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Long-Term Clinical and Radiographic Outcomes After Open Reduction for Missed Monteggia Fracture-Dislocations in Children

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Background: There have been few reports on the long-term outcomes after the operative treatment of missed Monteggia fracture-dislocations in children. The purpose of the present study was to evaluate the long-term clinical and radiographic outcomes after open reduction for the treatment of a missed Monteggia fracture-dislocation.

Methods: We postoperatively investigated the clinical and radiographic outcomes for twenty-two children with a missed Monteggia fracture. The study group included fourteen boys and eight girls who had had a mean age of ten years (range, four years to fifteen years and eleven months) at the time of open reduction. Each patient had been managed with open reduction of the radial head combined with a posterior bending elongation ulnar osteotomy and anular ligament reconstruction. Clinical and radiographic outcomes were reviewed over a mean duration of follow-up of seven years.

Results: The postoperative Mayo Elbow Performance Index at the time of follow-up ranged from 65 to 100, with nineteen excellent, two good, one fair, and no poor results. The radial head remained in a completely reduced position in seventeen patients and was subluxated in five patients at the time of the latest follow-up. In four patients, osteoarthritic changes were observed at the radiohumeral joint. Radiographically, there were fifteen good, seven fair, and no poor results. A good radiographic result was obtained in all of the patients who had undergone open reduction within three years after the injury or before the age of twelve years, whereas a fair result was obtained in seven of the remaining eight patients.

Conclusions: If open reduction for the treatment of a missed Monteggia fracture is performed when the patient is less than twelve years of age or within three years after the injury, good long-term clinical and radiographic outcomes can be expected.

Level of Evidence: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

A missed radial head dislocation is often observed in children who have undergone less-than-ideal primary treatment of a Monteggia fracture-dislocation. In most of these cases, the dislocation is not diagnosed initially and is left untreated. The neglected radial head dislocation is diagnosed several months after the injury when the patient complains of slight or moderate elbow pain, decreased elbow flexion, valgus deformity of the elbow, and neurologic problems (sensory or motor loss caused by a tardy ulnar nerve palsy or a posterior interosseous nerve palsy)[1-6]. If left untreated, the dislocated radial head loses its concave articular surface and displays hypertrophic changes and the humeral capitellum configuration flattens, thereby limiting the range of elbow flexion and extension[1,2,7]. Many authors have recommended that a missed radial head dislocation in a child should be treated with open reduction as early as possible once it is diagnosed[1,3,8-12]. However, the factors that affect the surgical outcome after open reduction, such as patient age at the time of open reduction and the interval between a Monteggia fracture and surgery, remain controversial. With respect to

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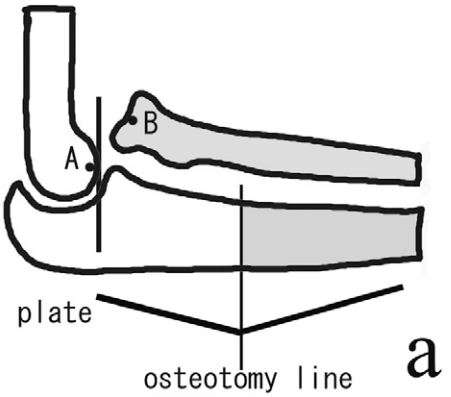

Fig. 1-A

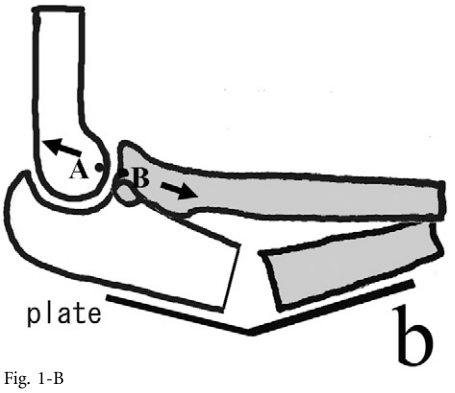

Fig. 1-B

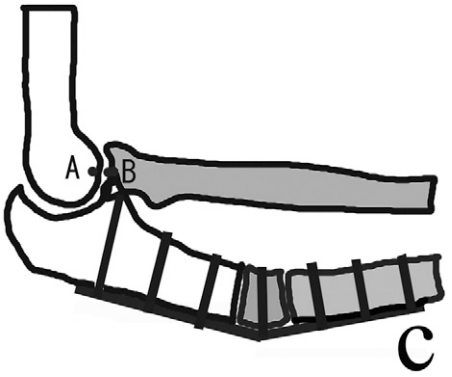

Fig. 1-C

Figs. 1-A, 1-B, and 1-C The modified Hirayama osteotomy. Point *A:* Anterior portion of the spherical surface of the capitellum. Point *B:* Center of the radial head. **Fig. 1-A** A seven-hole plate was applied to the dorsal cortex of the ulna. The most proximal screw was positioned at the level of the coronoid process. The osteotomy line was in the center of the plate. **Fig. 1-B** We mobilized both the distal part of the ulna (gray) and the radius (gray) to localize point *B* opposite to point *A*. We set the distance between point *A* and point *B* at 0.5 to 1.0 mm to avoid excessive pressure on the radiohumeral joint after radial head reduction. **Fig. 1-C** The osteotomized ulna was fixed with a plate.

age, Hirayama et al.[5] and Stoll et al.[13] recommended open reduction for children less than ten years of age; however, they did not recommend surgery when radial head deformity, flattening of the capitellum, or valgus deformity of the radial neck was present. Horii et al.[12] reported that open reduction was beneficial for patients younger than twelve years of age without radial head deformity, and this finding was confirmed by Wang and Chang[14]. With regard to the interval between the injury and open reduction, the findings have varied among reports, with Wang and Chang[14] stating that the acceptable interval is three years, Stoll et al.[13] stating that it is four years, and Best[15] stating that it is six years. However, none of those authors provided statistical evidence to support their indications. Kim et al. evaluated preoperative factors with use of stepwise linear regression analysis and found that the degree of preoperative carrying angle asymmetry, associated with a flexion contracture, correlated significantly with clinical elbow function[16].

To achieve an open reduction of a missed radial head dislocation, several operative procedures have been proposed, including ligament reconstruction[2,8,17-21], ulnar corrective osteotomy[15,22], ulnar bending osteotomy[4,9,23,24], combined ulnar bending and lengthening osteotomy[5], gradual lengthening and angulation of the ulna[25], ulnar osteotomy combined with radial shortening[13,26], and rotation osteotomy of the radius[27]. Recently, combination procedures employing ulnar osteotomy and anular ligament reconstruction have been proposed[1,12-14,28]. However, few reports have described the details related to these operative techniques, and no long-term investigations of clinical or radiographic results in a large number of patients have been published, to our knowledge.

Since 1983, twenty-two children with a missed radial head dislocation after a Monteggia fracture-dislocation have been managed by us with open reduction of the radial head combined with posterior bending elongation ulnar osteotomy and anular ligament reconstruction. The present report describes our surgical technique as well as the long-term clinical and radiographic outcomes.

Materials and Methods

During the period from 1983 to 2005, twenty-two children with a missed radial head dislocation after a Monteggia fracture were managed consecutively at our hospital with open radial head reduction combined with a posterior bending elongation ulnar osteotomy and an anular ligament reconstruction. Our inclusion criterion for a missed Monteggia fracture-dislocation was an interval of more than three months between trauma and open reduction. Thus, patients with a fresh or subacute injury were excluded from the present study. The study group included fourteen boys and eight girls with a mean age of ten years (range, four years to fifteen years and eleven months) at the time of open reduction. All patients were managed surgically and were followed for at least twenty-four months (mean, seven years; range, two to seventeen years). At the time of follow-up, all patients were interviewed individually

Fig. 2-A

Figs. 2-A, 2-B, and 2-C Anular ligament reconstruction with use of a remnant of the ligament. **Fig. 2-A** Identification of the remnant (white arrows) of the anular ligament and the defect (black arrow) in the ligament.

Fig. 2-B

After the osteotomy of the ulna, the radial defect of the anular ligament was augmented with the palmaris longus tendon (white arrowhead).

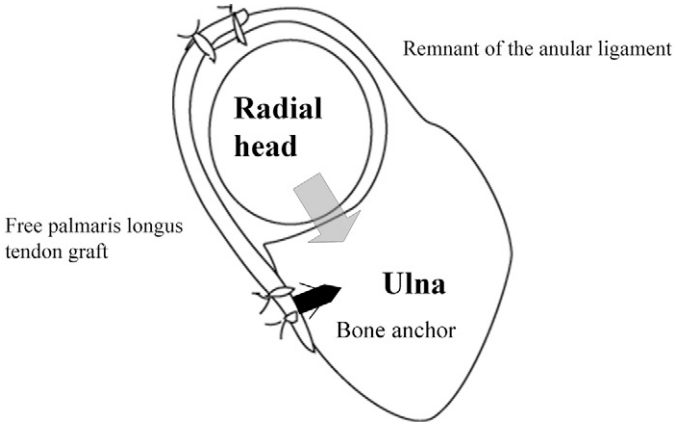

Fig. 2-C
Illustration depicting the method of anatomical anular ligament reconstruction with use of the remnant of the anular ligament and the free palmaris longus tendon graft.

by two of the authors (K.H. and H.K.) about elbow pain, range of elbow movement, elbow stability, and any disabilities in daily life, work, or sports. The preoperative and postoperative Mayo Elbow Performance Index (MEPI)[29] was ascertained for all patients. All patients had routine anteroposterior and lateral radiographs of the elbow, which were checked for deformity of the radial head, osteoarthritic changes, and dislocation or subluxation of the radial head. We quantified the deformity of the radial head on the anteroposterior or lateral radiographs according to the method of Kim et al.[30]. Radial head hypertrophy was determined by measuring the diameter of the radius at the widest portion of the metaphysis adjacent to the physis (a) and the narrowest portion of the neck just proximal to the bicipital tuberosity (b). If a/b was >1.5, radial head hypertrophy was considered to be present. Subluxation of the radial head was considered to be present when a line drawn down the center of the radial neck did not pass through the central one-third of the capitellum on the lateral radiograph. If subluxation of the radial head was suspected, lateral radiographs were made with the arm in the supinated and pronated positions or in an elbow-extended position to verify the subluxation.

The radiographic results were divided into three categories: good (complete reduction of the radial head without osteoarthritic changes of the elbow), fair (reduction with radial head subluxation or osteoarthritic changes of the elbow), and poor (radial head dislocation).

Surgical Technique

A skin incision was made, with the incision beginning at the lateral epicondyle of the humerus on the lateral side of the radiocapitellar joint, passing to the level of the proximal metaphysis of the ulna, and extending to the middle part of the posterior aspect of the ulna. The radiohumeral joint was approached between the extensor carpi ulnaris and anconeus muscles. The elbow joint was opened, the radial head was exposed, and the state of the cartilage of the radial head was assessed. The proximal part of the ulna was then approached between the flexor carpi ulnaris and the anconeus or the extensor carpi ulnaris. In all cases, an ulnar osteotomy was performed first, and then the radial head was reduced. A posterior bending ulnar osteotomy was performed for all patients; however, the technique was modified in 1997. For the first thirteen procedures, performed from 1983 to 1997, a transverse osteotomy was performed between the proximal one-third and the middle of the ulnar shaft according to the method of Hirayama et al.[5]. The ulna then was bent posteriorly and was elongated until the radial head faced the capitellum to avoid creating excessive joint pressure. The bending angle and the elongation distance of the ulna were determined during surgery by confirming the position of the radial head by means of direct observation. The mean posterior bending angle was 11.9° (range, 0° to 18°), and the mean amount of elongation of the ulna was 5.0 mm (range, 0 to 13 mm). The ulna was stabilized with a plate containing four to seven screw holes. In nine of the thirteen patients, an autogenous corticocancellous iliac crest bone graft was inserted at the ulnar osteotomy site.

For the latter nine procedures, performed after 1997, we modified the method of Hirayama et al. and performed additional posterior bending and elongation of the ulnar osteotomy site (Figs. 1-A, 1-B, and 1-C). The ulnar posterior bending angle and the site of the osteotomy were selected more precisely with use of a preoperative drawing that was traced from the lateral radiograph. On the drawing paper, we set plates with seven holes over the dorsal cortex of the ulna, with the most proximal screw hole at the level of the coronoid process. The osteotomy line was set just distal to the screw in the third hole from the most proximal screw hole. The distal part of the ulna and the entire radius were grouped as one and were mobilized in order to match the center of the joint surface of the radial head (Fig. 1-A, point *B*) opposite the

TABLE I Preoperative Data

Age* *(yr)*	10.7 (4.0 to 15.9)
Complaint *(no. of patients)*	
Pain with elbow flexion	8
Dull elbow pain	5
Restriction of elbow flexion	9
Restriction of elbow extension	2
Anterior bone protrusion	5
Cubitus valgus deformity	2
Ulnar nerve palsy	1
Interval from injury to surgery* *(mo)*	34.7 (3 to 107)
Elbow range of motion* *(deg)*	
Extension	10.9 (20 to −20)
Flexion	124.1 (100 to 140)
MEPI score*†	83.2 (65 to 95)

*The values are given as the mean, with the range in parentheses.
†MEPI = Mayo Elbow Performance Index.

TABLE II Postoperative Data

Duration of follow-up* *(mo)*	84.0 (24 to 203)
Elbow range of motion* *(deg)*	
Extension	2.3 (−20 to 20)
Flexion	137.5 (130 to 145)
Pronation	66.8 (40 to 90)
Supination	89.5 (70 to 95)
MEPI score*†	96.1 (65 to 100)
Radiographic finding *(no. of patients)*	
Subluxation	5
Osteoarthritic change	4
Radial neck notch	8
Ectopic ossification	1
Complication *(no. of patients)*	
Delayed union	2
Elbow contracture	2

*The values are given as the mean, with the range in parentheses.
†MEPI = Mayo Elbow Performance Index.

most anterior joint surface of the humeral capitellum (Fig. 1-A, point *A*). The amount of elongation of the ulna was also decided preoperatively on the basis of the drawing, with the goal of having 0.5 to 1.0 mm of joint space between the radial head and the capitellum at the completion of the procedure (Fig. 1-B). In these nine cases, the mean posterior bending angle was 15.8° (range, 8° to 25°) and the mean distance of elongation as measured on the lateral radiograph made after surgery was 7.8 mm (range, 4 to 15 mm). The gap at the osteotomy site was always filled with a cortico-cancellous iliac crest bone graft. The ulna and the grafted bone were fixed with the seven-hole plate (Fig. 1-C).

In all cases, the anular ligament was reconstructed after the ulnar osteotomy. The ligament reconstruction technique was also changed in 1997. From 1983 to 1997, reconstruction was performed with use of a modification of the technique of Speed and Boyd[21]. With that technique, forearm fascia is harvested over the extensor carpi ulnaris and the extensor digitorum muscles and is wrapped around the radial neck with its distal end fastened to its origin with sutures. An above-the-elbow cast is applied with the elbow in 90° of flexion, and the forearm is maintained in a position of 80° of supination for four to eight weeks after surgery. After 1997, we developed an original method for anular ligament reconstruction involving the remnant of the anular ligament and used this method for nine patients (Figs. 2-A, 2-B, and 2-C). With this technique, we identified the original anular ligament and carefully detached it from surrounding adhesions. In four of the nine patients, the anular ligament was

Fig. 3
Anteroposterior and lateral radiographs, made nine years and two months after surgery, showing mild osteoarthritic changes at the radiohumeral joint.

TABLE III Correlation Between Outcome and MEPI Score, Age at Time of Open Reduction, and Interval from Injury to Operation

Factor	Good Outcome (N = 15)	Fair Outcome (N = 7)
MEPI score at latest follow-up*†	99.7 (99.0 to 100.4)	88.6 (76.7 to 100.4)
Age at open reduction* *(yr)*	9.4 (8.0 to 10.9)	13.3 (11.9 to 14.7)
Time from injury to surgery* *(yr)*	1.5 (0.5 to 2.4)	5.9 (4.0 to 7.8)

*The values are given as the mean, with the 95% confidence interval in parentheses. †MEPI = Mayo Elbow Performance Index.

ruptured at the radial-sided origin of the radial notch of the ulna. In the remaining five patients, the anular ligament was not ruptured but was identified lying proximal to the radial head and was being impinged between the capitellum and the radial head. In those five cases, the space in the center of the anular ligament was filled with scar tissue. We excised this scar tissue and then cut the anular ligament at the radial-sided origin of the radial notch of the ulna. After reduction of the radial head and fixation of the ulna with use of a plate, we wrapped the radial neck with this anular ligament. The defect in the anular ligament was made on the radial side and was reconstructed with a free palmaris longus tendon graft.

All wounds were drained at the osteotomy site to prevent hematoma formation and to minimize heterotopic bone formation. Postoperatively, a cast was applied with the elbow flexed to 90° and the forearm in a position of neutral to 30° of supination. The immobilization period was approximately four weeks following surgery. After removal of the cast, active elbow motion was encouraged.

Although the present retrospective study was performed without approval from the review board at our institution, all patients were informed of the study procedure, purposes, and known risks.

Source of Funding

There was no external funding source in this investigation.

Results

A summary of the preoperative data is shown in Table I. In total, ten patients had multiple complaints. All patients had

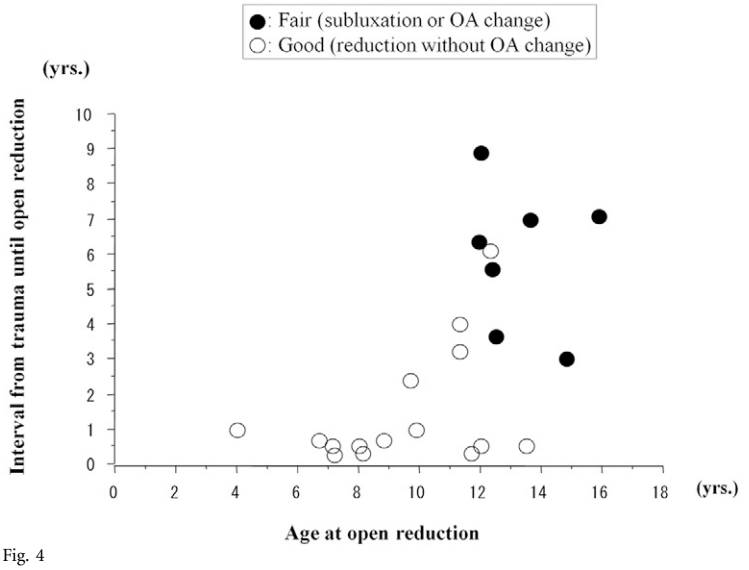

Fig. 4

Scatterplot showing the relationships between the radiographic results at the time of follow-up, the interval between the injury and the operation, and the age at the time of the operation. Open reduction of the radial head was successful in all cases in which the interval between the injury and the operation was less than three years or the age of the patient at the time of the operation was less than twelve years. When the interval to open reduction was three years or more and the age of the patient at the time of open reduction was twelve years or more, seven of eight patients had subluxation of the radial head or osteoarthritic (OA) changes in the elbow joint (solid circles).

Fig. 5-A

Fig. 5-B

Figs. 5-A through 5-F A twelve-year-old girl reported that she had fallen from a bar at the age of six years. At the time of the injury, the patient had sustained a fracture of the proximal part of the right ulna and a dislocation of the radial head. The fracture had been treated nonoperatively, and the dislocation had been missed. Approximately six years after the injury, open reduction with use of a posterior angulation and elongation ulnar osteotomy and anular ligament reconstruction with use of the remnant of the anular ligament augmented by the forearm fascia was performed. **Figs. 5-A and 5-B** Preoperative anteroposterior (Fig. 5-A) and lateral (Fig. 5-B) radiographs of the elbow, made six years after the injury.

a history of trauma involving the ipsilateral elbow or forearm. Of the twenty-two injuries, nineteen were classified as Bado type I, one was classified as Bado type III, and two were classified as Bado type IV on the basis of radiographs made at the time of the injury[31]. Anteroposterior and lateral radiographs of the elbow revealed that all patients had a complete dislocation of the radial head; the direction of the dislocation was anterior in twenty patients and anterolateral in two. Radial head deformity was observed in seven patients; loss of concavity of the radial head was seen in three of these patients, and hypertrophy of the radial head was noted in four. No patient had osteoarthritic changes of the elbow at the time of open reduction.

The overall postoperative clinical results, radiographic results, and complications are shown in Table II.

Clinical Results

The average MEPI score at the time of the latest follow-up was 96.1, with nineteen excellent, two good, one fair, and no poor results. Three patients complained of pain: moderate elbow pain was noted by one patient during work as an automobile mechanic, and mild pain was noted in two cases. One patient complained of limitations of daily life. That patient was a mechanic who experienced difficulty driving a motorcycle because of limited elbow extension and difficulty using a screwdriver because of a loss of pronation.

Radiographic Results

At the time of the latest follow-up, the radial head was maintained in a completely reduced position in seventeen of the twenty-two patients and was subluxated in five. In three of the latter five patients, the radial head center was shifted slightly anteriorly from the center of the capitellum at all elbow positions. In one patient, the radial head was subluxated during elbow extension with forearm pronation, and, in the remaining patient, the radial head was subluxated when the forearm was in pronation. Redislocation of the radial head was not observed in any patient, but osteoarthritic changes of the radiohumeral joint were observed in four patients; the changes were mild in two patients (Fig. 3) and moderate in two. The mean age of these four patients at the

Fig. 5-C

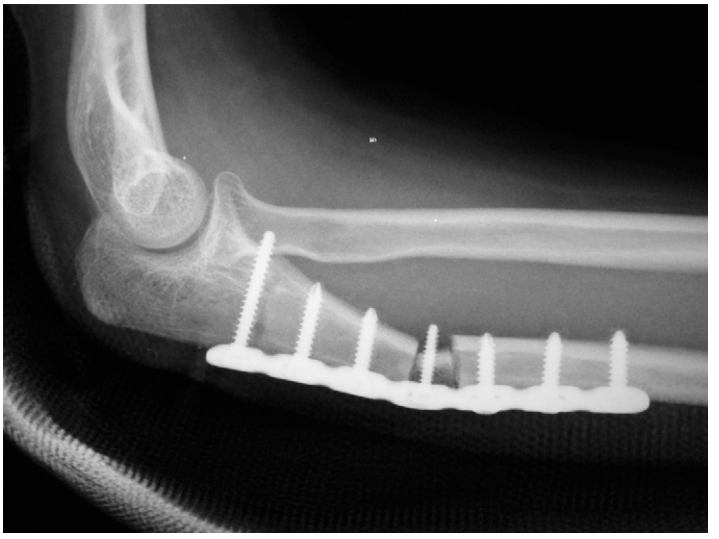

Fig. 5-D

Anteroposterior (Fig. 5-C) and lateral (Fig. 5-D) radiographs, made immediately after open reduction, showing that the middle screw is holding the iliac crest bone graft.

time of open reduction was 14.1 years, and the mean interval between the injury and open reduction was 5.9 years. A notch around the radial neck, which corresponded to the site of the reconstructed anular ligament, was visible radiographically at the time of follow-up in eight patients. Seven of these eight patients had undergone reconstruction with the technique of Speed and Boyd[21]. Slight hypertrophy of the radial head was found in six patients, all of whom showed radial head deformity preoperatively and had undergone surgery more than three years after the initial injury.

On the basis of our radiographic evaluation criteria, fifteen patients were rated as good, seven were rated as fair, and none were rated as poor. The mean MEPI score was 99.7 ± 1.3 for the patients who were rated as good and 88.6 ± 12.8 for those who were rated as fair. However, in all except two of the patients who were rated as fair, the MEPI score at the time of the latest follow-up was improved in comparison with the preoperative score. The mean interval between the injury and open reduction was 1.5 ± 1.7 years for the patients who were rated as good and 5.9 ± 2.1 years for those who were rated as fair. The mean age at the time of open reduction was 9.4 ± 2.6 years for the patients who were rated as good and 13.3 ± 1.5 years for those who were rated as fair (Table III).

The relationships between the clinical data at the time of open reduction and the radiographic results at the time of follow-up are shown in Figure 4. Reduction of the radial head was maintained without osteoarthritic change in all patients who were less than twelve years old at the time of the operation or who had an interval of less than three years between the injury and the operation. When the age at the time of open reduction was twelve years or more and the interval to open reduction was longer than three years, seven (88%) of eight patients experienced postoperative subluxation of the radial head or osteoarthritic changes of the elbow joint.

Complications

Two patients had a delayed union at the ulnar osteotomy site and were managed with refreshment of the nonunion site, application of an iliac crest bone graft, and repeat plate fixation. Two patients had postoperative contractures of the elbow joint that required a soft-tissue surgical release.

Case Presentation

A twelve-year-old girl reported that she had fallen from a play bar at the age of six years. At the time of the injury, the patient had sustained a fracture of the right ulna and a dislocation of the radial head. The fracture had been treated nonoperatively, and the dislocation had been missed. Six years and one month after the injury, radiographs revealed anterior dislocation and hypertrophy of the radial head. The patient was managed with the modified Hirayama method and anular ligament reconstruction, with the remnant of the anular ligament being

Fig. 5-E

Fig. 5-F

Anteroposterior (Fig. 5-E) and lateral (Fig. 5-F) radiographs, made six years after open reduction, demonstrating the reduced radial head.

augmented by the palmaris longus tendon. The angle of bending was 16°, and the amount of elongation was 13 mm. At the time of follow-up, six years after the operation, the patient had no complaints related to the right elbow. Radiographs showed good reduction of the radial head without osteoarthritic changes. Although enlargement of the radial head was recognized, the postoperative MEPI score was 100 (Figs. 5-A through 5-F).

Discussion

In the orthopaedic literature related to the surgical outcomes of open reduction of the radial head after a missed Monteggia fracture, several reports have included more than ten cases[4,12,14,16,24,30,32-35]. Tajima and Yoshizu reported the largest number of cases (twenty-three), but details on the results were not noted[24]. Fourteen studies have included follow-up periods of longer than three years[1,2,4,5,12-14,16,18,19,22,34,36,37]. Wang and Chang reported the longest mean follow-up period (more than seven years) and included the clinical and radiographic results for thirteen patients[14]. The present report is a detailed study of twenty-two patients with a mean duration of follow-up of seven years, representing the largest number of patients with the second-longest mean duration of follow-up to date.

Our results suggest that the older the child at the time of open reduction and the longer the interval from injury to open reduction, the lower the likelihood of a good result. No patient with an age of less than twelve years at the time of open reduction or with an interval of less than three years between the injury and open reduction showed subluxation of the radial head or osteoarthritic changes of the elbow joint. Rodgers et al.[1] mentioned that when the dislocated radial head was left unreduced, consistent enlargement of the radial head and a tendency for early closure of the proximal radial physis occurred. In our series, seven of ten patients for whom the interval between the injury and open reduction was longer than three years had radial head deformity, such as hypertrophy or loss of concavity of the joint surface. Of these seven patients, six subsequently showed subluxation of the radial head or osteoarthritic changes of the elbow joint, which indicates that reduction after a period of more than three years after an injury tends to increase the risk of complications. Furthermore, it is suggested that the radial head in children who are more than twelve years of age tends to lose the capability of remodeling itself. Therefore, one can expect satisfactory long-term clinical and radiographic outcomes after open reduction of a missed Monteggia fracture-dislocation when the patient is less than twelve years of age or the procedure is performed within three years after the injury. However, even if the patient does not meet these criteria, open reduction for a missed Monteggia fracture-dislocation is still advisable because almost

all clinical outcomes of our patients were improved after surgery. If open reduction is to be performed for such patients, however, they should be informed about the high risk of subluxation of the radial head and osteoarthritic changes. There were two cases of preoperative cubitus valgus deformity in the present study, but no relationship with radiographic results was found.

Judet et al.[38], Nishio et al.[36], and Bouyala et al.[32] all reported on the use of ulnar osteotomy for the treatment of radial head dislocation after a missed Monteggia fracture. The concept of ulnar osteotomy in those three reports was the same: the osteotomy tightened the interosseous membrane sufficiently to keep the radial head in a correct anatomical position. To preserve all of the interosseous membrane and to use its tension to pull the radial head posteriorly, the osteotomy should be done more proximally than at the junction of the proximal quarter and the distal three-quarters of the ulna[39]. In addition, a proximal ulnar osteotomy has the advantages of having an unnoticeable posterior curvature and avoiding restriction of forearm rotation because the tension in the whole interosseous membrane remains constant. Therefore, we believe that the best ulnar osteotomy site is the most proximal site that can accommodate a six or seven-hole plate. After the osteotomy site, we consider the degree of angulation and elongation as the next most important factors influencing the results of the osteotomy. We recommend making a plan based on a preoperative drawing traced from the radiograph, which will allow the ulnar posterior bending angle and the site of osteotomy to be decided more precisely.

Regarding the surgical procedures for reconstruction of the anular ligament, several methods have been proposed, such as using a free palmaris longus tendon[2,6,20], pedicled forearm fascia[21,34], pedicled fascia of the triceps[2,4,8,13,15,18,19,28,30,33,40,41], and the remnant of the anular ligament[9,18]. After reconstruction of the anular ligament, a radial neck notch, signaling constriction of the radial neck by the reconstructed ligament, often has been observed on postoperative radiographs[1,19,40]. In the present series, a radial neck notch was recognized in seven of thirteen patients in whom the anular ligament reconstruction had been performed with use of the pedicled forearm fascia. This notch developed because the running direction, width, and tightness of the forearm fascia differed from those of the original anatomical anular ligament, causing the fascia to constrict the radial neck locally during forearm rotation, especially when slight radial neck displacement remained. Since 1997, we have attempted to identify and preserve the damaged anular ligament during surgery and to use it for the reconstruction, augmenting it with a free tendon graft. We were able to detect the remnant in eight of our last nine patients, and we used it for anular ligament reconstruction in all of those cases. Kalamchi[9] also used the torn anular ligament to stabilize the radial head in two cases. Seel and Peterson[18] found that the anular ligament was impinged between the radial head and the humerus in all seven of their cases, and they used it for reconstruction in five. At the time of the latest follow-up, a radial neck notch was recognized in only one of our eight patients in whom the remnant of the anular ligament had been used. Thus, this reconstruction method involving the use of the damaged anular ligament seems to be reliable, less invasive, and more anatomical, and we believe that it should be considered as the first option for reconstruction.

The present study had several limitations. First, for the evaluation of the condition of the radial head, we measured its size and shape with use of conventional radiographs or arthrographic studies. Magnetic resonance imaging currently has the ability to evaluate the size, configuration of the articular surface, and quality of articular cartilage of the radial head, and it can also display the condition of the radial notch of the ulna. In the future, open reduction should be based on the preoperative anatomical or functional status of the radial head, the radial notch of the ulna, and the remnant of the anular ligament as detected with magnetic resonance imaging or other advanced imaging techniques. Second, we used the MEPI as a functional score although it has not been validated for use in studies of children. Third, in the present series, the first thirteen patients were managed with use of the osteotomy described by Hirayama et al. and with the anular ligament reconstruction described by Speed and Boyd whereas the last nine patients were managed with use of modified techniques. However, from the viewpoint of performing an open radial head reduction with a posterior bending elongation ulnar osteotomy combined with an anular ligament reconstruction, we considered these two methods to be similar enough to be analyzed as one group. Last, although multivariate analysis with logistic regression is necessary to identify significant risk factors related to outcome, the number of patients in our cohort was insufficiently large to be analyzed in this way. Therefore, we could not prove that patients who undergo the operation within three years after the injury or before the age of twelve years have a significantly higher chance of obtaining a good result.

Despite such limitations, our data suggest that, if open reduction for the treatment of a missed Monteggia fracture-dislocation is performed before the patient is twelve years of age or within three years after the injury, good long-term clinical and radiographic outcomes should be expected. ■

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