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Open Surgical Release of Post-traumatic Elbow Contracture in Children and Adolescents

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Abstract

Background: Post-traumatic elbow contractures in children and adolescents are challenging to manage, and studies investigating surgical treatment are limited by the rarity of this condition. Small case series have shown variable gains in immediate and long-term elbow arc of motion after open surgical release. We reviewed our experience with open surgical release of post-traumatic elbow contracture in patients less than 21 years old at two institutions.

Methods: A retrospective chart review identified patients who underwent post-traumatic open elbow contracture release by two surgeons at two institutions between 2006 and 2013. Non-traumatic contractures and arthroscopic releases were excluded. 26 patients were included in this study. Mean age at the time of injury was 12 years (5–19 years) and at the time of surgery was 14 years (7–20 years). Capsulotomy, osteoplasty, removal of hardware, ulnar nerve release or transposition, and ligament reconstruction were performed through medial and lateral approaches as indicated by the pathology. 10 patients had ligament repair or stabilization, and 16 patients used a CPM post-operatively. Outcomes included active range of motion and complications.

Results: Mean time from injury to surgical release was 29 months. Mean post-operative follow-up was 42 months. Elbow active flexion-extension and forearm rotation arcs both increased significantly by a mean of 49° and 70°, respectively, at final follow-up. A mean 85% of intra-operative flexion-extension arc was maintained at final follow-up. Ligament repair or reconstruction and the use of a postoperative CPM did not significantly change these outcomes. Outcomes were not significantly different if our contracture release was performed within a year from injury. Patients who had surgery prior to our contracture release had decreased restoration of forearm rotation after release. Complications included two recurrent contractures (one used a CPM and one did not), and two post-operative ulnar neuropathies (one used a CPM and one did not).

Conclusions: Open contracture release for post-traumatic elbow contracture in an adolescent population can significantly improve active range of motion.

Level of Evidence: Therapeutic 3

Keywords

Elbow; post-traumatic; contracture; stiffness; open surgical release; arthrolysis; pediatric; children; adolescent

Introduction

Elbow trauma is common in the pediatric and adolescent population and, although rare, persisting post-traumatic elbow stiffness can ensue. Elbow contractures develop in 3% to 6% of children following a supracondylar fracture of the distal humerus and 33% to 100% of children following a fracture of the neck of the radius.^{1,2} While a 100-degree elbow flexion-extension arc and forearm pronation-supination arc of motion have classically been considered adequate for activities of daily living in adults,^{3,4} the functional range of motion in children and adolescents has not been defined. Recent literature suggests that use of modern technology, such as the cellular phone and computer mouse and keyboard, may require additional elbow flexion (142 degrees) and forearm supination (65 degrees) than previously reported.⁴ Children may also participate in activities that require a unique range and total arc of motion, such as terminal extension in pitching and gymnastics. Preservation of forearm rotation is also important for full function, especially sports.

Treatment protocols for elbow contracture in both children and adults begin with physical therapy and bracing. If this fails to improve the contracture sufficiently, surgery may be indicated. While abundant literature on the adult post-traumatic elbow contracture describes its treatment and results, the literature describing post-traumatic stiffness in the pediatric and adolescent elbow is limited to small case series with varying results.^{5–8} The effectiveness of open surgical release of post-traumatic elbow contractures in adolescents remains uncertain, especially in cases where elbow stabilization is necessary after release. We evaluated the elbow and forearm motion after open contracture release in patients less than 21 years old with post-traumatic elbow stiffness and hypothesized that a significant improvement in both elbow and forearm motion can be obtained at surgery and maintained thereafter.

Materials and Methods:

After obtaining institutional review board approval, a retrospective chart review identified 26 patients under the age of 21 years who had undergone post-traumatic open elbow contracture release at two institutions between 2006 and 2013 and had at least one year of follow-up after surgery. Patients were identified by querying the medical records at each institution using the ICD-9 diagnosis code for contracture of elbow joint (718.42) as well as the CPT code for contracture release (24006). Non-traumatic contractures, osteochondritis dissecans, and arthroscopic releases were excluded. Patients with post-traumatic elbow contractures successfully treated by non-operative means were excluded.

All 26 of the patients included in this study developed an elbow contracture after acute trauma. 15 patients were male and the mean age at the time of injury was 12 years (5–19 years). 23 patients had a fracture of the radial head, proximal ulna, and/or the distal humerus; six of these had an elbow fracture dislocation and three had a simple dislocation.

15 were treated surgically at an outside hospital prior to their initial visit at our institution (Table 1). None of the patients had concurrent wrist or shoulder injuries. There were no nerve palsies.

All patients had plain radiographic evaluation of the elbow. If there was evidence of a complex malunion or abundant heterotopic ossification, a three-dimensional computer tomography scan was obtained to better localize the pathology and allow for surgical planning. Upon presentation to our institutions, all patients were treated initially with a full course of physical therapy and static progressive or dynamic bracing. This was continued until gains in range of motion had plateaued, typically by four months after bracing initiation. Our indication for surgery was a failure to attain functional range of motion, as defined by the needs of each patient, in either the flexion-extension or supination-pronation arc after completing non-operative treatment. The mean interval from injury to contracture release surgery was 29 months (6–120 months). Mean age at the time of surgery was 14 years (7–20 years) (Table 1). All patients were operated on by one of two senior surgeons.

Surgical technique

Pre-operative and intra-operative (after release) range of motion was recorded in all cases with the use of a goniometer. All surgeries were performed under general anesthesia with a sterile tourniquet. Either a lateral column approach or a medial over the top approach (or a combination of the two) was utilized in all cases.^{9–11} Surgical exposure was dictated by the location of the pathology. When possible, prior incisions were used. During the approach, care was taken to protect medial and lateral ligamentous structures. Anterior and posterior capsulectomies were performed sharply. Osteoplasties of the coronoid, coronoid fossa, olecranon fossa, and radial neck were performed as needed in patients of all ages, maintaining awareness of cartilage surfaces and physes. Heterotopic ossification was excised and prominent implants were removed. If the patient had less than 90 degrees of flexion or preoperative ulnar neuropathy, then the ulnar nerve was released or transposed. Transposition was performed in nine patients, and decompression in two patients. Transposition was performed if the nerve was noted to subluxate over the medial epicondyle at any point during a full range of motion. The posterior MCL was released in all 11 of those patients. No musculotendinous lengthenings were necessary.

A stability examination under anesthesia was performed at the start and conclusion of each surgery, which included a fluoroscopic lateral exam through a full range of motion to confirm a congruent joint, varus and valgus stress testing, a hanging arm test, and a pivot shift test. If instability was encountered, the lateral ulnar collateral ligament (LUCL) and medial collateral ligament (MCL) were repaired or reconstructed with autograft or allograft tendon using either bone tunnels or bio-interference screws (Arthrex, Naples, FL, USA).^{12,13} A hinged external fixator (Stryker DJD II, Kalamazoo, MI, USA), was used in elbows in which both ligaments were reconstructed (two patients, Table 1).¹⁴ The external fixator allowed full elbow flexion and extension and was removed in the OR at the sixth post-operative week. If the radial head had plastic deformity or malunion that blocked forearm rotation, it was excised or replaced (Tornier or Acumed, Hillsboro, OR, USA). This is an off-label use of radial head arthroplasty, however one of the senior authors will perform

radial head arthroplasty in adolescents with closed physes in select cases of overgrown radial heads with elbow instability.

After surgery, patients were treated with an indwelling nerve catheter and intravenous pain medication managed by the pain service while in the hospital. After one to two days in non-CPM patients, and three to four days in CPM patients, the patient was transitioned to oral pain medications for discharge.

If heterotopic ossification was the primary cause of the patient's contracture, then post-operative indomethacin was prescribed with weight-based dosing for six weeks. Radiation was not used for prophylaxis based on the National Cancer Institute's recommendation that no radiation should be used in children and adolescents.⁷

Post-operative Rehabilitation Protocol, No CPM Group

Outpatient therapy began on post-operative day two to five. Our therapy protocol included active and passive elbow and forearm range of motion and aggressive edema control (with an upper extremity therapist). Nighttime static splinting began immediately after surgery and continued for approximately 12 weeks. After 2–4 weeks, patients without full range of motion were treated with a static progressive bracing program. In patients with notable lack of extension, nighttime extension splinting was utilized with aggressive active and passive daytime motion for flexion. In patients demonstrating difficulty maintaining motion in both directions, static progressive splinting was utilized for both flexion and extension. Patients who underwent ligament repair or reconstruction were stabilized in a hinged elbow brace, which allowed range of motion from 30 degrees to full flexion in order to protect the newly reconstructed LUCL from the increased stress that occurs in full extension. Forearm rotation exercises were allowed with the elbow stabilized at 90 degrees of flexion.

Post-operative Rehabilitation Protocol, CPM Group

The CPM was implemented on post-operative day one and continued during the three to five day hospital stay (Artromot CPM, DJO Global, Vista, CA, USA; which allows both flexion/extension and pronation/supination as combined motions). Patients were discharged with the CPM, which was used for two to four weeks, depending on patient compliance, soft tissue swelling and availability of an experienced therapist near the patient's home. With patients that live locally, formal therapy was initiated at discharge and continued until maximum range of motion was achieved. In patients without known therapy in the community, the post-operative protocol consisted only of CPM and static progressive bracing until the patient was seen again at four weeks after surgery. If the soft tissues were soft and pliable at that time, then outpatient therapy was initiated.

Primary outcomes included gains in active range of motion at final follow up, percent of intra-operative range of motion maintained, and complications. Active and passive (intra-operatively only) range of motion in elbow flexion-extension and forearm supination-pronation, were measured with a goniometer by the surgeon or physical therapist at each time point. Elbow flexion-extension and forearm rotation represent the function of separate joints, and ideally our study would include independent analyses of these two arcs of motion. However, only 3 patients had isolated supination-pronation gains; which did not

provide adequate power for a formal subgroup analysis. Nearly all of our patients had limitations and subsequent gains in both flexion-extension and supination-pronation arcs concurrently, therefore we felt it was important to include both of these range of motion variables, rather than focusing only on one.

A student T-test with $P < .05$ was used to determine significant differences between groups.

Results:

Mean post-operative follow-up was 42 months (12–108 months). Elbow active flexion-extension and supination-pronation arcs both increased significantly at final follow-up: by a mean increase of 49 degrees in flexion-extension (increasing from a mean pre-operative arc of 58 degrees to a mean post-operative arc of 107 degrees, $P < .0001$) and a mean increase of 70 degrees in supination-pronation (increasing from a mean pre-operative arc of 66 degrees to a mean post-operative arc of 131 degrees, $P = .01$) (Table 2, Appendix). A mean 85% of intra-operative flexion-extension arc was maintained at final follow-up.

Outcomes in Patients who had Undergone Prior Surgery

15 patients had surgery prior to presenting to our institutions (either at the time of injury or a subsequent contracture release). Three of these patients had a previous surgery to treat elbow stiffness (two open and one arthroscopic contracture releases). Average age at injury (11 and 12 years) and age at surgery (13 and 14 years) were similar between those patients who had and who had not had surgery prior to presenting to our institution. 12 patients underwent contracture release at our institution within six to 12 months after injury, and 14 patients within 14–120 months after injury. Increases in arc of motion were not significantly different if the contracture release was performed within a year from injury (flexion-extension arc 55 degrees vs. 43 degrees, respectively, $P = .2$; supination-pronation arc 84 degrees vs. 56 degrees, respectively, $P = .03$; and maintenance of intra-operative flexion-extension arc 82 degrees vs. 87 degrees, respectively, $P = .3$). Average length of follow up was 49 months (12–108 months) in the group with prior surgery and 33 months (12–84 months) in the group without. Range of motion gains were not significantly different in those patients (flexion-extension arc 45 degrees with prior surgery vs. 53 degrees without, $P = .3$, and maintenance of intra-operative flexion-extension arc 83 degrees with prior surgery vs. 87 degrees without, $P = .3$). Forearm rotation was worse in the previously operated group (supination-pronation arc 43 degrees with prior surgery vs. 97 degrees without, $P = .03$) (Table 2).

Outcomes in Patients Undergoing Ligament Repair or Reconstruction

10 patients required repair or reconstruction of one or both of the primary elbow ligaments (LUCL, MCL). Average age at injury was 11 years in those with ligament surgery and 12 years in those without, and age at surgery was the same (14 years). Average time from injury to surgery was 32 months in those with ligament surgery and 27 months in those without. Average length of follow up was 34 months (12–72 months) in the group with ligament surgery and 48 months (12–108 months) in the group without. Range of motion gains were not significantly different in those patients (flexion-extension arc 41 degrees with ligament surgery vs. 53 degrees without, $P = .2$, supination-pronation arc 69 degrees with ligament

surgery vs. 72 degrees without, $P=.5$, and maintenance of intra-operative flexion-extension arc 83 degrees with ligament surgery vs. 86 degrees without, $P=.4$).

Three patients (two 14-year-olds and one 18-year-old) were treated with radial head arthroplasty in the setting of radial head deformity and elbow instability. Long-term follow-up is not yet available for these patients (patients 7, 8 and 13 in our tables), however is something we plan to further investigate.

Outcomes in Patients that Used a CPM

A CPM was used in 16 patients. The use of a postoperative CPM did not significantly change the increase in flexion-extension arc (47 degrees with vs. 52 degrees without CPM, $P=.4$), supination-pronation arc (74 degrees with vs. 61 degrees without CPM, $P=.4$), or maintenance of intra-operative flexion-extension arc (84 degrees with vs. 85 degrees without CPM, $P=.5$) (Table 2).

17 patients (65%) regained a functional 100-degree flexion-extension arc at final follow up (11 patients [69%] in the CPM group and six patients [60%] in the group without CPM). Three of those that did not gain a greater than 100-degree arc of flexion and extension, however, gained significant motion in the supination-pronation arc (all in the CPM group).

Complications occurred in three patients. One patient in the CPM group developed both recurrent contracture and ulnar neuropathy. One patient in the group without CPM developed a recurrent contracture and one developed post-operative ulnar neuropathy. There were no post-operative infections or other complications noted.

Discussion

Our study shows a significant increase in and maintenance of both elbow and forearm range of motion after open release of post-traumatic elbow contractures in adolescents at minimum one year from release. The gains in active arc of motion achieved at final follow up (49 degrees elbow flexion-extension and 70 degrees forearm rotation) are substantial enough to positively impact upper extremity function. These findings are consistent with literature demonstrating that open release is a viable option for children and adolescents with post-traumatic contractures that have failed conservative treatment. Several small studies focused specifically on pediatric and adolescent post-traumatic elbow stiffness have shown sustained gains in range of motion after open surgical release (these are summarized in Table 3).⁵⁻⁸ All of these groups used either lateral or medial approaches, or both, and addressed both soft tissue and bony pathology. Only two patients out of all four studies required ligament repair (both MCL),⁶ therefore no prior study of pediatric elbow contracture release has been able to evaluate the effects of ligament reconstruction on contracture release. Our study represents one of the largest studies to date of post-traumatic elbow contracture in pediatric and adolescent patients, and has the benefit of including a heterogeneous population from two institutions and two surgeons' protocols. This heterogeneity in patient population represents a common finding in elbow stiffness in this age group; while some patients have a capsular contracture alone, many others also have heterotopic ossification and ligament pathology.

Patients with prior surgery, either at the time of injury or through a previous contracture release at an outside institution, attained and maintained a comparable flexion-extension arc to those without prior surgery. However, these children had significantly less improvement in forearm rotation. Surgeons and institutions with an established approach to elbow stiffness should, based on these results, expect a notable improvement in the flexion-extension arc after a revision procedure.

Elbow stiffness can mask elbow instability, and it is crucial to recognize and treat instability uncovered intra-operatively by the contracture release.¹³ This is accomplished through repair or reconstruction of the LUCL and/or MCL as indicated. In our study population, elbow stabilization (including application of an external fixator) did not significantly impact gains in, or maintenance of, elbow or forearm range of motion. While our sample size is small, our findings suggest that surgeons should not be concerned that ligament repair or reconstruction to treat instability identified after contracture release will lead to poorer range of motion outcomes.

All previous studies of pediatric elbow contracture release included a rehabilitation program with four to six weeks of CPM use for at least 12 hours per day, along with physical therapy and bracing. In adults, the use of a post-operative CPM remains controversial. There have been no randomized, prospective studies comparing outcomes after elbow contracture release with or without CPM in either adults or children. Current studies show variable results in adults, but suggest that there is not a strong benefit to the use of CPM.^{15,16} The application of this information to the pediatric population remains unclear. In our small series, there was no significant difference in any outcome measure between children treated with or without a CPM at final follow up. Although there was no significant difference between these two groups, the CPM group may have had more complex injury patterns, since more of these patients required ligament surgery (11 patients in the CPM group versus two patients in the group without CPM). Of the two patients with recurrent contracture, one did not use a CPM and one did. Interestingly, the patient in the CPM group had recurrence in the flexion-extension arc, while the one in the group without CPM had recurrence in the supination-pronation arc. Our heterogeneous population of patients does not allow firm conclusions regarding the use of CPM, and further study is warranted to further assess the effectiveness of CPM use in this population.

There are several limitations to our study. First, and most notably, we have a small sample size with heterogeneity of pathology. This is the nature of elbow stiffness patients and will limit any such study.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Appendix:: Range of Motion Values

Patient	Pre-op Flexion (°)	Intra-op Flexion (°)	Post-op Flexion (°)	Pre-op Extension (°)	Intra-op Extension (°)	Post-op Extension (°)	Flex-Ext Arc Pre-op (°)	Flex-Ext Arc Intra-op (°)	Flex-Ext Arc Post-op (°)	Pre-op Pronation (°)	Post-op Pronation (°)	Pre-op Stipulation (°)	Post-op Stipulation (°)	Pre-Sup Arc Pre-op (°)	Pre-Sup Arc Post-op (°)
1	90	138	110	60	0	20	30	138	90	0	90	70	90	70	180
2	65	138	115	55	0	10	10	138	105	15	20	45	60	60	80
3	65	130	140	55	22	50	10	108	90	15	80	45	75	60	155
4	90	110	122	10	0	0	80	110	122	60	60	60	90	120	150
5	90	124	124	55	32	30	35	92	94	90	90	90	90	-	-
6	105	130	125	15	0	5	90	130	120	90	60	90	60	-	-
7	145	*	135	30	*	15	115	*	120	10	90	10	90	20	180
8	70	135	115	60	0	0	10	135	115	0	80	0	80	0	160
9	135	130	135	50	15	30	85	115	105	70	90	70	90	140	180
10	135	135	145	50	0	0	85	135	145	80	80	80	80	-	-
11	80	140	130	25	0	0	55	140	130	80	80	80	80	-	-
12	100	120	105	40	10	20	60	110	85	60	55	90	90	-	-
13	125	140	130	70	0	28	55	140	102	35	60	25	55	60	115
14	100	135	92	60	22	58	40	113	34	50	84	10	30	60	114
15	120	*	138	30	*	12	90	*	126	90	84	45	50	135	134
16	125	135	130	50	30	30	75	105	100	70	85	85	85	155	170
17	135	135	135	0	0	0	-	-	-	Fixed	50	Fixed	45	0	95
18	135	*	135	30	*	0	105	*	135	Fixed	75	Fixed	60	0	135
19	135	135	130	25	0	0	110	135	130	85	85	85	85	-	-
20	135	135	135	12	0	0	123	135	135	85	85	85	85	-	-
21	130	135	132	115	0	0	15	135	132	85	80	20	40	105	120
22	60	110	100	20	15	20	40	95	80	*	*	*	*	*	*
23	135	135	135	0	0	0	-	-	-	Fixed	Fixed	Fixed	Fixed	0	0
24	60	125	130	55	15	20	5	110	110	85	85	85	85	-	-
25	70	125	95	20	0	15	50	125	80	85	85	85	85	-	-
26	25	135	90	10	0	15	15	135	75	85	85	85	85	-	-
Mean	102	131	123	39	7	15	58	123	107	60	76	61	74	66	131

- Arc of motion was not affected by contracture; * Motion was not recorded

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Table 1:

Patient Data

Patient	Gender	Age at injury (Y)	Etiology	Prior Surgery	Approach	Procedure
1	F	8	Radial head & supracondylar humerus fracture	No	Combined	Anterior & posterior capsulectomy, olecranon fossa osteoplasty, UN transposition
2	F	9	Radial head & supracondylar humerus fracture	No	Combined	Anterior & posterior capsulectomy, osteoplasty, LUCL & MCL reconstruction, UN transposition, hinged ex fix
3	F	5	Supracondylar humerus fracture	CRPP	Combined	Anterior capsulectomy, coronoid fossa osteoplasty, LUCL & MCL reconstruction, UN decompression, hinged ex fix
4	F	9	Intra-articular distal humerus fracture & elbow dislocation	CRPP	Combined	Anterior & posterior capsulectomy, distal humerus osteoplasty, UN transposition
5	M	8	Monteggia fracture-dislocation & supracondylar humerus fracture	No	Combined	Anterior & posterior capsulectomy, olecranon fossa osteoplasty, radial head resection, UN transposition
6	M	12	Monteggia fracture-dislocation	No	Lateral	Anterior capsulectomy, coronoid osteoplasty, radial head resection, LUCL repair
7	M	13	Radial head fracture & elbow dislocation	No	Lateral	Anterior capsulectomy, radial head replacement, LUCL reconstruction
8	M	12	Radial head fracture	No	Combined	Anterior & posterior capsulectomy, osteoplasty, radial head replacement, UN transposition
9	M	5	Supracondylar humerus fracture	No	Lateral	Anterior capsulectomy, osteoplasty
10	F	12	Unspecified elbow fracture	No	Medial	Anterior capsulectomy, osteoplasty, UN transposition
11	M	14	Elbow dislocation	No	Combined	Anterior & posterior capsulectomy, osteoplasty, UN transposition
12	F	8	Intra-articular T-type supracondylar humerus fracture	ORIF	Combined	Anterior capsulectomy, humerus & olecranon osteoplasty, LUCL & MCL repair
13	M	17	Unspecified elbow fracture dislocation	No	Lateral	Anterior & posterior capsulectomy, olecranon osteoplasty, radial head replacement, LUCL repair
14	M	7	Open olecranon apophyseal fracture	ORIF, removal of hardware	Combined	Anterior & posterior capsulectomy, osteoplasty, partial radial head excision, UN decompression
15	M	14	Elbow dislocation & both bone forearm fracture	CRPP, elbow ligament reconstruction	Lateral	Anterior capsulectomy, LUCL reconstruction
16	M	11	Lateral condyle fracture	Arthroscopic contracture release	Lateral	Anterior capsulectomy, LUCL repair
17	F	6	Olecranon & radial neck fracture	ORIF	Posterior	Anterior & posterior capsulectomy, osteoplasty
18	M	12	Elbow dislocation	No	Lateral	Anterior capsulectomy, osteoplasty, LUCL repair

Patient	Gender	Age at injury (Y)	Etiology	Prior Surgery	Approach	Procedure
19	M	13	Medial epicondyle fracture	ORIF, flexor-pronator lengthening, UN transposition	Medial	Anterior & posterior capsulectomy, osteoplasty, removal of deep hardware
20	M	14	Medial epicondyle fracture	ORIF	Medial	Osteoplasty, hardware removal, capsulectomy
21	M	15	Radial neck fracture	Intramedullary nail radius	Lateral	Osteoplasty, removal of deep hardware
22	M	15	Lateral condyle fracture	ORIF	Lateral	Anterior & posterior capsulectomy, osteoplasty
23	F	12	Elbow dislocation	Scar tissue debondment	Lateral	Osteoplasty, LUCL reconstruction
24	F	15	Medial epi condyle & proximal humerus fracture	ORIF	Medial	Anterior capsulectomy, osteoplasty, UN transposition
25	F	16	Unspecified distal humerus fracture	Capsulectomy	Combined	Anterior & posterior capsulectomy, osteoplasty
26	F	19	Lateral condyle & olecranon fracture	ORIF	Posterior	Posterior capsulectomy, removal of deep hardware, osteoplasty, UN transposition

F, female; M, male; Y, years; M, months; Combined, medial and lateral approaches; OEIF, open reduction internal fixation; CRPP, closed reduction percutaneous pinning; UN; ulnar nerve; LUCL, lateral ulnar collateral ligament; MCL, medial collateral ligament

Table 2:

Patient Outcomes

Patient	Age at Injury (Y)	Injury to Surgery Interval (M)	Age at Surgery (Y)	Length F/U(M)	Increase in F/E Arc(°)	Increase in S/P Arc(°)	% Intra-op F/E Arc Retained	CPM	Complications
1	8	11	9	84	60	110	65	Y	
2	9	11	10	53	95	20	76	Y	
3	5	60	10	40	80	95	83	Y	
4	9	24	11	36	42	30	111	Y	
5	8	50	13	52	59	-	102	Y	
6	12	15	13	12	30	-	92	Y	
7	13	12	14	17	5	160	*	Y	
8	12	26	14	19	105	160	85	Y	
9	5	120	15	39	20	40	91	Y	
10	12	37	15	33	60	-	107	Y	
11	14	14	15	14	75	-	93	Y	
12	8	96	16	53	25	-	77	Y	
13	17	8	18	16	47	55	73	Y	
14	7	66	13	36	-6	54	30	Y	Recurrent contracture, UN
15	14	9	15	72	36	-	*	Y	
16	11	48	15	12	25	15	95	Y	
17	6	9	7	66	-	95	-	N	
18	12	7	13	23	30	135	-	N	
19	13	18	15	30	20	-	96	N	
20	14	8	15	57	12	-	100	N	UN
21	15	6	16	108	117	15	98	N	
22	15	7	16	21	40	-	84	N	
23	12	51	16	37	-	0	-	N	Recurrent contracture
24	15	11	16	18	105	-	100	N	
25	16	18	18	82	30	-	64	N	
26	19	6	20	66	60	-	56	N	
Combined Mean	12	29	14	42	49	70	85		

Y, years; M, months; F/U, follow up; F, flexion; E, extension; S, supination; P, pronation; UN, ulnar neuropathy -Arc of motion was not affected by contracture; * Intraoperative motion was not recorded

Table 3:

Summary of Findings from Other Studies

	Number of Patients	Average Age (Y)	Mean Injury to Surgery Interval (M)	Mean Increase in ME Arc (°)	% Intra-op F/EArc Retained	Mean Follow-up (M)
Mih et al, 1994	9	12	10	53	-	17
Bae et al, 2001	11	16	36	54	100	29
Stans et al, 2002	37	16	18	28	79	15
Darlis et al, 2006	12	17	21	54	93	19
Present Study	26	14	29	49	85	42

Y, years; M, months; F, flexible; E, extension