Evaluation and Experience in the Treatment of Coronal Plane Elbow Fractures via the Anterior Approach

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Abstract

Background: The existing approaches to treating elbow fractures include anterior, external, internal, and posterior approaches. Of these, the anterior approach is often not chosen by surgeons to avoid damaging important nerves and blood vessels. In fact, the anterior approach has unique advantages. The purpose of this study was to report the outcomes in 38 patients with coronal plane elbow fractures treated through the anterior approach.

Methods: We retrospectively analyzed 38 cases of coronal plane elbow fractures treated through an anterior approach at our institution between March 2015 and July 2019. The length of the surgical incision, operation time, intraoperative blood loss, and postoperative complications were recorded. The range of flexion, extension, and rotation of the affected elbow and the healthy elbow were collected at follow-up. Functional outcomes were evaluated using the Mayo Elbow Function Score (MEPS).

Results: All 38 patients were followed up. At the final follow-up, solid osseous union was confirmed for all coronal plane elbow fractures. The mean elbow flexion arc was 129.26 ± 6.9 degrees, and the extension arc was 8.87 ± 6.13 degrees. The mean pronation arc was 83.45 ± 2.9 degrees, and the supination arc was 80.05 ± 2.92 degrees. The mean MEPS was 90.0±7.53 points, with 18 excellent cases and 20 good cases. There was no significant difference in elbow extension, flexion, and pronation between 31 cases of single fracture and the healthy elbow ($P > 0.05$); the arc of supination was slightly worse than that of the healthy elbow ($P < 0.05$). The VAS pain scores of the patients before the operation, three months after the operation, and during follow-up were compared. The pain of the patients was significantly reduced after treatment ($P < 0.05$). Two patients experienced transient postoperative median nerve paralysis, from which they recovered within three months. One patient had mild heterotopic ossification and was not treated because it did not affect the function of the elbow joint. All patients returned to work and were satisfied with the treatment.

Conclusion: The anterior approach has the benefits of simplicity, safety, minimal invasion, excellent exposure, and satisfactory prognosis for coronal plane elbow fracture.

Background

The elbow joint is composed of the humeroulnar joint, the humeroradial joint, the proximal radioulnar joint, and the surrounding ligaments. It is one of the complex joints of the human body and plays a large role in the functional activities of the upper limbs.

Due to the specific nature of intra-articular fractures, the treatment of elbow fractures must conform to the criteria of anatomical repositioning, at which point a good surgical field and firm fixation are necessary. The desirable procedure should be performed in a way that minimizes soft tissue stripping without compromising fracture visualization and reduces the risk of elbow stiffness[1], which is closely related to the choice of surgical approach. At present, the available approaches for the treatment of elbow fractures include anterior, lateral, medial, and posterior approaches[2–4]. Of these, lateral, medial, and posterior are more commonly used, and patients with the more complex terrible triad are often treated with a combined approach. In contrast, the anterior approach to the elbow is less frequently chosen by operators due to its anatomical peculiarities, with nerves and vessels intertwined in the operative field.

In fact, the anterior approach also has unique advantages. It can reduce and fix the fracture and repair the anterior joint capsule through direct sight, providing more options for internal fixation, and is gradually being promoted in the treatment of coronoid process fractures[5, 6]. The anterior approach to the elbow has been considered in the last years a valid alternative for distal humerus articular fracture[7, 8] and for coronoid fractures[9], some of the existing literature anyway consider the distal humerus articular fracture in combination with other fractures (coronoid and radial head) and propose an altogether treatment with an anterior approach[7].

We have also found that anterior treatment of elbow fractures is not limited to the coronoid process. Radial head fractures and partial distal humeral fractures that occur in the coronal plane of the elbow, as well as the terrible triad, can be treated well with an anterior approach and even demonstrate unique advantages, which have rarely been reported in the literature. Previously, the outcome of treatment of a single elbow fracture through an anterior approach has usually been described, while a series of fractures in the coronal plane has not been summarized and reported.

The aim of this study was to introduce the treatment of a series of fractures in the coronal plane of the elbow joint by using an anterior approach and to analyze its effectiveness and unique advantages.

Methods

After receiving approval from our Institutional Review Board, we retrospectively analyzed 38 consecutive patients (25 males, 13 females; mean age, 32.8 years; range, 14–69 years) who had undergone open reduction and internal fixation through an anterior approach in our hospital for the treatment of coronal plane elbow fractures between March 2015 and July 2019 (Table 1).

Table 1

Baseline information

Case	Sex	Age (y)	Side	Fracture classification	Elbow dislocation	Operation time (m)	Bleeding amount (ml)	Incision length (cm)	Union time (w)
1	M	14	L	13B3.2	No	70	20	5	14
2	M	29	L	R-M: II; mason: IV	Yes	190	200	6	18
3	M	15	R	13B3.2	No	135	50	6	13
4	M	24	R	R-M: II	No	150	20	8	14
5	M	23	L	R-M: II	No	180	50	8	12
6	M	27	R	R-M: II	No	150	20	6	16
7	M	40	L	R-M: II	No	105	5	7	14
8	M	33	R	R-M: II	No	150	20	8	13
9	M	31	L	R-M: II	No	133	50	7	15
10	M	34	L	R-M: II	No	136	20	6	13
11	M	37	L	R-MII; mason: IV	Yes	310	150	12	14
12	F	19	L	R-M: III	No	120	10	10	13
13	M	32	R	mason: II	No	180	20	6	15
14	M	23	R	mason: II	No	105	10	6	14
15	F	37	L	mason: III	No	75	10	10	15
16	F	56	L	R-M: II	Yes	70	50	6	14
17	F	52	L	R-M: II	No	165	30	10	14
18	M	29	R	R-MII; mason: IV	Yes	180	50	6	16
19	F	48	R	mason: II	No	80	10	6	16
20	F	54	R	R-MIII; mason: IV	Yes	180	100	10	15
21	M	57	L	R-MIII; mason: III	Yes	150	50	8	15
22	M	34	L	R-MII; mason: IV	Yes	300	200	6	16
23	M	29	L	R-MIII; mason: III	Yes	150	150	10	16
24	M	28	R	R-M: II	No	77	30	7	12
25	M	32	R	mason: III	No	90	100	6	16

y = year, w = week, M = Male, F = Female, L = Left, R = Right

Case	Sex	Age (y)	Side	Fracture classification	Elbow dislocation	Operation time (m)	Bleeding amount (ml)	Incision length (cm)	Union time (w)
26	F	21	R	mason: III	No	60	10	10	12
27	M	29	R	R-M: III	No	65	25	12	12
28	F	39	L	mason: III	No	95	50	6	15
29	F	69	L	13B3.2	No	85	80	8	14
30	F	31	L	13B3.1	No	100	5	10	15
31	M	28	L	13B3.1	No	75	50	8	13
32	M	16	R	13B3.2	No	65	50	7	15
33	M	16	L	13B3.2	No	65	100	6	15
34	F	21	R	13B3.2	No	80	50	10	16
35	F	22	L	13B3.3	No	120	100	10	14
36	M	44	L	R-M: II	No	75	30	7	15
37	F	26	R	R-M: III	No	80	40	8	14
38	M	47	R	R-M: II	No	80	60	8	16
y = year, w = week, M = Male, F = Female, L = Left, R = Right									

The right extremity was injured in 17 patients, and the left extremity was injured in 21 patients. The primary goal of surgical fixation was to obtain a stable joint that permitted early movement. Regan-Morrey type I and Mason type I fractures with good elbow stability or fractures without significant displacement were excluded. The inclusion criteria were a Regan-Morrey type II or type III coronoid process fracture; Mason type II, III, and IV radial head fractures; and distal humeral fractures included in AO types 13B 3.1, 13B 3.2, and 13B 3.3. According to these classifications, there were 16 cases of Regan-Morrey type II, 6 cases of Regan-Morrey type III, 3 cases of Mason type II, 6 cases of Mason type III, and 5 cases of Mason type IV; for AO type, there were 2 cases of type 13B3.1, 6 cases of type 13B3.2, and 1 case of type 13B3.3. All 38 patients qualified for the final evaluation.

The mechanism of injury included 26 cases of falling on flat ground while walking, 8 cases of falling from a height, 3 cases of traffic accident, and 1 case of heavy object impact. There were 7 cases of coronoid process with radial head fracture. These patients received initial reduction therapy in the emergency room.

All patients had closed injuries without any neurovascular complications. All 38 elbows were treated surgically at a mean of 4.3 days (range, 2–12 days) after the initial injury. The specific indications for surgical intervention include displaced intra-articular fractures and instability of the elbow within a functional arc of motion after closed reduction.

Preoperative radiological examinations were routinely performed to determine the exact location of fractures located in the coronal plane. CT and 3D reconstruction were used to obtain additional information on fracture comminution and displacement that was not apparent on X-rays.

Surgical technique

All patients were treated with nerve block anesthesia, and the elbow joint was abducted in the supine position. Routine disinfection was extended to the area above the shoulder joint to avoid restriction of the operative area caused by a tourniquet. A tourniquet was applied to the proximal 1/3 of the upper arm after elevating the affected limb for 3–5 min, taking care to avoid excessive blood expulsion and appropriate retention of blood in the arteriovenous system of the forearm to help identify intraoperative anatomy. Approximately 5 cm above the elbow crease, an "*S*" incision was made from the medial or lateral border of the biceps muscle to the midline of the forearm, avoiding a 90° angle with the elbow crease and preserving intact soft tissue structures as much as possible.

When two or more fractures were involved, the skin incision was appropriately extended, and the subcutaneous tissue was bluntly separated after skin incision, identifying and protecting the medial cutaneous nerve of the forearm (identifying the lateral cutaneous nerve of the forearm when a lateral incision is used), basilic vein, cephalic vein, and median cubital vein.

(1) To manage a coronoid fracture, the bicipital aponeurosis was lifted with a vascular clamp and then incised. The biceps muscle was pulled laterally, and the pronator teres muscle was pulled medially, with the brachial artery and median nerve in its deeper layers and the median nerve medial to the brachial artery. At this point, the elbow joint was slightly flexed by 5° to 10° to keep the vascular nerve bundle in a tension-free state, and the brachial muscle was exposed in the interval between the brachial artery and the median nerve. The brachial muscle was incised along the course of the muscle fibers to expose the joint capsule.

(2) In the management of radial head fractures, the biceps brachii muscle was first pulled medially (Fig. 4d). The forearm was fixed in a state of extreme supination, the supinator muscle was cut at the insertion point where the supinator muscle attaches to the radius while avoiding the Frohse arch, and finally, the joint capsule was opened to expose the radial head.

(3) Both of these intervals were used to expose the distal humerus by extending proximally, but a closer interval was selected depending on the type of distal humeral fracture.

After the joint capsule was opened and the elbow joint was fully extended, most fracture fragments usually reset themselves at this point. A 1.5 mm Kirschner wire was typically used to temporarily fix the fragment in the anteroposterior direction and maintain pressure on the fragment. After fluoroscopy determined that the fracture fragments were satisfactorily repositioned, the appropriate internal fixation device was selected according to the different fracture types and fixed after shaping the fracture according to its morphology.

In patients with elbow dislocation, the elbow was examined for stability after reduction, and a concentric reduction should be achieved, with an arc of flexion-extension from 20° to 130° and no posterior or posterolateral subluxation or dislocation. Those who could not maintain stability required ligament repair or reconstruction, and if necessary, a combined approach was used. The tourniquet was released before closure, and meticulous hemostasis was performed. Drainage was placed, and the incision was sutured and dressed.

Postoperative Management

Patients were supplemented with a hinged plastic brace for postoperative fixation. The forearm was positioned in a pronation or supination position in cases of lateral or medial collateral ligament deficiency, respectively. The forearm was splinted in neutral rotation if both the medial and lateral collateral ligaments had been repaired. A light diet was taken 2 hours after the surgery, and cefuroxime sodium (3.0 g) was given intravenously on the same day to prevent infection.

The patients were given intravenous cimetidine, and the affected limbs could be elevated to reduce swelling to prevent stress after gastrointestinal anesthesia. Analgesic treatment was actively administered according to the VAS score, and single or combined analgesic drugs were used depending on the patient's condition, which facilitated rest and recovery and thus promoted healing to effectively reduce the length of hospitalization and the patient's medical expenses. Positive and lateral elbow films were reviewed the day after surgery. The medication was changed regularly, and drainage was usually removed within three days postoperatively. On the second postoperative day, passive flexion and extension exercises of the elbow were started. Active movement of the wrist and metacarpophalangeal joints can help determine whether the nerve is injured during surgery. Elbow flexion and extension and rotation exercises were gradually performed starting one week after surgery. Active flexion and extension exercises began in the second week. Unrestricted flexion and extension and strength exercises were performed in the 8th week. In addition, to prevent heterotopic ossification, patients were recommended to take oral nonsteroidal anti-inflammatory drugs such as indomethacin for six weeks, and those with severe gastrointestinal reactions could switch to etoricoxib tablets.

Data collection and analysis

At follow-up, clinical and radiological examinations were performed by a clinical investigator who was not involved in the treatment. The clinical evaluation included the patient's bilateral arc of motion in elbow flexion, extension, pronation, supination, the Mayo Elbow Performance Score (MEPS)[10], and examination of detectable surgical complications. Plain films were evaluated for fracture union, implant loosening, heterotopic ossification, degenerative changes, and joint congruency. Intraoperative and postoperative complications were also recorded. A confirmed fracture union was defined as when the fracture showed evidence of external bridging of the callus across the fracture line in the three cortices on the lateral view of the elbow. Statistical analysis was performed using SPSS version 26.0 software (SPSS Inc., Chicago, IL).

Results

All coronal plane fractures were successfully treated with internal fixation of the fracture using an anterior approach, and final follow-up X-rays showed solid osseous union. The average time to radiologic union was 14.4 weeks (range, 12–18 weeks).

The outcomes are shown in Table 2. The mean duration of follow-up was 21.26 months (range, 12–36 months). At the final follow-up, the mean elbow flexion arc was 129.26 ± 6.9 degrees, and the extension arc was 8.87 ± 6.13 degrees. The mean pronation arc was 83.45 ± 2.9 degrees, and the supination arc was 80.05 ± 2.92 degrees. The mean MEPS was 90.0 ± 7.53 points, with 18 excellent cases and 20 good cases. There was no significant difference in elbow extension, flexion, and pronation between 31 cases of a single fracture and the healthy side ($P > 0.05$); the arc of supination was slightly worse than that of the healthy side ($P < 0.05$) (Table 3; Fig. 1). The VAS pain scores of the patients before the operation, three months after the operation, and during follow-up were compared (Fig. 2). The pain of the patients was significantly reduced after treatment ($P < 0.05$) (Table 4).

Table 2
Follow - up information

Case	Follow–up (mo)	Arc of motion								MEPS
		AE	HE	AF	HF	AP	HP	AS	HS	
1	18	11	10	138	140	82	83	80	82	100
2	24	16	7	120	135	83	87	80	84	95
3	17	8	8	134	136	82	85	81	83	100
4	22	10	10	130	130	80	82	79	84	85
5	23	11	10	132	134	80	81	79	80	95
6	12	12	10	128	129	82	84	80	83	85
7	22	0	0	135	135	85	83	80	82	100
8	12	11	10	132	130	83	83	83	83	80
9	38	4	3	128	132	84	84	82	87	95
10	10	0	0	134	135	88	89	85	87	100
11	12	18	0	123	136	82	89	80	82	100
12	20	0	0	137	137	90	87	77	82	85
13	14	7	8	127	128	80	83	79	85	80
14	12	0	0	126	128	83	84	82	87	85
15	25	7	7	128	130	81	81	76	84	100
16	35	11	11	134	135	81	82	78	85	85
17	33	9	8	125	128	88	90	78	84	85
18	36	25	8	105	129	80	90	76	79	85
19	30	4	4	135	135	87	90	78	88	95
20	26	17	9	124	135	82	89	79	89	95
21	25	19	7	120	136	82	83	80	90	85
22	19	18	11	128	133	83	85	76	88	95
23	19	22	5	110	131	80	88	81	90	75
24	18	0	0	136	137	86	86	83	85	85
25	26	9	10	127	127	84	80	76	85	80
26	28	6	6	128	131	80	87	81	81	85
27	23	9	9	139	132	89	86	78	82	85
28	26	5	5	134	135	85	82	78	82	100

mo = month, AE = affected side extension degree, HE = healthy side extension degree, AF = affected side flexion degree, HF = healthy side flexion degree, AP = degree of affected pronation, HP = degree of healthy pronation, AS = degree of affected supination, HS = degree of healthy supination, MEPS = Mayo Elbow Performance Score

Case	Follow–up (mo)	Arc of motion								MEPS
		AE	HE	AF	HF	AP	HP	AS	HS	
29	18	6	6	131	132	80	81	77	82	80
30	17	4	4	133	133	85	86	84	83	85
31	19	9	8	127	129	80	81	76	84	85
32	21	8	9	132	133	82	86	80	85	85
33	15	7	6	132	135	87	90	82	89	90
34	21	9	9	133	133	83	79	82	83	85
35	21	8	7	128	128	85	86	79	83	100
36	14	5	5	132	133	85	88	85	86	95
37	17	7	8	133	135	83	87	83	85	100
37	19	5	5	134	130	89	89	89	90	95

mo = month, AE = affected side extension degree, HE = healthy side extension degree, AF = affected side flexion degree, HF = healthy side flexion degree, AP = degree of affected pronation, HP = degree of healthy pronation, AS = degree of affected supination, HS = degree of healthy supination, MEPS = Mayo Elbow Performance Score

Table 3

Comparison of the movement arc of the healthy side and the affected side in 31 cases of a single fracture

	Healthy Side	Affected Side	*p*
Flexion°	132.42 ± 3.3	131.68 ± 3.7	0.058
Extension°	6.32 ± 3.5	6.52 ± 3.7	0.136
Pronation°	84.68 ± 3.2	83.84 ± 3.0	0.072
Supination°	84.32 ± 2.4	80.32 ± 3.1	0.001

Table 4

Comparison of VAS scores of patients before and after surgery

	Before Surgery	3 Months After Surgery	Last Follow-up
	7.5 ± 0.9	4.7 ± 1.1	2.0 ± 1.1
t	25.895	10.724	22.569
P	<0.01	<0.01	<0.01

There were no intraoperative complications. There were also no wound complications or implantation failures. Two patients experienced transient postoperative median nerve paralysis, the symptoms disappeared after regular oral administration of nutritional nerve drugs, and the symptoms did not recur in subsequent follow-up. Two patients experienced transient postoperative median nerve paralysis, the symptoms disappeared after regular oral administration of nutritional nerve drugs, and the symptoms did not recur in subsequent follow-up. One patient had mild heterotopic ossification and was not treated because it did not affect the function of the elbow joint. All patients returned to work and were satisfied with the treatment (Fig. 3 ~ 6).

Discussion

The anterior approach has been widely used in upper limb surgery. It is considered a valuable option in the treatment of proximal radius fractures, reconstruction of the distal biceps tendon, resection of anterior elbow tumor, and soft tissue infection[11]. According to the mechanism of injury, after the occurrence of elbow fractures, the bone fragments often dislocate to the coronal plane. However, due to the anatomical characteristics of the anterior elbow joint, surgeons often avoid the anterior approach due to fear of damage to the neurovasculature and often choose the lateral approach, which makes it difficult to look directly at and address the fracture surface[12, 13]. With the gradual understanding of the anatomical relationship of the elbow joint by clinicians and the development of microsurgical techniques, the anterior approach is increasingly used in the treatment of elbow fractures.

Elbow joint fracture is an intra-articular fracture, and anatomical reduction of the articular surface is the key factor to achieving strong fixation and a satisfactory elbow joint[14, 15]. Adequate exposure of the articular surface is a prerequisite for anatomical reduction of fractures. Some scholars[8] compared the exposure area of the distal humerus articular surface by different surgical approaches and found that the average percentages of exposed articular surfaces by anterior and posterior olecranon osteotomy and medial and lateral approaches were 45.7% ± 2.0%, 53.9% ± 7.1%, 20.6% ± 4.9% and 28.5% ± 6.3%, respectively. We concluded that the anterior and posterior approaches are more adequate than the medial and lateral approaches for intraoperative articular surface exposure in the treatment of distal humerus fractures. Yang et al.[9] compared the exposure area of the coronoid process fracture between the biceps tendon-brachial artery interval (B-B interval) and brachial artery-median nerve interval (B-M interval) from an anterior approach, and the results of this study showed that the average exposed surface area of coronoid process was 2.26 times greater with the B-M interval compared with the B-B interval, allowing visualization for fracture reduction. The above study fully illustrates the theoretical feasibility of using an anterior approach to treat coronal plane elbow fractures.

Compared with other approaches, the anterior approach has some advantages[1, 6, 9]: (1) providing excellent visualization of and the most direct access for fractures in the coronal plane (Fig. 3c); (2) allowing anatomic reduction of the fracture and more fixation options, as anterior to posterior compression is more mechanically appropriate, which reduces the risk of fracture fixation failure (Fig. 3b); (3) avoiding a large amount of soft tissue dissection; (4) avoiding damaging the flexor-pronator muscle mass and the ulnar nerve; and (5) exploring the ulnar collateral ligament of the elbow joint and repairing the anterior joint capsule, which is beneficial to the stability of the elbow joint and reduces the occurrence of heterotopic ossification.

Our point of view is that it is not appropriate to directly choose the surgical approach without considering the type of fracture. One of the rules of classifying fractures is to better understand the mechanism of injury and local anatomical characteristics and then provide guidance for treatment. Scientific surgical protocols should not be limited to absolutely identical patterns, and the surgical approach should be individualized according to the patient's injury.

Since most elbow joint coronoid fractures are displaced forward, as long as the elbow joint is unstable, anterior surgery can be considered[16, 17]. The Kocher approach is commonly used in the treatment of the radial head[18], which is accessed from the extensor carpi ulnaris and the anconeus interval. It is primarily indicated for the repair of radial head fractures and lateral collateral ligaments, but there are a certain number of patients who have a combined coronoid fracture along with the presence of a radial head fracture[19]. In such cases, the use of the lateral access route is obscured by the radial head, which makes the operating space narrow. There are even doctors who treat coronoid fractures after osteotomy of the radial head. This method causes damage to the stability of the elbow joint and additional trauma, which is difficult for patients to accept. The radius itself has intraoperative rotatable properties, so even radial head fractures that occur laterally in the sagittal plane can fully expose the fracture surface when using the anterior approach.

The posterior approach provides the greatest exposure of the distal humeral articular surface for surgery for distal humerus fractures. However, nonunion in 30% of patients is a common complication of this approach[20, 21], along with a larger surgical incision and prolonged operation time. Due to the presence of an anatomical structure in the distal humerus that is tilted approximately 30° anteriorly, the advantage of the anterior approach allows internal fixation under direct vision[8]. Therefore, the anterior approach is recommended for AO type B fractures that mainly occur on the coronal plane, including the capitulum, trochlea, or combined fractures.

The terrible triad of the elbow is an incapacitating injury entailing posterior dislocation and fractures of the radial head and coronoid and is also often associated with a collateral ligament injury. Traditional treatment is usually a combined medial-lateral approach. However, it is worth considering that the occurrence of the terrible triad is posterior dislocation of the elbow joint caused by violence, along with forced anterior displacement of the radial head and coronoid process by the distal humerus. In terms of the injury mechanism, "smooth" reduction under direct vision by the anterior approach will bring advantages that other approaches cannot achieve. Some of the cases included in this study involved the terrible triad, and all were treated by the anterior approach with good results (Fig. 6).

Concerning complications, the serious neurovascular injury that many scholars worry about did not occur. Only two patients experienced transient postoperative median nerve paralysis, and the symptoms disappeared after regular oral administration of nutritional nerve drugs and did not recur in subsequent follow-up. There was only one case of mild heterotopic ossification in the front of the elbow joint, which was not found to bring subjective symptoms to the patient or affect the movement of the elbow joint during the follow-up process, so it was not treated. Some scholars[22] worry that injuring the brachialis will increase the incidence of heterotopic ossification. To reduce the occurrence of heterotopic ossification, one may choose not to cut the brachialis longitudinally and choose to expose the fracture end after distraction at its edge. Since there was no additional osteotomy, as in the posterior approach, we did not observe the occurrence of nonunion. The most common symptoms were pain and limitation of motion. For patients with significant pain, timely drug analgesic treatment was administered, and significant relief was obtained within a period after surgery. A considerable number of patients with postoperative limitation of motion experience fear, and it is effective to provide active rehabilitation guidance to such patients after surgery.

Based on the study results and long-term clinical practice, we summarized some noteworthy points regarding the anterior approach for the treatment of fractures of the elbow in the coronal plane:

(1) Intraoperative elbow flexion of 5° to 10° is beneficial to reduce muscle tension while allowing the sliding of vascular nerves between loose tissues and reducing the risk of vascular nerve injury.

(2) Since the deep fascia below the external epicondyle of the humerus penetrates the lateral antebrachial cutaneous nerve, the lateral side of the incision should be within 1.5 cm of the outer edge of the biceps tendon. It may be necessary to cross the cubital crease. In that case, the surgical incision should be selected in the position above the cubital crease to prevent the possibility of postoperative scar contracture affecting elbow joint activity, as the lateral antebrachial cutaneous nerve in this area is located in the deep layer and is not easily injured during surgery.

(3) When the biceps aponeurosis needs to be cut, it can be picked up with a vascular clamp and propped open, and then a scalpel can be used to reverse the cutting to avoid damage to the brachial artery and vein and median nerve below. In addition, the traction of the nerve should be gentle.

(4) In the treatment of coronoid fractures, interval access between the brachial artery and the median nerve is chosen for the anterior approach, whereas interval access between the median nerve and the pronator interval is high risk because of the nerve branches here. The advantages of this approach are that it is safer to enter from the vascular-neural interval; it directly exposes the fracture site and facilitates reduction; it also facilitates fixation with a plate and causes less tissue damage; the disadvantage is that the medial coronoid process cannot be fixed.

(5) Care needs to be taken when exposing the radial head, over which a deep branch of the radial nerve migrates across the Frohse arch as the posterior interosseous nerve. To avoid injury to the radial nerve, the radius needs to be rotated extremely posteriorly, the termination point of the posterior rotator muscle needs to be separated, and the joint capsule is pushed from the inside out with an osteotome. Simultaneously, using the characteristics of the radius, the radial head fracture area was rotated to the surgical field for exposure.

(6) Intraoperative placement of drainage is essential, and adequate drainage prevents hematoma formation and reduces the risk of infection and heterotopic ossification.

(7) Early rehabilitation activities are recommended for patients. One of the details here is that the elbow joint should not be bandaged too much, as a thick sterile dressing will greatly affect the arc of elbow bending.

(8) To prevent heterotopic ossification after surgery, it is recommended that patients take oral nonsteroidal anti-inflammatory drugs such as indomethacin for six weeks; those with severe gastrointestinal reactions can take etoricoxib instead.

There were a few shortcomings in this study. The study was essentially retrospective, and there was no control group for comparison. Furthermore, the sample size of the different fracture types included in the study was smaller. A final problem is that this study did not analyze the combined fractures separately from the simple fractures, which will be studied separately in the future when the sample size is sufficient. Future work may also explore the efficacy of the anterior approach in the treatment of the terrible triad based on prospective studies with expanded sample sizes.

Conclusion

The anterior approach for the treatment of coronal plane elbow fractures, especially combined fractures, has a clear surgical field, large operation space, easy reduction, more fixation options, less trauma, fewer complications, and good postoperative function recovery. Moreover, in the case of adequate visualization of the surgical field, clearly separated and protected vessels and nerves always warn the surgeon and make them less vulnerable. In conclusion, the anterior approach is reliable in the management of coronal plane elbow fractures and deserves to be used in clinical practice.

Abbreviations

MEPS: the Mayo Elbow Performance Score; B-B interval: the biceps tendon-brachial artery interval; B-M interval: brachial artery-median nerve interval

Declarations

Acknowledgments

Not applicable.

Author Contributions

QYJ: Conducted the study. Collected, analyzed, and interpreted the data. Wrote the manuscript.

XXL: Designed the study, and interpreted the data, and edited the manuscript.

JZ: Planned the project. Interpreted the data.

DSC: Interpreted the data.

KL: Edited the manuscript.

YBW: Edited the manuscript, reviewed the manuscript.

AY: Edited the manuscript, reviewed the manuscript.

CM: Planned the project. Reviewed the manuscript.

All authors read and approved the final manuscript.

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Availability of data and materials

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of The First Affiliated Hospital of Xinjiang Medical University. The patients provided written informed consent for the publication of individual clinical details and images. In addition, this study was performed in line with the international ethical guidelines for studies involving human subjects according to the Declaration of Helsinki.

Competing interests

The authors declare that they have no conflict of interest.

Consent for publication

Written informed consent for publication were obtained from patients.

Disclosure

The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

References

1. Ring D, Jupiter JB: **Surgical Exposure of Coronoid Fractures**. *Techniques in Shoulder & Elbow Surgery* 2002, **3**(1):48–56.
2. Cheung EV, Steinmann SP: **Surgical approaches to the elbow**. *J Am Acad Orthop Surg* 2009, **17**(5):325–333.
3. Hausman MR, Klug RA, Qureshi S, Goldstein R, Parsons BO: **Arthroscopically assisted coronoid fracture fixation: a preliminary report**. *Clin Orthop Relat Res* 2008, **466**(12):3147–3152.

4. Garrigues GE, Wray WH, 3rd, Lindenhovius AL, Ring DC, Ruch DS: **Fixation of the coronoid process in elbow fracture-dislocations**. *J Bone Joint Surg Am* 2011, **93**(20):1873–1881.
5. Reichel LM, Milam GS, Reitman CA: **Anterior approach for operative fixation of coronoid fractures in complex elbow instability**. *Tech Hand Up Extrem Surg* 2012, **16**(2):98–104.
6. Feng D, Zhang X, Jiang Y, Zhu Y, Wang H, Wu S, Zhang K, Wang Z, Zhang J: **Plate fixation through an anterior approach for coronoid process fractures: A retrospective case series and a literature review**. *Medicine (Baltimore)* 2018, **97**(36):e12041.
7. Ballesteros-Betancourt JR, Garcia-Tarrino R, Garcia-Elvira R, Munoz-Mahamud E, Fernandez-Valencia JA, Llusa-Perez M, Combalia-Aleu A: **The anterior limited approach of the elbow for the treatment of capitellum and trochlea fractures: Surgical technique and clinical experience in eight cases**. *Injury* 2020, **51 Suppl 1**:S103-S111.
8. Wu ZZ, Wang JD, Ji XX, Ma ZJ, Wu JH, Wang QG: **Surgical exposures of the distal humeral fractures: An anatomical study of the anterior, posterior, medial and lateral approaches**. *Chin J Traumatol* 2018, **21**(6):356–359.
9. Yang F, Feng K, Sun Y, Dai K, Wang X, Tang J: **A Modified Anteromedial Approach for Exposure of Coronoid Fractures: An Anatomical Cadaver Study**. *Biomed Res Int* 2019, **2019**:6872948.
10. Morrey BF, An KN: **Functional Evaluation of the Elbow - ScienceDirect**. *Morrey's The Elbow and Its Disorders (Fourth Edition)* 2009.
11. Henry, Arnold K: **Extensile Exposure**. 1957.
12. Ruchelsman DE, Tejwani NC, Kwon YW, Egol KA: **Coronal plane partial articular fractures of the distal humerus: current concepts in management**. *J Am Acad Orthop Surg* 2008, **16**(12):716–728.
13. Ring D: **Open reduction and internal fixation of an apparent capitellar fracture using an extended lateral exposure**. *J Hand Surg Am* 2009, **34**(4):739–744.
14. Alonso-Llames M: **Bilaterotricipital approach to the elbow. Its application in the osteosynthesis of supracondylar fractures of the humerus in children**. *Acta Orthop Scand* 1972, **43**(6):479–490.
15. Gupta R, Khanchandani P: **Intercondylar fractures of the distal humerus in adults: a critical analysis of 55 cases**. *Injury* 2002, **33**(6):511–515.
16. Budoff JE: **Coronoid fractures**. *J Hand Surg Am* 2012, **37**(11):2418–2423.
17. Yang X, Chang W, Chen W, Liu S, Zhu Y, Zhang Y: **A novel anterior approach for the fixation of ulnar coronoid process fractures**. *Orthop Traumatol Surg Res* 2017, **103**(6):899–904.
18. Van Glabbeek F, Van Riet R, Verstreken J: **Current concepts in the treatment of radial head fractures in the adult. A clinical and biomechanical approach**. *Acta Orthop Belg* 2001, **67**(5):430–441.
19. Ramesh M, Iwan FA, Anuar A, Benard D: **Salvage of elbow function in chronic complex elbow fracture dislocation with total elbow arthroplasty: a case report**. *Medical Journal of Malaysia* 2013, **68**(4):353.
20. Gainor BJ, Moussa F, Schott T: **Healing rate of transverse osteotomies of the olecranon used in reconstruction of distal humerus fractures**. *Journal of the Southern Orthopaedic Association* 1995, **4**(4):263–268.
21. Holdsworth BJ, Mossad MM: **Fractures of the adult distal humerus. Elbow function after internal fixation**. *Journal of Bone & Joint Surgery British Volume* 1990, **72**(3):362–365.
22. Ruchelsman D, Tejwani NC, Kwon YW, Egol KA: **Coronal plane partial articular fractures of the distal humerus: current concepts in management**. *Journal of the American Academy of Orthopaedic Surgeons* 2008, **16**(12):716.

Figures

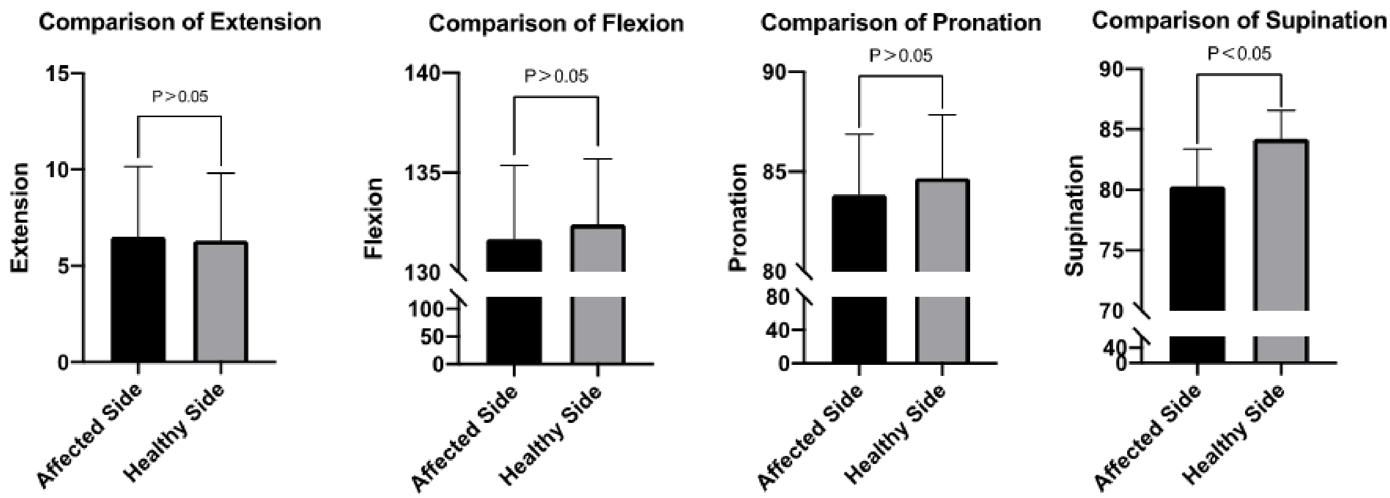

Figure 1

Comparing the mobility of the affected and healthy elbow joints after surgery.

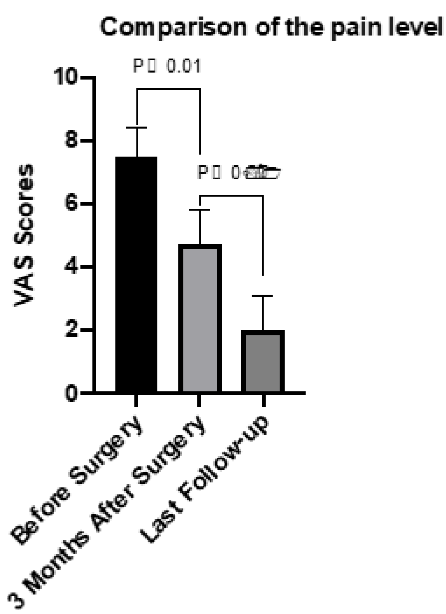

Figure 2

The VAS scores of patients before surgery, at three months after surgery, and at the final follow-up were compared.

Figure 3

A 40-year-old man presented with a Regan and Morrey type II coronoid process fracture. Preoperative radiographs (a). Intraoperative exposure of the coronoid process through the anterior elbow approach (c). Solid union and good outcomes were achieved at the 8-month follow-up (b, d).

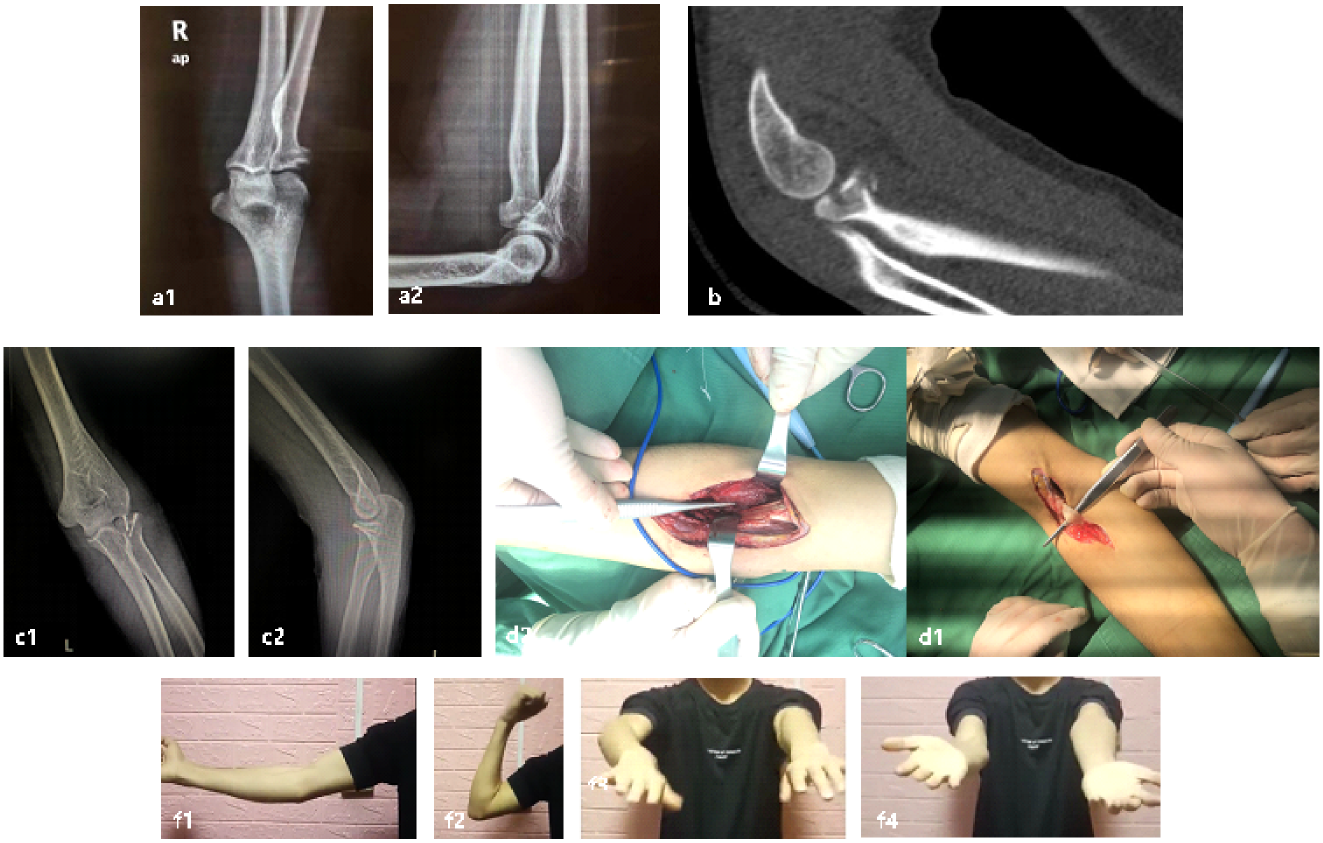

Figure 4

A 23-year-old man presented with a type of mason: II radial head fracture. Preoperative X-ray (a) and computed tomography (b). Intraoperatively, the biceps brachii was exposed and pulled medially to enter between the brachioradialis and biceps brachii interval (d1). The supinator muscle was located in its deeper layers (d2). Solid union and good outcomes were achieved at the 1-year follow-up (c, f).

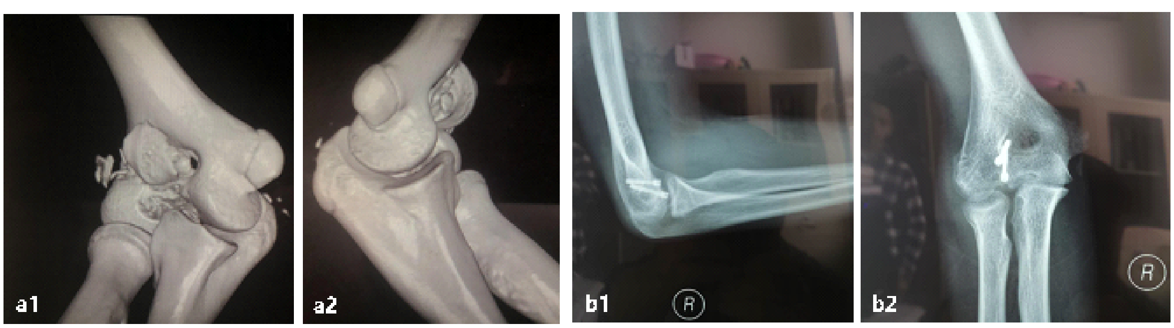

Figure 5

A 16-year-old boy diagnosed with AO type 13B3.2 humeral trochlear fracture (a1, a2). At the final follow-up, plain roentgenograms showed good bone union with good function (b1, b2).

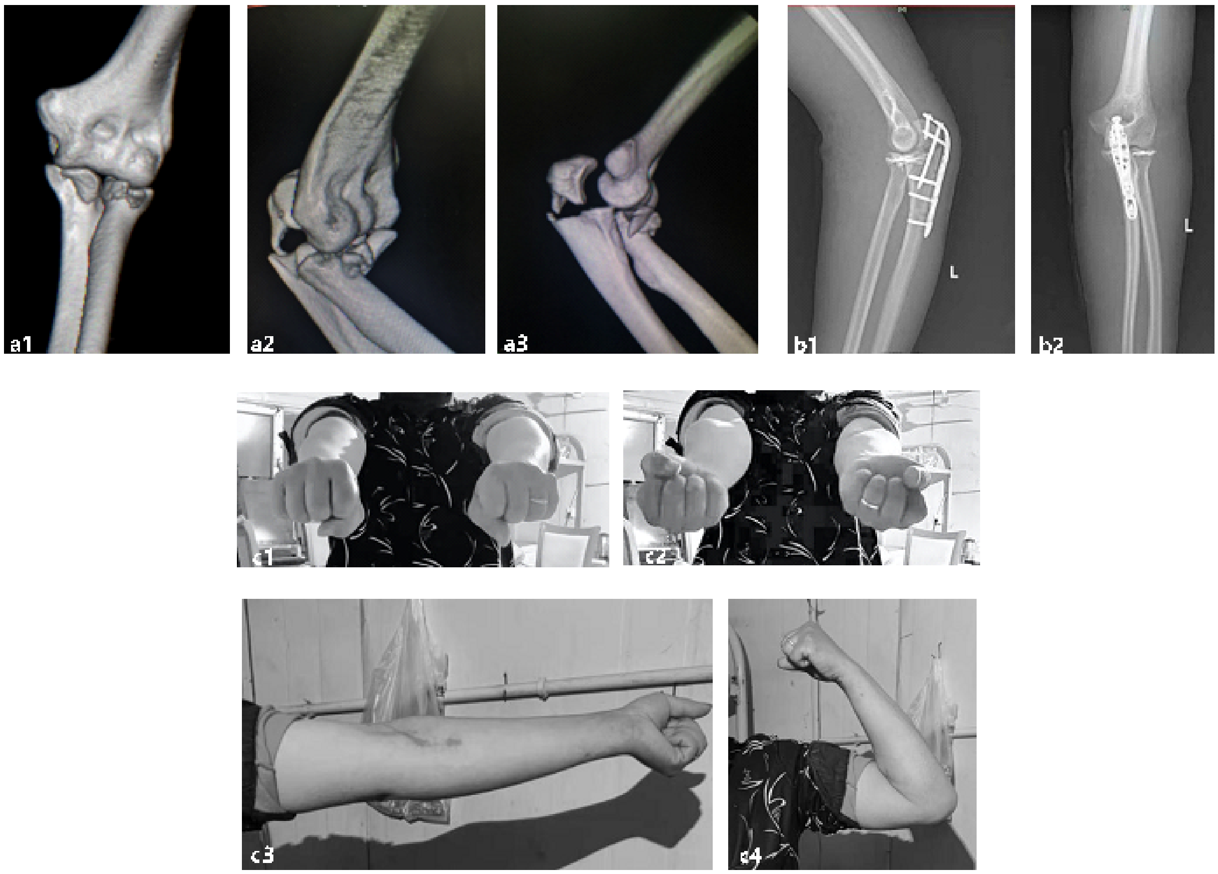

Figure 6

A 37-year-old man presented with a terrible triad of the elbow and an ipsilateral olecranon fracture. Preoperative CT 3D reconstruction (a). Postoperative plain radiographs at one month showed strong internal fixation and good alignment of the fracture (b). Good outcome was achieved at the 1-year follow-up (c).