

Clinical and Radiological Assessment of Modified Weaver-Dunn Technology, Arthroscopic Single Tunnel Technique and Arthroscopic Coracoid Sling Technique Three Different Surgical Techniques in the Treatment of Acute Rockwood III-V Acromioclavicular Dislocations

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Objective: The purpose of this study was to evaluate and compare the clinical efficacy and radiological results of three surgical methods for treating Rockwood III–V acromioclavicular dislocation.

Methods: A retrospective analysis was conducted on 62 patients with acute Rockwood III–V acromioclavicular dislocation who were admitted to our hospital from September 2017 to December 2022. Among these patients, 19 received the modified Weaver-Dunn technique (Group A), 20 underwent the arthroscopic single tunnel technique (Group B), and 23 received the arthroscopic coracoid sling technique (Group C). The clinical outcomes assessed included perioperative indicators, shoulder joint function outcomes, VAS scores, acromioclavicular joint redislocation rates, and complications. The radiological results primarily focused on the changes in the distance between the beak and the clavicle (CCD).

Results: All patients were followed for an average duration of 32.72 ± 7.93 months. At the final follow-up, the shoulder joint function scores, pain scores, and imaging findings of all three patient groups exhibited significant improvements compared to their preoperative values. Three months post-surgery, a comparative analysis among the three groups revealed that Groups B and C demonstrated significantly superior shoulder joint function scores and pain relief in comparison to Group A ($p < 0.05$). Regarding complications, all three groups experienced various postoperative complications; however, no significant differences were found in the incidence of complications among the groups ($p > 0.05$).

Conclusion: Three surgical methods have demonstrated favorable and comparable clinical and imaging outcomes in the treatment of acute acromioclavicular dislocation. Compared to the modified Weaver-Dunn technique, coracoid process single tunnel fixation and coracoid process non-tunnel suspension fixation may be more effective and provide a higher level of mobility.

Keywords: acromioclavicular dislocation, beak process single tunnel technology, beak process without tunnel suspension technology, coracoclavicular ligament

Introduction

Dislocation of the acromioclavicular (AC) joint is often caused by the shoulder touching the ground or being impacted by external forces when the upper limb is in an adduction state, resulting in the rupture of the AC ligament, coracoid (CC)

ligament, and triangular thoracic fascia, leading to dislocation. It is a complex and severe scapular injury that can cause sustained pain and functional impairment of the acromioclavicular joint.¹ This disease is common in young and active people. The incidence rate of this disease in the general population is the annual incidence is 3–4/100,000, with males predominating; these injuries comprise 9–12% of all shoulder trauma.^{2,3} The horizontal stability of the normal acromioclavicular joint is maintained by the acromioclavicular joint capsule and the acromioclavicular ligament,^{4–6} whereas the vertical stability is maintained by the coracoclavicular ligament complex,⁷ which consists of two parts: the trapezoid ligament and the conoid ligament. The trapezoid ligament mainly resists forward and upwards forces, whereas the conoid ligament mainly resists forces in the horizontal anterior posterior direction. In addition, they provide rotational stability and stability for scapular extension and retraction, making the acromioclavicular ligament and coracoid ligament important structures for maintaining the static stability of the acromioclavicular joint. In addition, studies have shown that during the movement of the clavicle and scapula, the deltoid and trapezius muscles provide dynamic stability for maintaining the micromotion state of the acromioclavicular joint.^{8,9}

Acromioclavicular (AC) dislocation can be classified into acute and chronic types based on the time of injury. Currently, dislocations occurring within three weeks post-trauma are categorized as acute, while those persisting beyond this period are considered chronic.¹⁰ Evidence from clinical studies supports the initiation of early intervention following AC dislocation, emphasizing that non-surgical management should ideally be implemented within the first three weeks after injury. Conservative treatment involving continuous immobilization using shoulder and elbow slings, adhesive taping, or plaster casts may yield satisfactory outcomes in terms of joint reduction and functional recovery for Rockwood type I–II injuries. While surgical intervention is generally accepted as the preferred approach for Rockwood type IV–VI dislocations,^{11,12} the optimal management strategy for Rockwood type III injuries remains a subject of ongoing debate.^{13,14} In clinical practice, surgical treatment may be indicated for Rockwood type III AC dislocations in patients with high physical demands, failure of conservative therapy, significant displacement, or persistent pain.¹⁵

To date, over one hundred surgical techniques have been documented in the literature for the treatment of symptomatic acromioclavicular dislocation. Traditional approaches include fixation using Kirschner wires and hook plates, with the clavicle hook plate being the most commonly utilized method due to its reported favorable clinical outcomes. However, while these procedures can restore joint mobility, they fail to achieve anatomical reconstruction, often leading to complications such as subacromial bone resorption, concomitant proximal clavicle fractures, and implant failure.^{16–18} With advancements in arthroscopic techniques and graft materials, the use of arthroscopic looped suspensory devices for coracoclavicular ligament reconstruction has gained increasing popularity in recent years. This method enables anatomical restoration of acromioclavicular joint stability, offering advantages including minimal soft tissue trauma, reduced intraoperative blood loss, and accelerated functional recovery of the shoulder joint. Despite the variety of available surgical interventions, a consensus on the optimal approach for treating acromioclavicular dislocation remains elusive. Therefore, this study retrospectively analyzed three widely adopted surgical techniques that have been successfully applied in our institution. The objective was to compare the efficacy of these three methods in treating acute Rockwood type III–V acromioclavicular dislocations, evaluate their clinical and radiological outcomes over a minimum follow-up period of two years, and provide evidence-based guidance for surgical decision-making.

Method

General Information of Patients

Sixty-two patients with acromioclavicular dislocation who met the inclusion criteria and were admitted to our hospital from September 2017 to December 2022 were selected from our medical records database. The inclusion criteria were as follows: (1) diagnosed with acromioclavicular dislocation through imaging examination and Rockwood classification as III–V; (2) previous good shoulder joint function; and (3) provided informed consent for this study, good compliance, and active cooperation with follow-up requirements. The exclusion criteria were as follows: (1) previous shoulder joint dysfunction; (2) open injuries combined with nerve damage; (3) immature bone development or osteoporosis; and (4) other diseases that affect postoperative efficacy evaluation. All patients underwent preoperative examinations, including bilateral shoulder joint X-ray, CT+3D reconstruction of the affected shoulder joint, and shoulder joint MRI. The surgeries included the use of

improved Weaver-Dunn technology, arthroscopic single tunnel technique and Arthroscopic coracoid sling technique. The reconstruction materials for both the arthroscopic single tunnel technique and Arthroscopic coracoid sling technique group were all tight rope titanium plates with loops (Arthrex, Inc). The groups included the modified Weaver-Dunn technology group (19 patients in Group A), arthroscopic single tunnel technique group (20 patients in Group B), and the Arthroscopic coracoid sling technique (23 patients in Group C). There were 15 males and 4 females in the modified Weaver-Dunn technology group. Rockwood classification was as follows: 12 cases were type III, 4 cases were type IV, and 3 cases were type V. Fifteen males and 5 females in the arthroscopic single tunnel technique. The Rockwood classification was as follows: 11 cases were type III, 5 cases were type IV, and 4 cases were type V. There were 17 males and 6 females in the group Arthroscopic coracoid sling technique. The Rockwood classification was as follows: 14 cases of type III, 4 cases of type IV, and 5 cases of type V. This study was approved by the Ethics Committee of the Sixth Affiliated Hospital of Xinjiang Medical University. All patients included in this study provided informed consent in writing for the procedure and study. All methods were carried out in accordance with relevant guidelines and regulations.

Operative Methods

Modified Weaver-Dunn Technology

After successful general anaesthesia, the patient was placed in the beach chair position. The head should be raised and fixed appropriately (the tension of the neck should be adjusted to avoid damage to the brachial plexus), disinfected, a cloth should be laid, and surface markers such as the acromioclavicular joint and clavicle should be marked with a marker pen. A 7–10 cm incision was made at the center of the dislocation, the skin was separated layer by layer, the acromioclavicular joint, distal clavicle, and acromion were fully exposed, the damaged joint disc and hematoma inside the joint were removed, the distal clavicle was separated, the coracoid shoulder ligament along the acromion to the coracoid process was peeled off, small bone blocks attached to the coracoid shoulder ligament acromion were chisel out, the blocks were opened with ultrastrong thread for later use, the bone grooves on the acromioclavicular joint surface of the distal clavicle were drilled, Kirschner wires were used to drill holes on the inside and outside of the bone grooves, and the small bone blocks connected to the coracoid shoulder ligament were perfectly embedded into the bone groove of the distal clavicle. The acromioclavicular joint was temporarily repositioned via a Kirschner wire, a suitable clavicular hook steel plate was selected, and the plate was bent moderately. The plate hook from under the periosteum was inserted into the lower back of the acromion, the steel plate above the clavicle was placed, and good adhesion was ensured. Cooking forceps were used to maintain the reduction, 4 screws were screwed for fixation, and then the high-strength wire was tied for fixation. After removing the Kirschner wire, the stability of the reduction was good under the C-arm X-ray device, and the patient's locked joint movement was good. The joint capsule was sutured, the incision was closed layer by layer, the dressing was completed, and the surgery was ended. (Figure 1 shows a Modified Weaver Dunn technique surgical procedure and results).

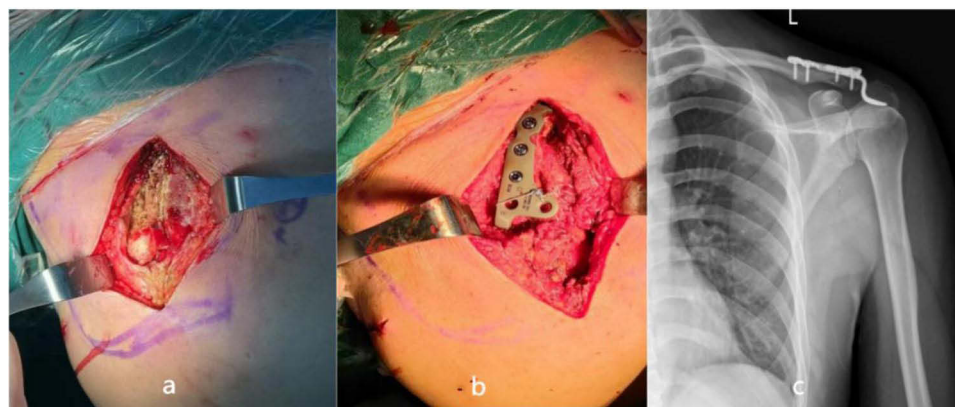


Figure 1 Modified Weaver Dunn technique surgical procedure and results. (a) ACJ exposure; (b) After the small bone block of the coracoid ligament is perfectly embedded, the clavicle hook plate is implanted; (c) The postoperative X-ray in Figure 1c shows good reduction of ACJ.

Arthroscopic Single Tunnel Technique

After successful general anaesthesia, the patient was placed in the beach chair position. The head should be raised and fixed appropriately (the tension of the neck should be adjusted to avoid damage to the brachial plexus), disinfected, a cloth should be laid, and surface markers such as the coracoid process, acromioclavicular joint, and scapula should be marked with a marker pen. First, 2 cm below the posterior angle of the acromion and 1 cm inside is taken as the observation channel to enter the arthroscope, the shoulder joint cavity is entered, and the anterior inferior approach is established through the skin and touches below the tip of the coracoid process in the gap between the long head of the bicipital tendon and the subscapular muscle. A puncture needle was used to locate the anterior superior approach 1 cm inside and 2 cm above the tip of the coracoid process. Electrocautery and planning were used to clean the synovial tissue around the coracoid process and expose the base of the coracoid process. The arthroscopic lens was placed into the anterior inferior approach as the observation channel, and then the positioning sight was placed into the midpoint of the base of the coracoid process through the posterior anterior superior approach. Then, a guide pin was drilled through the attachment of the conical ligament and oblique ligament of the clavicle. After satisfactory inspection of the guide pin position under fluoroscopy, a 4.5 mm hollow drill bit was used to drill holes in the clavicle and coracoid process to establish a tunnel. The traction wire was placed into the tunnel and removed from the joint cavity. The wire is then introduced into the TightRope loop steel plate and fixed on the lower surface of the coracoid process with a flip loop. The adjustable wire of the loop steel plate on the surface of the clavicle was tightened and knotted for fixation. For some patients with poor stability of the acromioclavicular joint, the TightRope tail line is threaded through the acromioclavicular joint and knotted for fixation to restore horizontal stability between the acromioclavicular joints. Under fluoroscopy, the alignment of the clavicle and acromion is good, and the stability of the acromioclavicular joint is good. The incision was closed, and the surgery was completed. (Figure 2 shows a typical case).

Arthroscopic Coracoid Sling Technique

After successful general anaesthesia, the patient was placed in the beach chair position. The head should be raised and fixed appropriately (the tension of the neck should be adjusted to avoid damage to the brachial plexus), disinfected, a cloth should be laid, and surface markers such as the coracoid process, acromioclavicular joint, and scapula should be marked with a marker pen. First, 2 cm below the posterior angle of the acromion and 1 cm inside is taken as the observation channel to enter the arthroscope, the acromioclavicular joint cavity is entered, and an anterior inferior approach channel is established through skin indication and touching of the coracoid process tip in the gap between the long head of the bicipital tendon and the subscapularis muscle. Electrocautery and planning were used to clean the synovial tissue around the coracoid process and expose the base of the coracoid process. A puncture needle was inserted 3 cm below the anterior angle of the acromion to establish a channel on the coracoid process below the acromion. After arthroscopy, the surface of the coracoid process is gradually exposed. The surface of the coracoid process is cleaned with an electric burner to avoid damaging nerves and blood vessels. The pectoralis minor muscle, trapezius ligament, cone-shaped ligament, and coracoid shoulder ligament were identified. Two 1–1.5 cm incisions are made at the distal end of the clavicle, and the guide needle is positioned at the

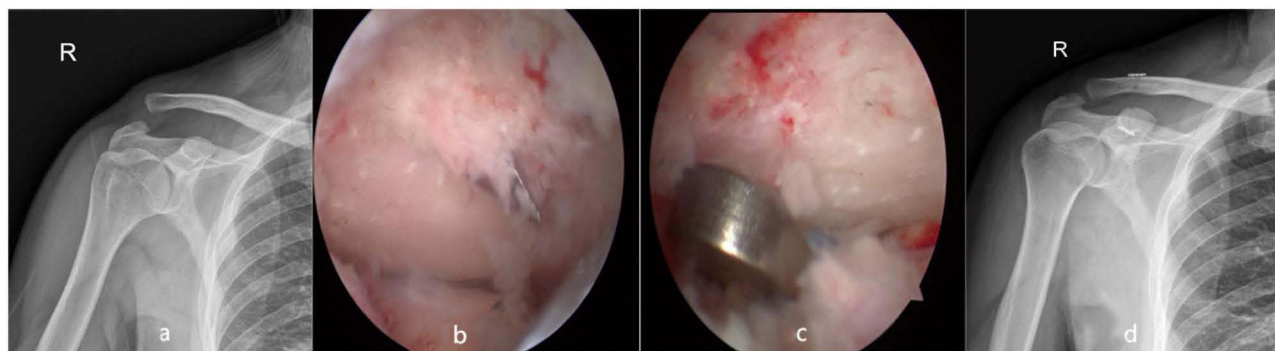


Figure 2 Arthroscopic single-tunnel technique. (a) Preoperative acromioclavicular dislocation. (b) Arthroscopic coracoid process drilling for tunnel extraction. (c) shows a titanium plate suspended at the base of the coracoid process observed under arthroscopy. (d) Postoperative X-ray image showing good reduction of the acromioclavicular joint.

tunnel position of the clavicle. A 4.5 mm hollow drill is then used to drill two clavicle tunnels. The traction line PDS2 is introduced from the clavicle tunnel, and the traction line PDS2 is wound around the coracoid process at the coracoid locking ligament and pulled out from the clavicle tunnel. Then, the TightRope loop steel plate is pulled out of the clavicle. The loop line of the htRope steel plate is located at the position of the coracoid process. For some patients with poor stability of the acromioclavicular joint, the TightRope tail line is threaded through the acromioclavicular joint and knotted for fixation to restore horizontal stability between the acromioclavicular joints. The TightRope strap steel plate was tightened on the clavicle surface to reduce the acromioclavicular joint, the satisfactory alignment of the clavicle and acromion was observed under fluoroscopy, the stability of the acromioclavicular joint was checked, the incision was closed, and the surgery was ended. (Figure 3 shows a typical case).

Postoperative Treatment

We recommend that patients who undergo clavicle hook plate combined with coracoid ligament transposition undergo routine removal of the hook plate 4–8 months after surgery to avoid potential complications such as acromion irritation or rotator cuff impingement. Three groups of patients received postoperative limb suspension and fixation protection for 4 weeks. On the second day after surgery, they actively engaged in active functional exercise of the elbow and wrist joints. Four to six weeks after surgery, they received guidance from a rehabilitation therapist for active shoulder joint movement and resistance training. Strength training began 8 weeks after surgery, and the patients gradually recovered their daily living ability within 12 weeks. Within 6 months after surgery, heavy objects and other strenuous activities that may cause significant downwards traction of the affected limb or arm are prohibited.

Clinical and Imaging Evaluation

Basic information, including age, sex, Rockwood classification, and follow-up time, was collected for the included patients. Perioperative indicators, including surgical time and surgical incision length, were recorded. Shoulder joint function was evaluated via the Constant–Murley (CMS) score, American Shoulder and Elbow Surgeons (ASES) score, and Visual Analog Scale (VAS) pain scores (VAS; 0: painless; 10: most severe pain). The CMS score is a 100-point scale consisting of four parameters: pain (0–15 points), activity level (0–20 points), range of motion (0–40 points), and strength (0–25 points). The ASES score is mainly based on patients' subjective ratings, including pain (50%) and life function (50%), with a maximum score of 100 points. The higher the score is, the better the recovery of shoulder joint function. The imaging evaluation involved X-ray plain films before surgery, 3 months after surgery, and at the final follow-up. The images were analysed to measure the coracoclavicular distance (CCD), which is the height between the subclavian edge and the upper edge of the coracoid process. The observed complications mainly included subacromial bone resorption, acromioclavicular arthritis, postoperative incision infection, and redislocation.

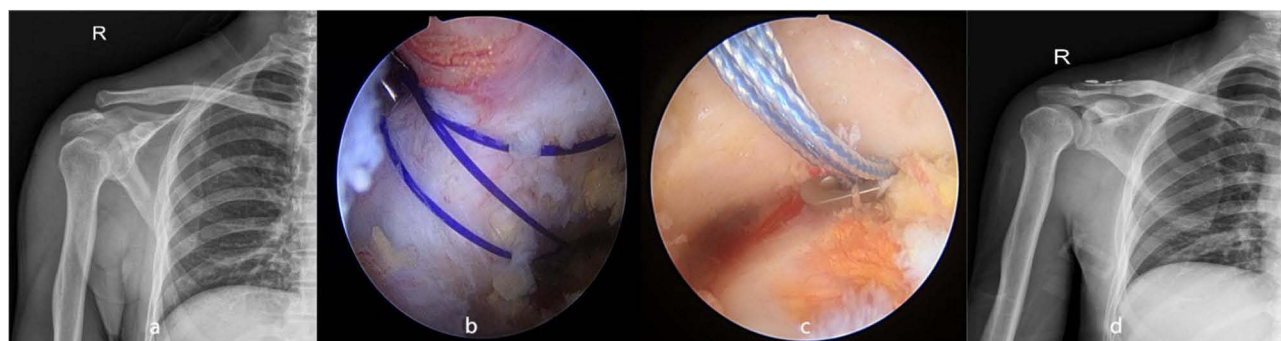


Figure 3 Nontunnel suspensory technique. (a) Preoperative dislocation of the acromioclavicular joint. (b) shows the traction line PDS2 wrapped around the coracoid process under arthroscopy. (c) shows a titanium plate with a loop wrapped around the base of the coracoid process observed under arthroscopy. (d) Postoperative X-ray image showing good reduction of the acromioclavicular joint.

Statistical Analysis

The data were analysed via IBM SPSS 26.0 (SPSS Inc.) software. The Shapiro–Wilk test was used to determine the normality of each variable, the Levene test was used to evaluate the homogeneity of variance, Use Mann Whitney *U*-test to compare non normal distribution measurement data. One-way analysis of variance was used for comparisons among multiple groups and Fisher’s LSD test was used for further pairwise comparisons. Comparisons between binary and multiclass unordered variables are made via the chi square test. The data of continuous variables are represented as mean and standard deviation or median and range, while the data of categorical variables are represented as numbers and percentages. $P < 0.05$ was considered to indicate a significant difference. Patient selection process diagram is shown in Figure 4

Results

Baseline Characteristics of Patients

The characteristics of the three groups of patients are shown in Table 1. This study presents the clinical outcomes of 62 patients with acute Rockwood III–V clavicle dislocation treated with three different surgical methods. There were no statistically significant differences between patient groups in terms of age, gender ratio, affected side, Rockwood classification, follow-up time, and injury mechanism ($p > 0.05$).

Perioperative Outcomes

The perioperative results of the three groups of patients are shown in Table 2. The average surgical time (min) of Groups A and C was significantly shorter than that of Group B ($P < 0.05$). There was no significant difference between Groups A and C, and the difference was not statistically significant ($P > 0.05$). The incision length in Group A was significantly greater than that in Groups B and C, and the difference was statistically significant ($P < 0.05$). There was no significant difference in the incision length between B and C ($P > 0.05$).

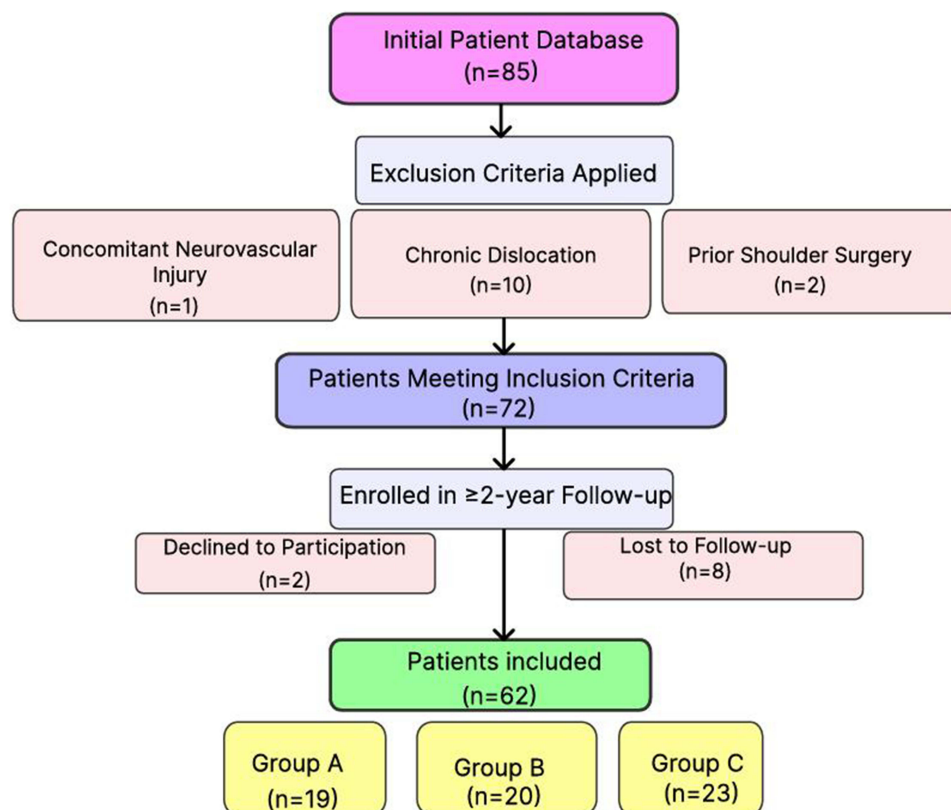


Figure 4 Patient selection flowchart.

Table 1 Demographic Characteristics of Patients

Variable	Group A(n=19)	Group B(n=20)	Group C(n=23)	Statistical Value	P value
Age (years)	44.84±8.95	40.80±10.98	44.04±8.08	F=1.04	0.36
Gender				$\chi^2=0.15$	0.93
Male (%)	15(78.95%)	15(75%)	17(73.91%)		
Female (%)	4(21.05%)	5(25%)	6(26.09%)		
Affected side				$\chi^2=1.17$	0.56
Left side (%)	7(36.84%)	6(30%)	5(21.74%)		
Right side (%)	12(63.16%)	14(70%)	18(78.26%)		
Follow-up (month)	32.47±8.36	33.70±9.23	32.07±7.93	F=0.23	0.79
Rockwood classification				$\chi^2=0.61$	0.96
Type III (%)	12(63.16%)	11(75%)	14(60.87%)		
Type IV (%)	4(21.05%)	5(25%)	4(7.391%)		
Type V (%)	3(15.789%)	4(20%)	5(21.74%)		
Injury mechanism				$\chi^2=4.61$	0.33
Traffic collision	3(15.79%)	3(15%)	2(8.7%)		
Falling (from heights and stairs)	14(73.68%)	15(75%)	20(86.96%)		
Sports	2(10.53%)	2(10%)	1(4.34%)		

Table 2 Comparison of Perioperative Outcomes Between the Three Groups

Variable	Group A	Group B	Group C	Statistical Value	p value
Surgical duration (minutes)	71.00±10.89	82.30±8.02	72.39±8.35	F=9.20	<0.001 <0.001 ^a 0.624 ^b 0.001 ^c
Surgical incision length (cm)	7.77±1.06	4.16±0.82	4.30±0.69	F=111.42	<0.001 <0.001 ^a <0.001 ^b 0.57 ^c

Notes: ^aComparative results between Groups A and B. ^bComparative results between Groups A and C. ^cComparative results between Groups B and C.

Three Sets of Shoulder Joint Function Scores

All patients were followed up for 24–50 months, with an average follow-up of 32.72 ± 7.93 months. The shoulder joint Constant, VAS, and ASES scores of the three groups of patients at the final follow-up are shown in Table 3. At the last follow-up, the shoulder joint function scores (Constant Murley scale (ASES) scores) were significantly improved in the three groups compared with the preoperative values, and the difference was statistically significant ($P < 0.001$). Compared with the preoperative score, the VAS score was significantly lower at the last follow-up, and the difference was statistically significant ($P < 0.001$). There was no statistically significant difference in the VAS score, Constant-Murley score, or ASES score among the three groups of patients before surgery or at the last follow-up ($P > 0.05$), but there was a significant difference in the shoulder joint function score (Constant-Murley score or (ASES) score) among the three groups at the 3-month follow-up after surgery ($P < 0.001$). At the 3-month follow-up after surgery, the shoulder joint function scores (Constant Murley, scale (ASES) scores) of groups B and C were significantly greater than those of Group A ($P < 0.001$). B. The VAS scores of Group C were significantly lower than those of Group A ($P < 0.05$). There was no significant difference in shoulder joint function scores (Constant Murley scale (ASES) scores) or Visual Analog Scale (VAS) pain scores between groups B and C, and the difference was not statistically significant ($P > 0.05$).

Table 3 Comparison of the Shoulder Joint Function of the Three Fixation Techniques

Variable	Group A	Group B	Group C	Statistical Value	p value
CMS rating					
Preoperative	38.74±4.14	40.00±4.40	39.15±4.00	F=0.67	0.52
3 months after surgery	75.74±5.33	83.70±1.75	85.17±2.15	F=45.38	<0.001
					<0.001 ^b
					<0.001 ^c
					0.045 ^d
At the last follow-up visit	93.52±3.22	93.10±3.58	93.34±3.45	F=0.08	0.93
p value	P<0.001 ^a	P<0.001 ^a	P<0.001 ^a		
ASES rating					
Preoperative	39.28±3.37	38.52±3.22	39.59±3.38	F=0.58	0.56
3 months after surgery	78.23±4.53	86.10±4.69	85.29±4.52	H=15.64	<0.001
					<0.001 ^b
					<0.001 ^c
					0.57 ^d
At the last follow-up visit	91.93±3.83	93.51±3.74	92.47±3.84	F=3.97	0.03
p value	P<0.001 ^a	P<0.001 ^a	P<0.001 ^a		
VAS scores					
Preoperative	5.87±1.26	6.10±0.88	6.00±1.06	F=0.23	0.80
3 months after surgery	1.87±0.72	1.34±0.61	1.28±0.56	F=4.21	<0.05
					0.01 ^b
					0.004 ^c
					0.79 ^d
At the last follow-up visit	0.45±0.47	0.42±0.47	0.40±0.50	F=1.05	0.36
p value	P<0.001 ^a	P<0.001 ^a	P<0.001 ^a		

Notes: ^aComparison of preoperative and final follow-up. ^bComparative results between Groups A and B. ^cComparative results between Groups A and C. ^dComparative results between Groups B and C.

Imaging Results

Table 4 shows the radiological results from before to the final follow-up. There was no significant difference in the CCD among the three groups before surgery, 3 months after surgery, or at the last follow-up ($p>0.05$). However, the CCD significantly decreased from preoperatively to the last follow-up ($P<0.001$).

Complications

During the follow-up period of this study, the complications of the three surgical techniques are shown in Table 5. Group A experienced 3 cases of complications (15.79%), including 2 cases of subacromial bone resorption and 1 case of acromioclavicular arthritis. After physical therapy, the symptoms improved, and no patients experienced re dislocation. In Group B, there were 2 cases (10%) of complications: 1 patient experienced a coracoid process fracture during tunnel drilling during surgery, and 1 patient experienced redislocation 3 months after surgery. There were also 2 cases (8.70%) of complications in Group C, both of which involved redislocation within 3 months after surgery, and satisfactory results

Table 4 Comparison of Imaging CCD Results

Variable	Group A	Group B	Group C	Statistical Value	p value
Preoperative	19.85±2.89	19.31±3.44	18.05±3.10	F=1.84	0.29
3 months after surgery	7.13±0.88	7.10±1.01	7.06±0.88	F=0.03	0.97
At the last follow-up visit	7.98±0.84	8.00±0.98	7.68±0.73	F=0.94	0.40
p value	P<0.001 ^a	P<0.001 ^a	P<0.001 ^a		

Note: ^aComparison of preoperative and final follow-up.

Table 5 Complications of the Three Groups of Patients

Variable	Group A	Group B	Group C	Statistical Value	p value
Total complications	3 (15.79%)	2 (10%)	2 (8.70%)	$\chi^2=57$	0.75
Redislocation	–	1 (5%)	2 (8.70%)	–	n.s
Subacromial bone resorption	1 (5.26%)	–	–	–	n.s
Fracture (clavicle, coracoid process)	–	1 (5%)	–	–	n.s
Acromioclavicular arthritis	2 (10.53%)	–	–	–	0.13

Abbreviation: n.s., non significant.

were still achieved after revision via previous techniques. At the last follow-up, none of the three groups of patients experienced complications, such as redislocation or incision infection. [Figure 5](#) shows a case study of complications that occurred in this study. [Table 5](#) Complications of the three groups of patients.

Discussion

The traditional surgical method for treating acromioclavicular dislocation mainly involves internal fixation with a clavicular hook plate. This method uses the lever principle to reduce acromioclavicular dislocation vertically and horizontally and maintain the stability of the coracoclavicular space to promote scar healing of the coracoclavicular ligament. Owing to its advantages of simple surgical operation, allowing patients to perform early functional exercise of the shoulder joint to avoid muscle atrophy caused by long-term immobilization and limited shoulder joint movement caused by adhesions around the shoulder joint, it has been widely used in clinical practice. However, clinical and biomechanical studies have revealed that the incidence of complications and the risk of dislocation after removing the hook plate via this method are greater.^{16,17,19} Therefore, in our previous surgical approach, we used an modified Weaver-Dunn technology to avoid further dislocation after removing the steel plate. However, the insertion of the hook tip of the clavicular hook plate leads to narrowing of the subacromial gap, which may increase the occurrence of complications such as friction and impact between the rotator cuff and the hook tip.²⁰ Although we instructed all patients treated with internal fixation of the clavicular hook plate to remove the internal fixator within 4 to 8 months after surgery, one case of chronic shoulder joint pain with limited upper limb abduction activity and one case of subacromial impact combined with rotator cuff injury occurred during the follow-up after surgery with the clavicular hook plate combined with the coracoid ligament. After internal fixation was removed, the symptoms of these two patients improved significantly. The main reason for pain and subacromial impact was the stimulation of inflammatory substances generated by the continuous friction of the clavicular hook plate under the acromion, which persisted in these patients. There is a foreign body sensation and pain, which affects the range of motion of the shoulder joint. In addition, according to our follow-up results, the shoulder joint function score of the Improved Weaver-Dunn technology group was significantly lower than that of the other two groups at the third month after surgery,



Figure 5 Complications. (a and b) show X-ray images of the single tunnel of the clavicular coracoid process and the suspension around the coracoid process after surgery, revealing the reduction and loss of acromioclavicular joint dislocation. (c) shown in Under arthroscopy, a coracoid process fracture was observed during the middle of the tunnel.

indicating that early use of this surgical method may affect the shoulder joint function and activity of patients. However, at the final follow-up, all patients' shoulder joint function had recovered well, and there was no significant difference in shoulder joint function scores among the three groups of patients.

Biomechanical studies have shown that the use of clavicular hook plates to treat acromioclavicular dislocation results in nonanatomical reduction, which may lead to functional activity of the shoulder joint. With the development of loop steel plates and arthroscopy technology, various surgical techniques have been reported by scholars. Currently, the use of loop steel plates to assist in the treatment of acromioclavicular dislocation under shoulder arthroscopy is considered to be safer and more effective than traditional surgical methods.²¹ Arthroscopic single tunnel technique is widely promoted in clinical practice because it involves the use of loop titanium plates placed on the clavicle and coracoid process and achieves anatomical reconstruction through elastic fixation. This surgery requires the establishment of bone tunnels on the clavicle and coracoid process. Drilling holes on the clavicular coracoid process is a key step in this technique, as the structure of the CP is irregular and the cortex is relatively thin. Drilling bone tunnels on the clavicle or coracoid process may increase the risk of fractures. Gerhardt²² reported a study on a patient who underwent clavicle and coracoid process bone tunnel with loop steel plate treatment. During the 1-week follow-up after surgery, the patient developed a coracoid process fracture. In a study of 12 cadavers, Koh²³ et al simulated the placement of a tunnel via the clavicular coracoid bone drilling technique during surgery. In their study, they reported that drilling the bone tunnel through the clavicular coracoid bone resulted in cortical rupture on the inner side of the coracoid process in 6 out of 12 shoulder joints. In addition, in another study, Milewski et al²⁴ reported 10 patients with acromioclavicular dislocation treated with anatomical reconstruction of the coracoid process tunnel CC ligament. After surgery, 8 patients in the coracoid process tunnel group reported complications, including 2 cases of coracoid bone fractures. Similarly, in our study, one patient in arthroscopic single tunnel technique group experienced intraoperative coracoid process fracture. The reason was that the drill bit deviated from the center of the coracoid process during drilling, resulting in cortical fracture of the coracoid process. Although we did not find any cases of coracoid process or clavicle fractures in our postoperative follow-up study, we believe that the use of the a single tunnel technique group to drill bone tunnels through the clavicle coracoid process poses a great challenge for surgical operators, as it increases the risk of coracoid process fracture. In addition, some studies have shown that this surgical method can effectively restore vertical stability, but there may be shortcomings in restoring the horizontal stability of acromioclavicular joint dislocation.²⁵ Nevertheless, at our follow-up, all patients' postoperative acromioclavicular joint function returned to normal.

To reduce the risk of coracoid fracture caused by drilling a tunnel in the coracoid process, we used the arthroscopic coracoid sling technique. This surgical technique achieves anatomical reconstruction of the CC ligament by using a looped steel plate to wrap around the coracoid process and fix it on the clavicle tunnel. Compared with single tunnel technique, arthroscopic coracoid sling technique avoids the need to drill a bone tunnel on the coracoid process, greatly reducing tunnel-related complications. Moreover, for patients with severe acromioclavicular joints (type V), loop sutures are used to suture the joint capsule and AC ligament in an "8" shape during surgery, while the triangular oblique fascia is sutured to further increase the horizontal stability of the AC joint.^{8,9} During a follow-up period of at least 2 years after surgery, all patients in the coracoid process without tunnel suspension fixation group had no coracoid process fractures, no loss of reduction, firm fixation of the acromioclavicular joint, and good functional recovery from surgery to the last follow-up.

In terms of imaging, the CCDs measured in the three groups of patients at the last follow-up were significantly lower than the preoperative values ($P < 0.001$), indicating that all three surgical techniques can effectively restore the anatomical alignment of the acromioclavicular joint, which is consistent with previous research reports.^{26,27} Although there were slight differences in the CCD values between the groups in the early postoperative period (3 months) and the late postoperative period (last follow-up), there was no statistically significant difference between the groups ($P > 0.05$), indicating that the three surgical methods had similar effects on maintaining midterm imaging stability, which may be related to the biomechanical properties of internal fixation materials (such as TightRope) and standardized surgical procedures. In addition, the significant improvement in postoperative CCD further confirms the advantages of precise reduction and reliable fixation with arthroscopic technology. However, the homogeneity of imaging results cannot completely rule out potential differences in long-term complications (such as bone resorption and internal fixation failure) among different surgical procedures, and further verification is needed with larger sample sizes and longer follow-up periods.

Compared with the three fixation techniques for treating acromioclavicular dislocation, arthroscopic single tunnel technique and Arthroscopic coracoid sling technique have definite clinical efficacy in treating acromioclavicular dislocation. They have the advantages of minimal trauma, few complications, fast postoperative joint function recovery, and no need for secondary surgery to remove internal fixation, greatly reducing patient pain and economic burden. In addition, Compared with single tunnel technique, the coracoid sling technique, coracoid sling technique avoids patients from drilling bone tunnels on the coracoid process, effectively reducing the occurrence of complications such as massive bone loss caused by bone tunnels, coracoid process fractures caused by drilling deviation from the center, and surgical failure. Therefore, the efficacy and postoperative complications of the three surgical methods were compared. In the selection of surgical treatment plans, we tend to use coracoid sling technique to treat patients with acromioclavicular dislocation.

However, despite the advantages of the three surgical methods in our study, our research also has several limitations: (1) This study is a retrospective study, and some patients' shoulder joint function scores recorded during telephone follow-up may have errors compared with actual measurements. Moreover, all measurements of the distance between the beak and the clavicle were manually measured and deviated from the actual values. We consider that these measurement data may have a certain degree of subjectivity and selection bias in the research results. (2) The sample size of patients included in this study was small, and the follow-up period was short. To reach clearer conclusions, we hope to conduct multicenter studies, increase the sample size, and extend the follow-up time in the future to further explore long-term clinical effects to better serve and guide clinical practice. Provide the best surgical treatment plan for patients.

In summary, this study revealed that three surgical methods can significantly improve shoulder joint function in the treatment of acute type III to V acromioclavicular dislocation. However, in the early postoperative period, compared with the modified Weaver-Dunn technology, arthroscopic single tunnel technique and Arthroscopic coracoid sling technique have the advantages of being minimally invasive, resulting in fewer complications, faster postoperative joint function recovery, and no need for secondary surgery to remove internal fixation. Compared with single tunnel technique, coracoid sling technique requires a shorter surgery time, faster short-term shoulder joint function recovery, and avoids the establishment of bone tunnels on the coracoid process, resulting in greater surgical safety.

Data Sharing Statement

The follow-up study on “Three surgical methods for treating acute Rockwood III-V acromioclavicular dislocation: a retrospective study of clinical efficacy and imaging results” is incomplete. Therefore, the data analyzed in this study cannot be made public, but can be provided to the corresponding authors upon reasonable request.

Declaration and Ethical Approval

We confirm that all experimental studies are conducted in accordance with the Helsinki Declaration. This study has been approved by the Ethics Committee of the Sixth Affiliated Hospital of Xinjiang Medical University. All included patients provided written informed consent prior to participating in the study.

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Disclosure

All authors of the article strongly declare that there is no conflict of interest in this retrospective study and the writing process of the article.

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