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Treatment of posteromedial and posterolateral dislocation of the acute unstable elbow joint: a strategic approach

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Background: The purpose of this study was to evaluate the different treatment strategies for posterolateral and posteromedial elbow dislocation.

Methods: The study enrolled 21 patients with unstable simple elbow dislocation including 16 cases of posterolateral dislocation (PLDL) and 5 cases of posteromedial dislocation (PMDL). In patients with PLDL, the medial side was evaluated and repaired first, followed by the lateral side. In patients with PMDL, the lateral side was repaired first, followed by the medial side according to residual instability.

Results: Among the 16 cases of unstable PLDL, 7 of 9 presenting with complex combined tear of the ulnar collateral ligament (UCL) and flexor muscle on magnetic resonance imaging showed abnormality on valgus stress testing and UCL repair. Three of 7 cases required additional lateral collateral ligament complex (LCLC) repair. Two of 9 cases showing medial complex dual lesions had normal findings on valgus stress testing and were treated only with LCLC repair. Seven of 16 cases without medial complex dual lesion had normal findings on valgus stress testing, and only LCLC repair was performed. All 5 cases of unstable PMDL showed distraction-type LCLC injury on magnetic resonance imaging and required no additional UCL repair after LCLC repair. There were no cases of recurrent instability following this treatment algorithm.

Conclusions: In unstable elbow dislocation, PLDL and PMDL are caused by different mechanisms following damage to different structures. Therefore, different strategies are needed to ameliorate the dislocation and instability.

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

Keywords: Elbow; dislocation; posterolateral; posteromedial; mechanism

Elbow dislocation occurs commonly in adults and is the second most frequent cause of upper arm dislocation, following shoulder dislocation.[16] Simple elbow dislocation without intra-articular elbow fracture is usually stable after closed reduction, and no surgical treatment is required as reported in many studies.[1,4,8]

This study was approved by Pohang SM Christianity Hospital Institutional Review Board (PSMCHIRB-18-04).

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However, acute unstable elbow dislocation that has been redislocated or is unstable after closed reduction may require surgical treatment. Studies have attempted anatomic repair based on magnetic resonance imaging (MRI) findings of unstable simple elbow dislocation after closed reduction.[10,14,17] However, there is no consensus on the therapeutic strategy for identification of impaired anatomic structures causing unstable elbow dislocation and the injured ligaments or muscles requiring repair.

Rhyou et al[12] have proposed an alternative mechanism for posterior dislocation of the elbow joint after studying the injury pattern of soft tissue and site of bone contusion using objective MRI findings (Fig. 1). Accordingly, simple elbow dislocation can be classified into posterolateral dislocation (PLDL) and posteromedial dislocation (PMDL), depending on the direction of the dislocation. Furthermore, the type and degree of soft tissue structure damage may differ according to the direction of the dislocation.

Based on this mechanism, in the case of the most common PLDL, rupture of the ulnar collateral ligament (UCL) should be preceded by valgus force on the ulnar side followed by stripping-type injury while the lateral collateral ligament complex (LCLC) and overlying extensor muscles (OEMs) are peeled off the lateral epicondyle. In severe injury, a combined rupture of UCL and the flexor-pronator muscle group (complex dual lesion) may lead to loss of the medial static and dynamic stabilizers simultaneously (Fig. 2).

On the other hand, PMDL is rare because of the anatomic characteristics of the elbow and the native cubitus valgus alignment. As a first step, the varus force applied to the elbow joint results in tension failure and distractive-type injury of LCLC and OEMs. It affects whether the UCL is intact or torn. Cho et al[3] also reported that the LCLC is significantly impaired in PMDL, warranting surgical treatment more than in PLDL.

The damage to the medial structures in PLDL might be more severe compared with the lateral and contralateral sides in PMDL. Therefore, we assumed that different approaches are needed according to the type of dislocation and the degree of soft tissue injury. The purpose of this study was to introduce a treatment strategy for acute unstable elbow dislocation by the direction of dislocation and the severity of soft tissue injury and to report the radiologic findings.

Materials and methods

In this retrospective case series investigating treatment strategies for unstable elbow, we reviewed 56 patients diagnosed with a simple elbow dislocation who underwent MRI. From January 2012 to August 2017, data pertaining to 50 patients with PLDL and 6 cases of PMDL were retrieved. MRI scans were obtained for target patients who were thought to be unstable on the basis of radiographs after closed reduction or who manifested a clinically high-energy trauma for elbow dislocation. Plain radiographs, MRI, and medical records of patients were retrospectively reviewed. MRI equipment included Intera 1.5T and Achieva 1.5T (Philips, Eindhoven, The Netherlands) and Titan 1.5T (Toshiba, Tokyo, Japan). T1, T2, and T2-weighted fat suppression MRI sequences in axial, sagittal, and coronal planes based on the long axis of the humerus were acquired, with the affected elbow in a long arm splint (60°-90° of flexion, depending on the degree of pain and swelling).

Indication for examination under anesthesia (EUA)

Patients with significant asymmetric widening of radiocapitellar or ulnohumeral joints in simple radiographs or complaining of an unstable sensation after closed reduction were indicated for EUA. In case of PMDL, EUA was performed because it may be unstable after closed reduction in many cases as already documented.[3,12] PMDL is diagnosed radiologically before manual reduction or by MRI findings after closed reduction. Medial bone contusion (MBC) observed at the medial trochlea or proximal ulna (Fig. 3, *B*) and distraction-type LCLC (Fig. 1, *G*) injury based on MRI findings may also facilitate the diagnosis of PMDL. PLDL with a medial complex dual lesion was another indication for EUA. PLDL may also be distinguished by radiography before reduction or by MRI findings of lateral bone contusion (LBC) observed in the posterior capitellum or radial head (Fig. 3, *A*). A concurrent injury involving both UCL and the flexor-pronator muscle group (Fig. 2) may trigger damage to the dynamic and static stabilizers on the medial side of the elbow joint, suggesting the need for evaluation of the stability with EUA.

EUA and treatment algorithm for surgical repair

In EUA, redislocation or subluxation within the range of full flexion to 30°-40° during passive range of motion exercise under general anesthesia or regional block was also considered an acute unstable elbow warranting surgical treatment.

A treatment algorithm based on a new posterior elbow dislocation mechanism[12] was separately used in this study according to the type of dislocation, as shown in Figures 4 and 5.

Surgical treatment of PLDL

A manual valgus stress test was performed initially to evaluate the need for UCL repair in patients with PLDL. The manual valgus stress test was performed at 30°-40° of elbow flexion with forearm in pronation.

In patients with a stable medial side during the manual valgus stress test, usually only the UCL was torn without rupture of the overlying flexor-pronator muscles, and only the LCLC was repaired. In the absence of a firm end point or dislocation during the valgus stress test, the UCL was repaired first. The stability of the elbow joint was then re-evaluated during the range of motion test. No repair of LCLC was performed if a stable elbow joint was obtained. However, if dislocation recurred after UCL repair, additional repair of LCLC was performed (Fig. 4). Further interventions, such as anterior capsule repair or external fixation, were not indicated in any case after surgical repair bilaterally. All torn ligaments including flexor-pronator and extensor muscles were reattached to their origin with 1 or 2 suture anchors (Mitek; DePuy, Raynham, MA, USA). In case of midsubstance tear, the ruptured ligament and muscles were primarily repaired and augmented with a suture anchor. During surgical repair of the

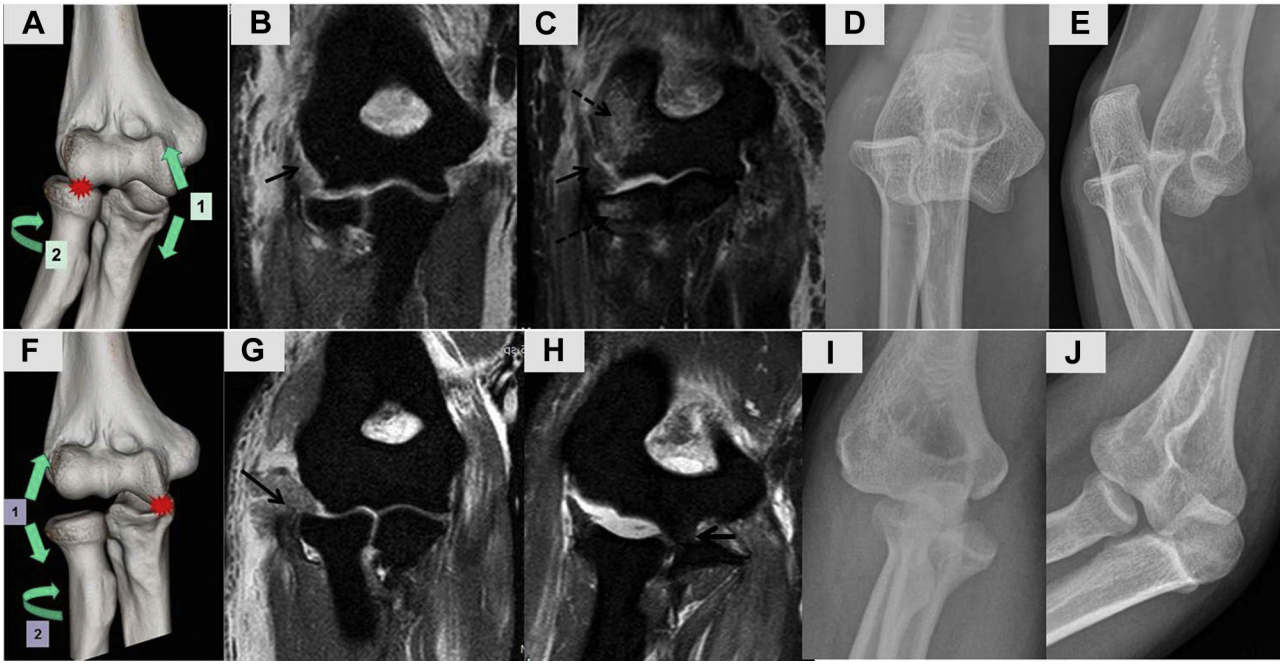

Figure 1 (**A-E**) In a typical posterolateral type of elbow dislocation (**D, E**), lateral collateral ligament complex and overlying extensor muscles are peeled off the lateral epicondyle by sequential forearm external rotation force (*2*) accompanying valgus force (*1*) to produce stripped injury (**B** and **C,** →). Lateral bone contusions caused by the abutment of radial head against the posterior capitellum (**C,** ⇢) are observed. (**F-J**) By contrast, in a typical posteromedial dislocation (**I, J**), the initial varus force (*1*) causes tension failure of the lateral collateral ligament complex and overlying extensor muscles to produce distraction-type injury (**G,** →). During varus force and sequential forearm external rotation (*2*), the medial bone contusion is due to the impact of medial trochlea and medial proximal ulna (**H,** →).

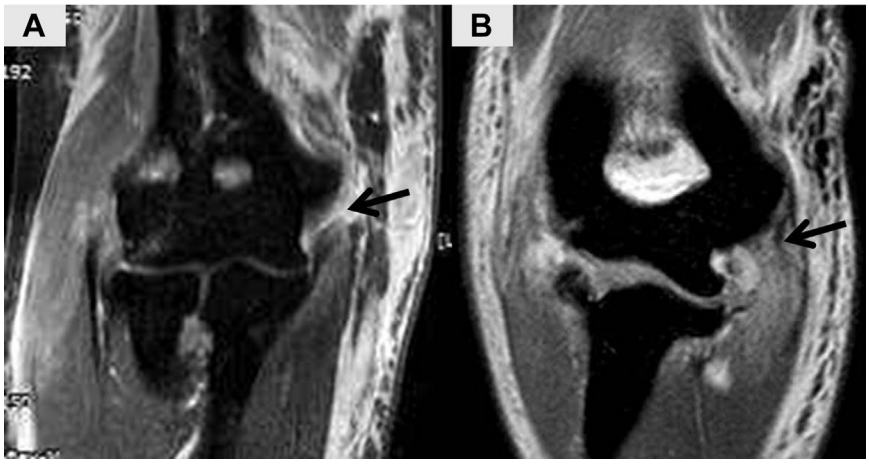

Figure 2 (**A**) Complex dual lesion (→) presenting with combined ruptures of the ulnar collateral ligament and overlying flexor muscles. (**B**) Isolated ulnar collateral ligament rupture and strain of flexor-pronator muscle (→).

UCL and overlying flexor-pronator muscle, the cubital tunnel was released in situ.

Surgical treatment of PMDL

Patients with PMDL underwent repair for LCLC with OEMs as the first step because the prognosis was poor for the distraction-type injury of LCLC.[3,12] Subsequently, the stability of the elbow joint was re-evaluated during the range of motion test. In case of a stable elbow joint, no additional repair of ligaments, such as UCL, was performed. However, any redislocation after LCLC repair prompted additional UCL repair (Fig. 5).

Postoperative management

The immobilization position was set according to the type of ligament repaired. In case of UCL repair alone, the forearm was set at supination; whereas for LCLC repair only, the forearm was set at pronation. If both sides were repaired, the forearm was set to neutral position. A hinge brace was applied after 5 to 7 days of immobilization, and active assisted range of motion exercise for

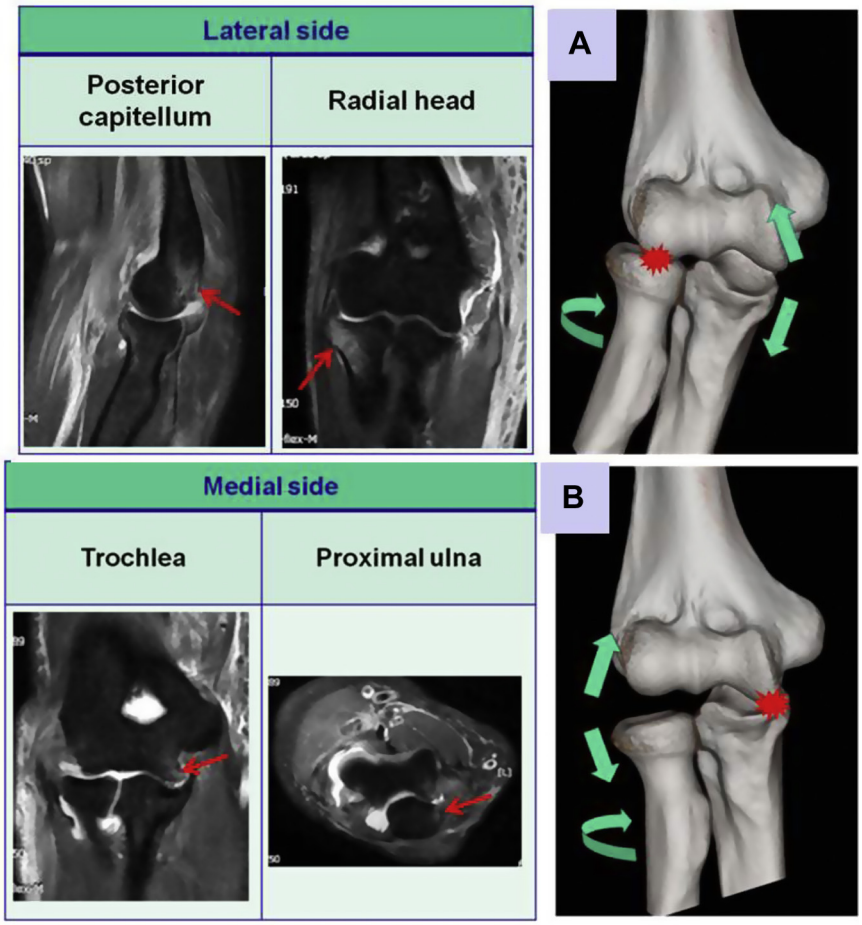

Figure 3 (**A**) Lateral bone contusion caused by abutment of the radial head against the posterior capitellum (→) during the typical progress of posterolateral dislocation of elbow joint by the initial valgus force and sequential accompanying forearm external rotation force. (**B**) Medial bone contusion caused by abutment of medial side of the proximal ulna against the posteromedial trochlea (→) during the typical progress of posteromedial dislocation of elbow joint by the initial varus force followed by forearm external rotation force.

the elbow joint was allowed as tolerated to protect repaired ligaments. After 6 weeks, the hinge brace was used intermittently until 12 weeks. At 3 months, return to active daily living and occupational activities were allowed without the brace.

Simple radiographs of 4 views of the elbow joint were routinely obtained postoperatively at 1 week, 2 weeks, 6 weeks, 3 months, 6 months, and 1 year and then yearly thereafter. An asymmetric widening of joint space and joint incongruency were evaluated, and any arthrosis or ectopic ossification was identified on postoperative simple radiographs. Arthrosis was evaluated using the Broberg and Morrey (B-M) method.[2] Ectopic ossification was evaluated around medial or lateral epicondyles in 4 views of the elbow joint.

Functional outcomes were evaluated using the Mayo Elbow Performance Score (MEPS), the shortened Disabilities of the Arm, Shoulder, and Hand questionnaire (QuickDash), and elbow range of motion.

Statistical analysis

After surgery, the functional outcomes of PLDL and PMDL including B-M grading were compared using a *t*-test. The effect of ectopic ossification on functional outcomes and the frequency of bone contusion in PLDL compared with that of PMDL were evaluated using *t*-test. Statistical significance was considered at $P < .05$.

Results

EUA was performed in 22 of 56 patients. All 5 patients with PMDL and 9 patients with PLDL carrying a medial dual complex lesion underwent EUA. Eight PLDL patients without medial dual complex lesion manifesting an asymmetric widening of elbow joint or reporting subjective elbow joint instability after reduction were also indicated for EUA. Only 1 case of PLDL without medial complex dual lesion was stable during EUA and was excluded from surgical treatment. Finally, the remaining 21 cases (16 cases of PLDL and 5 cases of PMDL) were diagnosed with acute unstable elbow warranting surgical intervention (Table I).

PLDL

Patients with PLDL included 9 men and 7 women with a mean age of 46 years (range, 20-62 years). The right elbow

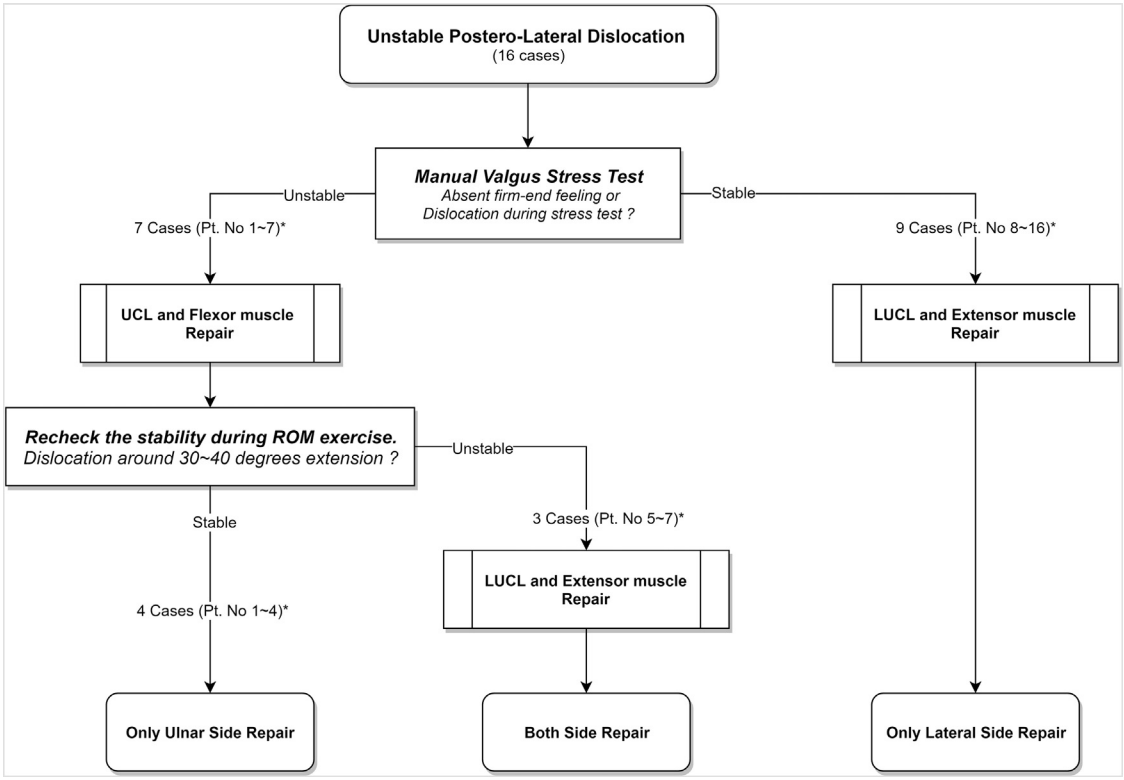

Figure 4 Treatment algorithm for unstable posterolateral dislocation of the elbow joint. *UCL*, ulnar collateral ligament; *LUCL*, lateral ulnar collateral ligament; *ROM*, range of motion. *Patient number noted in Table I.

was involved in 10 cases, and the left elbow was involved in 6 cases. Causes of injury included slip (n = 8), fall from a height (n = 3), sports accidents (n = 3), traffic accidents (n = 1), and industrial accidents (n = 1). The mean follow-up duration was 41 months (range, 12-69 months; Table II).

The 16 cases of PLDL included 9 cases without instability on manual valgus stress testing under anesthesia that underwent only LCLC and OEM repair. In the remaining 7 cases with valgus instability, UCL and flexor-pronator muscle repair were performed first. Additional lateral-side repair was performed in 3 cases presenting with instability after UCL repair (Fig. 4).

PMDL

Patients with PMDL included 2 men and 3 women with a mean age of 43 years (range, 36-54 years). Two cases involved the right elbow; the left elbow was involved in 3 cases. Causes of injury included slip (n = 4) and industrial accidents (n = 1). The mean follow-up duration was 40 months (range, 13-59 months; Table II).

All 5 cases of PMDL underwent LCLC and OEM repair initially. UCL and flexor-pronator muscle repair was not indicated in any case (Fig. 5).

In 20 (15 cases of PLDL and 5 cases of PMDL) of 21 cases, patients were evaluated as outpatients; the remaining 1 patient (1 case of PLDL) was followed up by telephone interview.

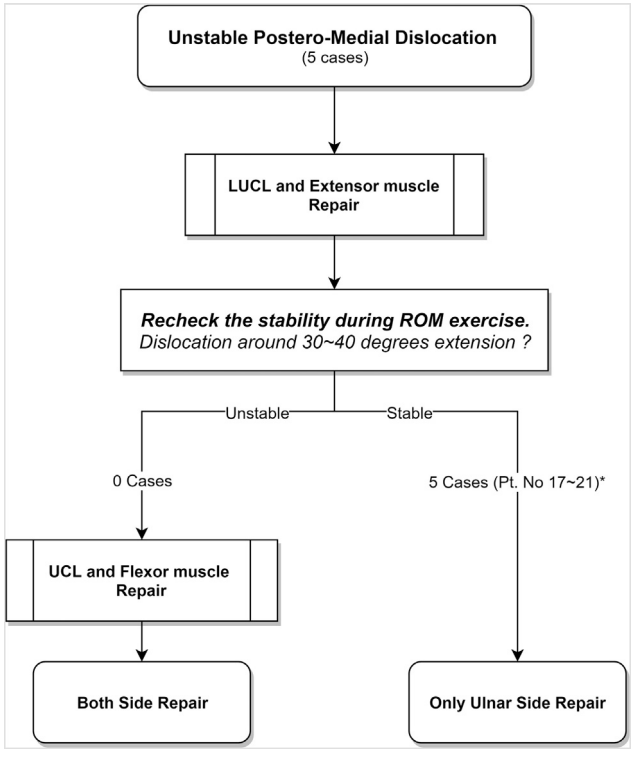

Figure 5 Treatment algorithm for unstable posteromedial dislocation of the elbow joint. *LUCL*, lateral ulnar collateral ligament; *ROM*, range of motion; *UCL*, ulnar collateral ligament. *Patient number noted in Table I.

Table I Summary of patients' demographics, MRI findings, surgical procedure, and functional outcomes

Patient	Sex/age (yr)	Laterality	Direction	Soft tissue injury					Bone contusion				Surgical treatment	Follow-up (mo)	Functional outcomes		ROM (°)			
				Ulnar side		Radial side			Ulnar side		Radial side									
				UCL	Flexor	LUCL	Extensor	Injury type	MT	PU	PC	RH			MEPS	DASH	Flex	Ext	Pro	Sup
1	M/37	L	PL	CR	CR	CR	CR	S	No	No	*Yes*	*Yes*	UCL only	12	85	20.5	130	0	80	90
2	M/48	L	PL	CR	CR	CR	CR	S	No	No	No	No	UCL only	38	100	0.0	140	25	75	90
3	F/58	R	PL	CR	CR	CR	CR	S	No	No	No	No	UCL only	33	85	2.3	135	0	60	90
4	F/61	R	PL	CR	CR	CR	CR	S	No	No	*Yes*	No	UCL only	62	100	0.0	140	0	60	90
5	M/20	R	PL	CR	CR	CR	CR	S	No	No	*Yes*	*Yes*	UCL and LCLC	31	NA	0.0	NA	NA	NA	NA
6	M/55	R	PL	CR	CR	CR	CR	S	No	*Yes*	No	No	UCL and LCLC	69	85	NA	125	0	75	90
7	F/62	R	PL	CR	CR	CR	CR	S	No	No	*Yes*	No	UCL and LCLC	19	85	0.0	140	0	80	90
8	F/39	R	PL	CR	CR	CR	CR	S	No	No	No	*Yes*	LCLC only	58	100	0.0	140	10	65	90
9	F/45	R	PL	CR	CR	CR	CR	S	No	No	*Yes*	*Yes*	LCLC only	60	100	9.1	140	0	75	90
10	M/27	R	PL	CR	PR	CR	CR	S	No	No	*Yes*	*Yes*	LCLC only	76	100	0.0	140	0	70	90
11	M/32	L	PL	CR	PR	CR	CR	S	No	No	*Yes*	No	LCLC only	60	100	0.0	140	0	80	90
12	M/42	L	PL	CR	PR	CR	CR	S	No	No	*Yes*	No	LCLC only	43	100	0.0	140	0	75	90
13	M/51	L	PL	CR	PR	CR	CR	S	No	No	*Yes*	No	LCLC only	60	85	15.9	140	0	70	90
14	M/58	R	PL	CR	PR	CR	CR	S	No	No	*Yes*	*Yes*	LCLC only	16	85	4.6	135	0	75	90
15	F/49	L	PL	CR	PR	CR	CR	S	No	No	*Yes*	No	LCLC only	16	85	2.3	140	0	75	90
16	F/50	R	PL	CR	PR	CR	CR	S	No	No	*Yes*	*Yes*	LCLC only	60	85	0.0	140	0	70	90
17	F/42	L	PM	CR	CR	CR	CR	D	*Yes*	*Yes*	No	No	LCLC only	52	100	0.0	140	0	80	90
18	M/43	R	PM	CR	PR	CR	CR	D	*Yes*	No	No	No	LCLC only	55	100	0.0	140	0	75	90
19	F/36	R	PM	CR	PR	CR	CR	D	*Yes*	*Yes*	No	No	LCLC only	13	75	13.6	140	25	65	90
20	F/54	L	PM	CR	PR	CR	CR	D	*Yes*	*Yes*	No	No	LCLC only	43	100	0.0	140	10	75	85
21	M/38	L	PM	PR	PR	CR	CR	D	*Yes*	No	No	No	LCLC only	33	85	18.2	135	5	75	90

MRI, magnetic resonance imaging; *ROM*, range of motion; *UCL*, ulnar collateral ligament; *LUCL*, lateral ulnar collateral ligament; *MT*, medial trochlea; *PU*, proximal ulna; *PC*, posterior capitellum; *RH*, radial head; *MEPS*, Mayo Elbow Performance Score; *DASH*, Disabilities of the Arm, Shoulder, and Hand; *Flex*, flexion; *Ext*, extension; *Pro*, pronation; *Sup*, supination; *PL*, posterolateral dislocation; *PM*, posteromedial dislocation; *CR*, complete rupture; *PR*, partial rupture; *S*, stripping; *D*, distraction; *NA*, not available.

Table II Patients' demographic data

	PLDL	PMDL
No. (total)	16	5
Sex (male:female)	9:7	2:3
Affected side (R:L)	10:6	2:3
Age (yr)	46 ± 12.3	43 ± 7.0
Follow-up period (mo)	45 ± 21.2	39 ± 17.0

PLDL, posterolateral dislocation; *PMDL*, posteromedial dislocation. Continuous variables are presented as mean ± standard deviation.

The overall MEPS was assessed in 20 (95.3%) patients, with a mean value of 92 (range, 75-100). The mean QuickDASH score was 4.3 (range, 0.0-20.5) in 20 (95.3%) patients at an average follow-up of 43 months (range, 12-76 months; Table III). In terms of the range of motion, the mean flexion was 138° (range, 120°-140°), extension was 4° (range, 0°-25°), pronation was 73° (range, 60°-80°), and supination was 90° (range, 85°-90°). The MEPS and QuickDASH score were 92 (range, 85-100) and 3.6 (range, 0.0-20.5) in the PLDL group and 92 (range, 75-100) and 6.4 (range, 0.0-18.2) in the PMDL group, respectively. Postoperative radiographs were obtained in 19 (90.5%) of 21 cases at a mean of 44 months (range, 12-76 months). The B-M grading[2] revealed arthritic changes in 16 patients at stage 0 and in 3 patients at stage 1. Based on the *t*-test, the B-M grading was statistically insignificant for MEPS ($P = .059$) and QuickDASH ($P = .656$). No ulnar nerve symptoms were observed preoperatively or at the final follow-up. In 4 cases undergoing PLDL repair only on the ulnar side, no posterolateral rotatory instability was detected. Arthrolysis was performed in only a single case 6 months after primary surgery (patient 19), and no case required additional surgery or manifested specific complications.

The MRI scan revealed LBC in 13 (81.2%) cases in the PLDL group, including 6 cases involving the posterior capitellum, 1 case involving the radial head alone, and 6 cases bilaterally; MBC was observed in a single (6%) case. In the PMDL group, MBC was observed in 5 (100%) of 5 cases (2 cases involving the posteromedial trochlea, none involving the medial side of proximal ulna, and 3 cases involving both sides); no LBC was observed. Statistically significant differences were found in the frequencies of LBC ($P = .003$) and MBC ($P < .001$) in PLDL and PMDL groups based on χ^2 test (Table IV).

Table III Result of treatment

	PLDL	PMDL
No. (total)	16	5
Surgical treatment		
Lateral only repair	9	5
Medial only repair	4	0
Both sides	3	0
Functional scores		
MEPS	92 (±7.5)	92 (±10.3)
QuickDASH	3.6 (±6.3)	6.4 (±7.9)
ROM of elbow (°)		
Flexion	138 (±4)	139 (±2)
Extension	2 (±7)	8 (±9)
Supination	72 (±6)	74 (±5)
Pronation	90 (±0)	89 (±2)

PLDL, posterolateral dislocation; *PMDL*, posteromedial dislocation; *MEPS*, Mayo Elbow Performance Score; *QuickDASH*, shortened Disabilities of the Arm, Shoulder, and Hand; *ROM*, range of motion. Continuous variables are presented as mean (± standard deviation).

Table IV Evaluation of MRI findings

	PLDL	PMDL
No. (total)	16	5
Lateral structure		
Soft tissue injury		
LCLC injury (complete/partial)	16/0	5/0
Extensor muscle group (complete/partial)	16/0	5/0
Type of injury (stripping/distraction)	16/0	0/5
Bone contusion		
Posterior capitellum	12 (75.0%)	0 (0.0%)
Radial head	7 (43.8%)	0 (0.0%)
Medial structure		
Soft tissue injury		
UCL injury (complete/partial)	16/0	4/1
Flexor muscle group (complete/partial)	9/7	1/4
Bone contusion		
Medial trochlea	0 (0.0%)	5 (100%)
Proximal ulnar	1 (6.3%)	3 (60.0%)

MRI, magnetic resonance imaging; PLDL, posterolateral dislocation; *PMDL*, posteromedial dislocation; *LCLC*, lateral collateral ligament complex; *UCL*, ulnar collateral ligament.

Based on the injury patterns of LCLC and OEMs, all cases with PLDL showed the stripping type due to peeling damage caused by forearm external rotation force (FERF) administered to the elbow joint. In comparison, the PMDL group showed a distraction type affected by varus force leading to tension failure. Radiologic characteristics varied between the 2 groups.

Discussion

According to the Hori circle describing the mechanism of elbow dislocation reported by O'Driscoll et al[11] in 1992, elbow dislocation originates laterally and progresses medially. However, contradictory findings have been reported since then. A higher incidence of UCL rupture compared with lateral UCL rupture during surgical exploration of simple elbow dislocation has been reported by Josefsson et al,[5-7] suggesting that ruptured UCL preceded elbow dislocation. Sojbjerg et al[15] have studied experimentally induced elbow dislocation and also found that the incidence of UCL rupture was higher than that of lateral UCL rupture. PLDL is the most common elbow dislocation and PMDL is rare.

Based on a new posterior elbow dislocation mechanism reported by Rhyou et al,[12] in the case of the most common PLDL, rupture of UCL is preceded by valgus force on the ulnar side. As a result, the coronoid process is disengaged from the trochlear notch for LCLC and OEM ruptures without fracture of the coronoid process by FERF in the stripping type. Rupture of the UCL has been observed in all patients with PLDL in this study. Considering that the elbow is anatomically cubitus valgus, the axial force applied to the elbow when the palm is grounded is likely to rupture the UCL first by applying a valgus distractive force to the ulnar side of the elbow joint. FERF is applied sequentially after valgus force when the coronoid process is disengaged from the trochlear notch. It induces stripping-type injury while peeling off the LCLC and OEMs from the lateral epicondyle. The posterior dislocated radial head moves to the posterior part of the humerus and collides with the posterior capitellum, resulting in the formation of LBC, the most common type of PLDL (Fig. 6).

In this study, LCLC and OEMs showed stripping-type injury in all cases of PLDL (Table IV). All 12 cases requiring repair of LCLC and OEMs showed at least a partial rupture of the posterior portion of the overlying deep forearm fascia in the surgical field. In 7 cases requiring ulnar-side repair, complex dual lesions of concomitant injuries of the UCL and overlying the flexor-pronator muscle group were more frequently observed compared with those managed by lateral repair alone. LBC was observed in 13 (81%) of 16 cases of PLDL whereas MBC was seen in only 1 (6%) case, which provided a rationale for the proposed treatment strategy and the new dislocation mechanism proposed by the authors.

On the other hand, PMDL is rare because of the anatomic characteristics of the elbow based on the native cubitus valgus alignment. In rare cases, the varus force applied to the elbow joint produces distractive-type injury laterally as a first step of PMDL due to tension failure of LCLC and OEMs, which leads to medial translation of the forearm. FERF applied sequentially leads to posterior mobility of the forearm, resulting in PMDL (Fig. 7). At this time, MBC is triggered by bone collision between the posteromedial trochlea and the medial side of proximal ulna. The degree of medial displacement and rotational

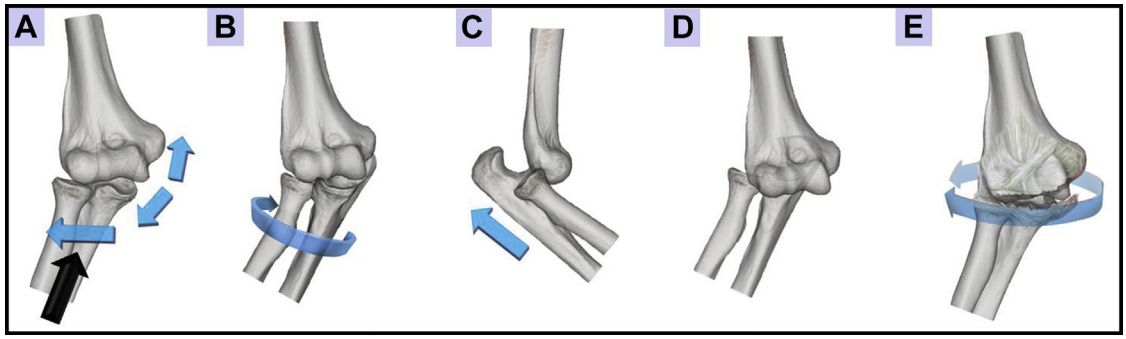

Figure 6 Schematic diagram showing progression of the most common posterolateral dislocation of the elbow joint. (**A**) The axial force (➡) applied along the forearm during slip down produces valgus distractive force at the medial side of elbow joint and lateral translation of forearm (blue arrows) due to anatomic cubitus valgus, causing distractive injury of the ulnar collateral ligament and flexor-pronator muscles, triggering posterolateral dislocation of the elbow joint. (**B**) Accompanying forearm external rotation force (blue arrow) peels off the lateral ulnar collateral ligament and overlying extensor muscles from the lateral epicondyle, causing stripping-type injury at the lateral side. It moves the radial head to the posterior capitellum. (**C**) Continuous applied axial force (blue arrow) moves the forearm posterior to the humerus, during which abutment of the radial head against posterior capitellum induces lateral bone contusion at these loci. (**D**) A posterolateral dislocation of the elbow joint develops as a result. (**E**) The sequence of soft tissue injury (blue arrow) including joint capsule, collateral ligament, and overlying muscles is presented here.

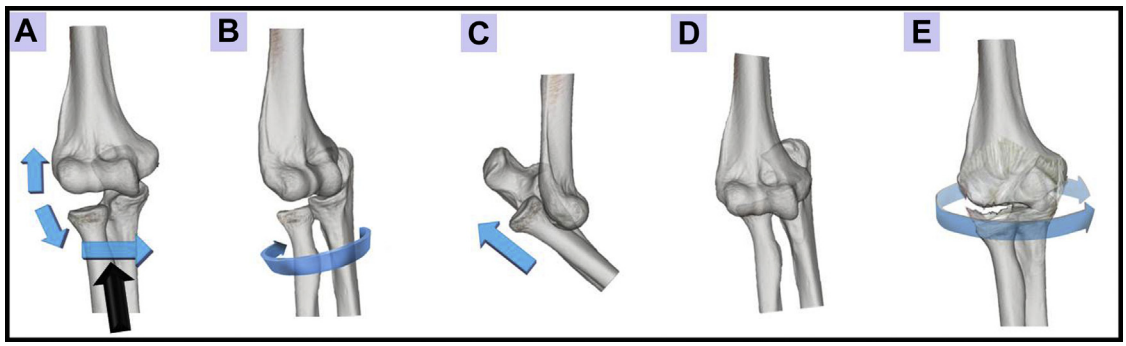

Figure 7 A schematic representation of the progression of rare posteromedial dislocation of the elbow joint. (**A**) The axial force (➡) applied along the forearm during slip down rarely triggers varus force on the elbow joint laterally and forearm medially. It causes distractive injury of the lateral collateral ligament complex and extensor muscles, which triggers posteromedial dislocation of the elbow joint (blue arrows). (**B**) Accompanying forearm external rotation force (blue arrow) moves radial head posterior to the posterior capitellum. (**C**) Continuous applied axial force (blue arrow) relocates the forearm posterior to the humerus, during which abutment of the medial trochlea against medial side of proximal ulna causes medial bone contusion at these loci. (**D**) A posteromedial dislocation of the elbow joint develops. (**E**) The sequence of soft tissue injury (blue arrow) including joint capsule, collateral ligament, and overlying muscles is depicted here.

injury of the forearm is determined by varus force and FERF, which determines whether UCL is intact or torn. In the case of PMDL, because the rupture of LCLC and OEMs is mostly distractive type that results in a continuity failure of these structures under tension, the displaced and torn LCLC and OEMs usually remain displaced from their origin after closed reduction of the dislocated elbow joint. Therefore, it often results in persistent instability warranting surgical repair (Fig. 8). In general, the prevalence of PMDL injury with elbow dislocation is $<10\%$.[3] Therefore, if the degree of surgical necessity is similar, the frequency of surgical treatment is about 10:1 in PLDL and PMDL, theoretically. However, as shown in this report, 16 cases including 5 reported cases (at about 3.2:1) suggest that the need for surgical treatment is much higher in PMDL.

In all cases of PMDL reviewed in this study, distractive types of injury involving LCLC and OEMs were observed on MRI. MBC was also observed in all cases; however, no LBC was detected in any of these cases. The findings were consistent with the mechanism of PMDL suggested by the authors.

The degree of injury during dislocation determines the extent of unstable elbow joint. On the ulnar side, the degree of valgus force determines the degree of damage to the flexor-pronator muscle group, which is a secondary dynamic stabilizer. The flexor-pronator muscle is less likely to be torn because it exhibits a greater excursion compared with UCL. It acts as a secondary dynamic stabilizer in most cases. However, damage to both UCL and flexor-pronator muscles (complex dual lesions)[13] in rare cases increased the risk of elbow joint instability after closed reduction. The forearm deep fascia was less likely to be injured and was more

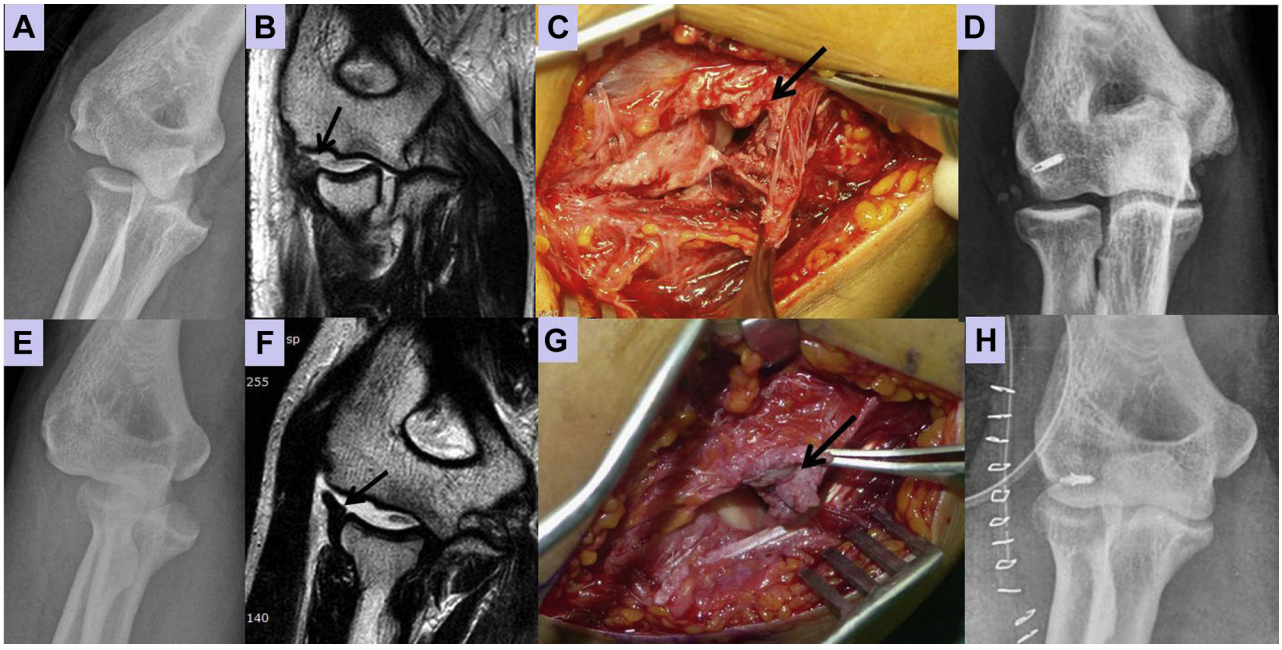

Figure 8 (**A-D**) In this case of posteromedial dislocation, a distracted type (**B,** →) of injury of the lateral collateral ligament complex and overlying extensor muscles is seen on T2-weighted coronal magnetic resonance scan. Intraoperative finding of this injury (**C,** →) is observed. Only lateral repair was performed (patient 28). (**E-H**) Another case of this type of injury (patient 31) shows similar findings on T2-weighted coronal magnetic resonance scan (**F,** →) and intraoperatively (**G,** →). In this case, only lateral repair was performed, resulting in a stable elbow joint (**H**).

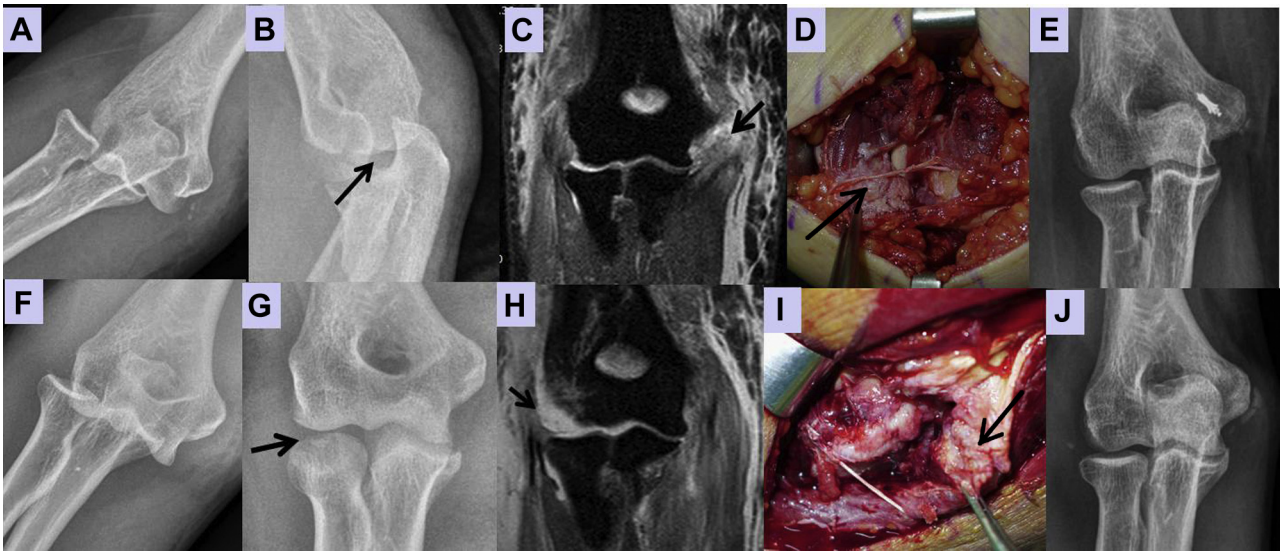

Figure 9 (**A-E**) During unstable posterolateral dislocation, a widening of the ulnohumeral joint space (**B,** →) after closed reduction is observed. A complex dual lesion of the medial side (**C,** →) is detected on T2-weighted fat-suppression coronal view of magnetic resonance scan. Intraoperative finding is consistent with this finding (**D,** →). A stable elbow joint was observed after medial-side repair (patient 18). (**F-J**) Another case of this type of injury (patient 23) shows widened radiocapitellar joint, suggesting unstable elbow joint after closed reduction (**G,** →). The stripped and displaced lateral collateral ligament complex and overlying extensor muscles from the original attachment site of lateral epicondyle are seen on T2-weighted coronal magnetic resonance scan (**H,** →). Intraoperative finding is compatible with this finding (**I,** →). A stable elbow joint was observed after only lateral-side repair, where the soft anchor was used and not detected in a simple radiograph (**J**).

conserved than the underlying LCLC and OEMs after stripping injury in the axial plane due to FERF because of its superficial location, requiring greater rotational displacement and disruption compared with the deeper structure. The fully preserved deep fascia facilitates stabilization of the stripped LCLC and OEMs to the origin after closed reduction. It also allows conservative treatment of the dislocated elbow joint. Therefore, the incidence of posterolateral rotatory instability is rare despite such frequent PLDL of the elbow joint. However, similar to the case involving the ulnar side, if the forearm has a greater FERF and posterior transition, LCLC and OEMs can be severely damaged with concomitant deep fascia damage, leading to complete and combined loss of the static and dynamic stabilizers of the radial side of elbow, prompting surgical treatment (Fig. 9).

The presence or absence of ectopic ossification and the degree of B-M grading[2] were independent of postoperative functional outcomes based on QuickDASH score or MEPS, suggesting the absence of any clinical significance, similar to other reports.[9] All 7 patients with UCL repair had only in situ decompression of the ulnar nerve during surgery, and no ulnar nerve symptoms were observed after surgery.

This study has several limitations. First, the patients in this study were operated on by several surgeons at our center, suggesting wide variation in surgical protocols despite attempts to adjust for the discrepancies. Second, the elbow joint might have been considered overtly unstable for surgical repair because of the effect of brachial plexus anesthesia or general anesthesia while excluding the contribution of dynamic stabilizers. Third, the follow-up period was relatively short, which prevented any study of late complications, such as elbow joint arthrosis. However, the objective of this study was not to determine the criteria for instability of simple elbow dislocation but to suggest a new strategic treatment according to the mechanism of PLDL and PMDL, which is distinct from the objective findings of MRI.

Conclusion

In unstable elbow dislocations, PLDL and PMDL are caused by different mechanisms. Damage to different structures induces instability, prompting the need for different treatment strategies.

Disclaimer

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