X: horizontal baseline; reference K-wire set along the longitudinal axis of the clavicle passing the anteroposterior midpoint of the distal and proximal clavicle; Y: reference K-wire drilled from the anterior aspect of the clavicle to the posterior aspect, perpendicular to wire-X; α : abduction angle between wire-X and -T; β : abduction angle between wire-X and -C. C. Lateral view of the right shoulder. γ : retroversion angle between wire-Y and -T; δ : retroversion angle between wire-Y and -C. D. C2: second conoid K-wire inserted at the midpoint of the anteroposterior diameter of the clavicle on a line perpendicular to reference wire-X and parallel to wire-C; 9: insertion point of the second conoid K-wire.

horizontally. Therefore, we were able to observe the orientation of the coracoclavicular ligament from all directions, which allowed us to drill through the insertion center of the coracoclavicular ligaments (conoid and trapezoid) along the directions of these ligaments.

These ligamentous attachments were observed under the clavicle, and one 2-mm Kirchner wire (K-wire) was introduced through the insertion center of the trapezoid (wire-T) and another through the conoid ligament (wire-C) directed as accurately as possible to the coracoid origins of the coracoclavicular ligaments, along their trajectory. We then measured the distance from the respective K-wire insertion point to the lateral edge and anterior or posterior border of the distal clavicle (Fig. 1A).

Both K-wires were evaluated for abduction and retroversion angles. To set the horizontal baseline, we placed a 2-mm K-wire on the longitudinal axis of the clavicle, which passed the anteroposterior midpoint of the distal and proximal clavicles as reference K-wire X. To set the anteroposterior baseline, another 2-mm K-wire was drilled in the anteroposterior direction horizontally and perpendicular to K-wire X as reference K-wire Y (horizontal baseline). A digital camera was then placed at the same height as the clavicle so that each reference K-wire (X, Y) was seen as a dot on the coronal or sagittal view of the scapula, and photographs of the shoulder were taken in both planes (Fig. 1B and C). Using the photographs, we measured the oblique angle of wire-T or wire-C to the reference K-wire (X or Y) using Image J image analyzing software (National Institutes of Health, Bethesda, MD, USA).

Blowout of the posterior wall of the medial clavicular tunnel leads to a loss of reduction, as the clavicular attachment area of the conoid ligament was located around the conoid tubercle posteriorly [12]. Lower bone density and the thinnest dorsal cortex in the lateral clavicle also contributes to blowout [13]. To place the bone tunnel at a more robust position, we drilled another 2-mm K-wire (C2 conoid K-wire, wire-C2) at the midpoint of the anteroposterior diameter of the clavicle perpendicular to reference wire-X, which was inserted parallel to wire-C (Fig. 1D). We performed the same measurements for wire-C2 as wire-C.

Next, we measured the location of each K-wire penetrating the medial cortex of the coracoid process (Fig. 2A). The proximal parts of the suprascapular artery and nerve were resected when dissecting the scapula from the trunk, so the shortest distance from each K-wire insertion point to the suprascapular artery and nerve was measured at the superior transverse ligament level.

The footprints of the insertion areas for each coracoclavicular ligament attached to the coracoid were clearly marked circumferentially with India ink after each ligament was incised, leaving a short stump. Because the clavicle was an obstruction to the following measurements, the clavicle was removed. The closest distance from the respective K-wire insertion point on the superior surface of the coracoid process to the suprascapular artery and nerve was then measured (Fig. 2B). Finally, we completely removed the ligament stump and confirmed K-wire placement near the center of the coracoclavicular ligament insertion on the clavicular undersurface and the coracoid surface.

2.3. Measuring the distances

All geometric measurements were recorded with calipers accurate to 0.1 mm, and the photographs were taken at the same time to confirm the tip of the caliper fit the measurement points accurately. Measurements were performed by a single investigator. We then calculated the ratio of the distance between the lateral edge of the clavicle and the K-wire insertion point in the trapezoid and the conoid divided by the clavicular length.

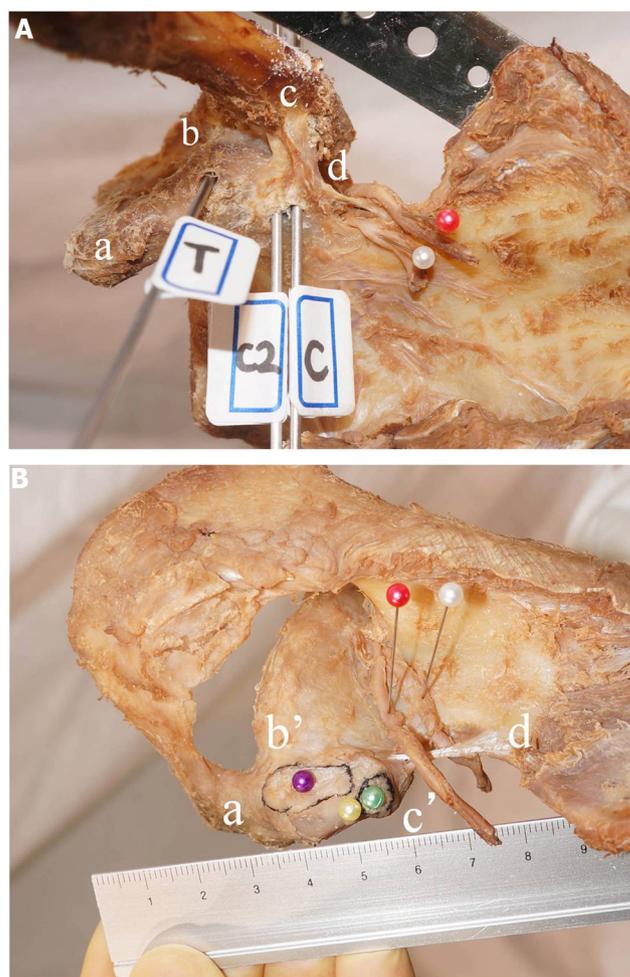


Fig. 2. A. Anteroinferior view of the right shoulder. a: coracoid process; b: trapezoid ligament; c: conoid ligament; d: superior transverse ligament of the scapula; white mark: suprascapular nerve; red mark: suprascapular artery; T: K-wire drilled through the trapezoid ligament; C: K-wire drilled through the conoid ligament; C2: K-wire drilled parallel to wire-C. B. Superior view of the right shoulder. b': attachment of the trapezoid ligament; c': attachment of the conoid ligament; purple mark: insertion point of the K-wire passing through the trapezoid ligament; green mark: insertion point of the K-wire passing through the conoid ligament; yellow mark: insertion point of the second conoid K-wire.

2.4. Statistical analysis

Statistical analyses were performed using IBM SPSS, version 21 (IBM, Armonk, NY, USA). Data are presented as means \pm standard deviations (range). We used a paired *t*-test for normally distributed data or the Mann–Whitney U test for non-normally distributed data to compare sex differences. We also investigated whether the distance from the acromioclavicular joint to the respective K-wire insertion point and the clavicular length correlated with height. Pearson's correlation was performed to evaluate the strength of the relationship between corresponding variables. $p < 0.05$ was considered statistically significant.

3. Results

The cadaver demographic characteristics and the measurements of each K-wire at the clavicular surface appear in Table 1. We found significant differences between male and female height, total clavicular length, and distance from the lateral edge of the clavicle to the K-wire insertion in the conoid ligament. The distance from the lateral edge of the clavicle to the wire-T and wire-C2 insertion

Table 1
Cadaver demographic characteristics and measurements of the insertion points and oblique angles of each K-wire at the clavicular surface.

Characteristic, mean ± SD (range)	Male (n = 17)	Female (n = 8)	p-value
Age, years ^a	73.9 ± 13.2 (52–99)	79.5 ± 9.6 (63–91)	0.30
Height, cm ^a	163.5 ± 8.2 (150–174)	154.3 ± 6.0 (146–164)	0.009
Clavicular length, mm ^a	164.8 ± 10.6 (146–182)	147.8 ± 11.1 (137–165)	0.001
Lateral edge to wire-T insertion, mm ^a	21.6 ± 4.4 (15.7–32.3)	18.2 ± 4.5 (10.6–24.4)	0.08
Anterior border to wire-T insertion, mm ^a	9.0 ± 2.1 (5.0–12.9)	8.8 ± 1.7 (6.4–11.0)	0.86
Lateral edge to wire-C insertion, mm ^a	39.9 ± 3.7 (32.7–47.3)	34.8 ± 5.8 (26.8–40.5)	0.044
Posterior border to wire-C insertion, mm ^a	6.3 ± 1.8 (3.6–9.0)	5.4 ± 0.78 (4.6–6.8)	0.12
Lateral edge to trapezoid/clavicle length ^a	0.132 ± 0.027 (0.090–0.19)	0.122 ± 0.027 (0.077–0.16)	0.41
Lateral edge to conoid/clavicle length ^a	0.243 ± 0.025 (0.19–0.28)	0.234 ± 0.026 (0.19–0.27)	0.43
Lateral edge to wire-C2 insertion, mm ^a	37.7 ± 4.1 (30.2–46.2)	33.9 ± 5.7 (25.6–40.5)	0.066
Posterior border to wire-C2 insertion, mm ^b	10.3 ± 1.7 (6.6–12.3)	9.6 ± 1.7 (7.3–12.8)	0.26
Oblique angle of each K-wire			
(α) Abduction angle, trapezoid (°) ^a	51.3 ± 6.7 (41.2–64.8)	47.7 ± 5.7 (40.0–57.8)	0.20
(β) Abduction angle, conoid (°) ^a	88.2 ± 3.0 (83.8–96.3)	88.2 ± 7.6 (79.2–103.1)	0.99
(γ) Retroversion angle, trapezoid (°) ^b	88.6 ± 10.0 (76.8–116.2)	92.5 ± 6.1 (84.1–102.3)	0.14
(δ) Retroversion angle, conoid (°) ^b	82.1 ± 7.3 (72.1–103.1)	81.7 ± 1.7 (78.4–83.4)	0.67

Wire-T: K-wire drilled through the trapezoid ligament; wire-C: K-wire drilled through the conoid ligament; wire-C2: K-wire drilled parallel to wire-C; SD: standard deviation.

^a Paired *t*-test.

^b Mann–Whitney U test.

Table 2
Correlation coefficients of the corresponding variables.

	Correlation coefficient	p-value
Height and clavicular length ^a	0.52	0.008
Clavicular length and Lateral edge to wire-T insertion ^a	0.43	0.034
Clavicular length and Lateral edge to wire-C insertion ^a	0.60	0.002

^a Pearson's correlation.

points tended to be longer in males. The distance from the posterior border of the clavicle to the wire-C2 insertion was longer than that of wire-C ($p < 0.001$). Other measurements for respective K-wire insertion points to the clavicular bony landmarks were comparable between sex, as were abduction and retroversion angles. We found high positive correlations between clavicular length and cadaver height, and for the distance from the lateral edge to each K-wire insertion (Table 2).

Measurements including the location of each K-wire exit point on the coracoid process are shown in Table 3. We found significant differences between sex for total coracoid length and the distance from the coracoid tip to the respective K-wire exit point. The shortest distances from respective K-wire exit points to the suprascapular nerve at the superior transverse ligament were smaller than those to the suprascapular artery.

Geometrical parameters including the location of respective K-wire insertion points at the coracoid surface side are summarized in Table 4. No injury to neurovascular structures by the K-wires was observed, but the wire-C insertion point was extremely close to the suprascapular artery.

4. Discussion

Our main finding was that the distance from the acromioclavicular joint to the coracoclavicular ligament insertion tended to be longer in males. We also found high positive correlations between clavicular length and cadaver height, and for the distance from the acromioclavicular joint to the K-wire insertion points of the trapezoid or conoid ligaments. Because males were generally taller than females in our study, clavicular length and the length from the

Table 3
Locations of each K-wire penetrating the medial cortex of the coracoid process and their relationships to the suprascapular nerve and artery.

Characteristic, mean ± SD (range)	Male (n = 17)	Female (n = 8)	p-value
Coracoid length, mm ^a	43.7 ± 4.0 (32.8–49.8)	39.0 ± 2.6 (35.8–43.0)	0.006
Coracoid tip to wire-T exit point, mm ^a	28.0 ± 3.6 (22.5–33.2)	24.5 ± 2.3 (20.3–27.8)	0.021
Coracoid surface to wire-T exit point, mm ^a	9.8 ± 2.6 (5.0–14.1)	8.5 ± 2.6 (5.3–14.0)	0.27
Coracoid tip to wire-C exit point, mm ^a	36.7 ± 3.7 (29.0–43.8)	32.9 ± 3.3 (27.1–37.1)	0.019
Coracoid surface to wire-C exit point, mm ^a	14.7 ± 4.2 (5.3–21.3)	14.2 ± 4.9 (6.1–21.4)	0.79
Coracoid tip to wire-C2 exit point, mm ^a	31.6 ± 4.6 (22.6–40.1)	27.2 ± 4.0 (22.8–33.8)	0.030
Coracoid surface to wire-C2 exit point, mm ^a	14.3 ± 3.4 (5.3–20.9)	13.1 ± 4.7 (5.4–19.2)	0.47
Wire-T exit point to wire-C exit point, mm ^a	11.1 ± 2.9 (4.5–15.0)	11.2 ± 4.2 (5.6–19.6)	0.95
Wire-T exit point to wire-C2 exit point, mm ^a	7.5 ± 2.8 (2.4–11.9)	7.9 ± 3.6 (4.0–14.4)	0.79
Each K-wire exit point distance to neurovascular structures			
Wire-T exit point to suprascapular nerve, mm ^b	21.5 ± 6.5 (7.0–28.6)	20.8 ± 4.6 (11.8–26.7)	0.51
Wire-T exit point to suprascapular artery, mm ^b	24.0 ± 5.6 (10.0–30.8)	22.6 ± 3.2 (15.8–24.9)	0.26
Wire-C exit point to suprascapular nerve, mm ^a	12.4 ± 3.1 (8.0–18.3)	11.2 ± 4.5 (6.2–17.1)	0.43
Wire-C exit point to suprascapular artery, mm ^a	15.7 ± 2.6 (11.3–21.3)	14.8 ± 4.0 (8.1–21.0)	0.52
Wire-C2 exit point to suprascapular nerve, mm ^a	17.4 ± 4.0 (11.2–25.0)	16.5 ± 3.6 (9.6–22.2)	0.59
Wire-C2 exit point to suprascapular artery, mm ^a	20.1 ± 4.1 (13.8–29.7)	19.0 ± 3.7 (12.0–24.8)	0.52

Wire-T: K-wire drilled through the trapezoid ligament; wire-C: K-wire drilled through the conoid ligament; wire-C2: K-wire drilled parallel to wire-C; SD: standard deviation.

^a Paired *t*-test.

^b Mann–Whitney U test.

Table 4

Location of respective K-wire insertion points and the shortest distance from each K-wire to the neurovascular structures on the coracoid surface.

Characteristic, mean \pm SD (range)	Male (n = 17)	Female (n = 8)	p-value
Wire-T insertion to suprascapular nerve, mm ^a	23.7 \pm 3.7 (17.7–31.2)	21.5 \pm 5.4 (14.0–29.4)	0.24
Wire-T insertion to suprascapular artery, mm ^a	17.1 \pm 3.0 (12.4–21.5)	15.9 \pm 3.5 (12.2–20.3)	0.41
Wire-C insertion to suprascapular nerve, mm ^b	14.3 \pm 3.4 (6.4–19.0)	12.7 \pm 5.2 (8.0–20.9)	0.29
Wire-C insertion to suprascapular artery, mm ^a	7.3 \pm 3.1 (2.1–13.6)	6.5 \pm 3.8 (2.7–12.2)	0.59
Wire-C2 insertion to suprascapular nerve, mm ^a	18.1 \pm 3.2 (12.5–24.3)	17.3 \pm 4.4 (10.3–22.8)	0.61
Wire-C2 insertion to suprascapular artery, mm ^a	11.6 \pm 3.0 (6.2–17.2)	12.2 \pm 3.7 (7.2–16.1)	0.70
Wire-T insertion to wire-C insertion, mm ^a	10.9 \pm 1.7 (8.0–14.5)	10.8 \pm 2.3 (7.6–13.6)	0.93
Wire-T insertion to wire-C2 insertion, mm ^a	6.5 \pm 2.0 (3.0–10.0)	6.6 \pm 2.4 (3.8–11.0)	0.90

Wire-T: K-wire drilled through the trapezoid ligament; wire-C: K-wire drilled through the conoid ligament; wire-C2: K-wire drilled parallel to wire-C; SD: standard deviation.

^a Paired *t*-test.^b Mann–Whitney U test.

acromioclavicular joint to the K-wire insertion point were proportionally longer than for females.

Although the length from the acromioclavicular joint to the respective K-wire insertion points was longer in males, the ratio of these insertion points to total clavicle length was constant between sex. The BTP measurements required to reconstruct the coracoclavicular ligaments are uncomplicated at one-eighth of the clavicular length for the trapezoid ligament and one-quarter of the clavicular length for the conoid ligament regardless of sex. Several clinical studies [4,12] adopted the constant distance from the acromioclavicular joint to the respective BTP. The BTP was altered by the total clavicular length, and the ratio of the BTP to the total clavicular length in our study can aid the surgeons in performing the reconstruction.

Cook et al. [14] reported the ratio of the distance from the acromioclavicular joint to the center of the trapezoid or the conoid tunnel divided by the total clavicular length was significantly higher in surgical failures than for nonfailures. Eisenstein et al. [15] also suggested excessive lateralization smaller than 0.20 for the conoid tunnel ratio and 0.13 for the trapezoid increased the risk of clavicular fracture. They recommended a conoid tunnel ratio of 0.20–0.25 and a trapezoid tunnel ratio <0.16. Their ratios were based on clinical results, and the ratios that they advocated almost equaled the ratios we obtained from our detailed anatomical analyses. When trapezoid and conoid ratios are too small or too large, optimal clinical results are not obtained; therefore, correct BTP for the coracoclavicular ligament is crucial.

Some reports investigated the risk of neurovascular injuries during coracoclavicular reconstruction [6,7]. However, their measurement points at the coracoid process were not the origin of the coracoclavicular ligament. Our study demonstrated that the wire-C insertion point was just proximal to the suprascapular artery. In contrast, at the exit point of the anteromedial portion of the coracoid process, the relationship between each K-wire and the suprascapular nerve or artery was reversed. Because the suprascapular nerve runs below the superior transverse ligament, and the suprascapular artery passes superior to it [16], the height of respective K-wire exit points tended to be lower than for the superior transverse scapular ligament (Fig. 2A).

Placing the conoid tunnel further posteriorly on the clavicle results in an increased risk of breaching the posterior cortex [12]. Preparation for conoid tunnel placement at the midpoint of the anteroposterior distal clavicle where bone failure is least likely could reduce the risk of fracture. Because of the anterior insertion of wire-C2 at the clavicular surface, the mean distance from the wire-C2 exit or insertion point to the suprascapular artery and nerve was longer than from wire-C.

Several limitations of our study must be considered. First, our sample size was small because of the limited number of cadavers in our institution. Because the distance from the wire-T insertion point to the acromioclavicular joint was small, our sample size

might be too small to detect a significant difference between sex. Second, K-wire insertion in the coracoclavicular ligament was near center but not exactly center, which might influence our results. Third, creating the second conoid bone tunnel at the center of the clavicular anteroposterior diameter did not match the anatomical path of the conoid ligament. Fourth, we evaluated intact acromioclavicular joints. We must reduce the dislocated acromioclavicular joint prior to bone tunnel creation to use our data in surgical practice. Drilling the bone tunnels based on our data in patients with insufficient or excessive reduction of the acromioclavicular dislocation may compromise results.

5. Conclusion

The distance from the acromioclavicular joint to the coracoclavicular ligament insertion tended to be longer in males. The appropriate position and orientation of the bone tunnels, and the ratio of the BTPs to the total clavicular length, aid surgeons in performing the reconstruction. The conoid ligament insertion to the coracoid was just proximal to the suprascapular artery, so surgeons should be careful with conoid insertion.

Disclosure of interest

The authors declare that they have no competing interest.

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Author contributions

Terufumi Shibata, Teruaki Izaki, Yozo Shibata: conception and design, data collection, manuscript preparation.

Satoshi Miyake, Yutaka Irie: conception and data collection.

Nobunao Doi: conception and design.

Katsuro Tachibana, Takuaki Yamamoto: study supervision.

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