Displaced Proximal Humeral Fractures: PART II. TREATMENT OF THREE-PART AND FOUR-PART DISPLACEMENT

CHARLES S. NEER, II
Displaced Proximal Humeral Fractures

Part II. Treatment of Three-Part and Four-Part Displacement*

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In the preceding article, a description and classification of fractures of the proximal end of the humerus was presented. Since the selection of treatment seemed most difficult in patients with three-part and four-part displacements, it was thought important to compare the results of the various methods used in recent years. The purpose of this study was to analyze the results of closed reduction, open reduction, and prosthetic reconstruction and to consider the technical problems encountered in the treatment of these specific groups of fractures.

Material and Method

A consecutive series of 117 patients with displaced three-part and four-part fractures and fracture-dislocations, followed for a minimum period of one year, were analyzed. All were treated by members of the permanent staff of the New York Orthopaedic Hospital-Columbia-Presbyterian Medical Center between the years 1953 and 1969. The age of the patients ranged from twenty-five to eighty-four years and averaged 53.3 years. The distribution of their ages by decades was: third, two; fourth, ten; fifth, twenty-one; sixth, forty-one; seventh, thirty-one; eighth, nine; and ninth, one. The patients had been followed for from one to sixteen years; the average period of follow-up after injury was 4.8 years. Thirty-seven patients were followed for from one to two years; forty-six, two to five years; fourteen, five to ten years; and twenty, ten to sixteen years. The results in these patients were rated by the numerical system described in the preceding paper.

Treatment of the entire series, according to classification, is shown in Table I. Closed reduction under anesthesia was attempted in seventy-seven patients and the position was accepted in thirty-one patients who were then treated by a Velpeau bandage, a hanging cast, or overhead ulnar-pin traction. Open reduction was performed in forty-three patients in whom the articular segment was discarded in five and internal fixation was used in the remaining thirty-eight: wire loops in sixteen, Rush nails in eight, silk or nylon in six, splines in three, Kirschner wires or screws in four, and staples in one. Prosthetic replacement of the head and reconstruction of the tuberosities were done in forty-three patients.

Findings and Results

Three-Part Fractures and Fracture-Dislocations

Group IV

There were twenty-three fractures of this type, in which there was a displacement of over 1.0 centimeter of the greater tuberosity and the shaft but the articular segment remained in continuity with the lesser tuberosity. The attached subscapu-
TABLE I
TREATMENT BY CLASSIFICATION

<table>
<thead>
<tr>
<th>No. of Patients</th>
<th>Closed Treatment</th>
<th>Open Reduction</th>
<th>Prosthesis</th>
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</thead>
<tbody>
<tr>
<td>Three-Part</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group IV</td>
<td>23</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Group V</td>
<td>13</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>VI anterior</td>
<td>17</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>VI posterior</td>
<td>8</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Four-Part</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-part fracture</td>
<td>19</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>VI anterior</td>
<td>31</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>VI posterior</td>
<td>6</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>117</td>
<td>31</td>
<td>43</td>
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</table>

TABLE II
RESULTS OF CLOSED REDUCTION

<table>
<thead>
<tr>
<th>No. of Patients</th>
<th>Reduction Accepted</th>
<th>Satisfactory Result</th>
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</thead>
<tbody>
<tr>
<td>Three-Part</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group IV</td>
<td>12</td>
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<tr>
<td>Group V</td>
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<td>5</td>
</tr>
<tr>
<td>VI anterior</td>
<td>13</td>
<td>6</td>
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<td>VI posterior</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Four-Part</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-part fracture</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>VI anterior</td>
<td>23</td>
<td>4</td>
</tr>
<tr>
<td>VI posterior</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>77</td>
<td>31</td>
</tr>
</tbody>
</table>

lars tendon internally rotated the head, exaggerating the defect in the rotator cuff and causing the articular surface to face posteriorly (Fig. 3-A).

Closed reduction was consistently unsuccessful in twelve patients; however, closed treatment in overhead traction or hanging casts was continued in six patients. In two patients, treated in hanging casts, non-union developed at the surgical-neck level (Fig. 1-C). In the other four patients disabling malunions occurred, with resorption of the head in one (Table II, Fig. 1-A). Open reduction was performed in fourteen patients (Figs. 3-A, 3-B, and 3-C), two of whom had been initially treated in traction. Their results were: four excellent, five satisfactory, and five failure. The five poor results from open reduction followed technical errors consisting in failure to approximate the tuberosities and to repair the defect in the rotator cuff. The vertical fixation (Rush nails, splines, or Kirschner wires) failed to hold the tuberosities in apposition (Fig. 6-B). Non-union occurred in three of these patients at the level of the surgical neck (Table III). A prosthesis was used early in the series in two patients and their results were rated as one excellent and one satisfactory (Table III).

**Group V**

In thirteen fractures there was displacement of the lesser tuberosity and shaft while the greater tuberosity remained in continuity with the articular segment. The external rotators caused the articular surface to face anteriorly (Fig. 4-A).

Eight were treated by closed reduction without success. Closed treatment was continued in five patients, four in overhead traction, and one in a Velpeau bandage,
followed by functional exercises. The fractures united but with significant rotational deformity (Fig. 1-B), and much of the head resorbed in one patient. One elderly patient was satisfied with her recovery but all received poor numerical ratings (Table II). Open reduction was performed in seven patients (Figs. 4-A, 4-B, and 4-C). The results were: two excellent, two satisfactory, and three failures. Each failure was due to loss of fixation following the use of a Rush nail or spline. Wire-loop fixation and cuff repair consistently gave satisfactory results (Table III). One
patient had a torn axillary artery that required a vein graft and, during this procedure, the fracture was treated with a prosthesis. Four years later she was given an unsatisfactory functional rating, largely, however, because all three cords of the brachial plexus had been damaged by the injury (Table III).

Group VI, Anterior

There were seventeen subcoracoid fracture-dislocations of this type, in which the lesser tuberosity and its soft parts remained in continuity with the articular segment.

Closed reduction was attempted in thirteen patients and found to be difficult. The subscapularis, attached to the head, tended to prevent its being reduced (Fig. 2-A). Even when reduction was accomplished, the subscapularis often rotated the head so that the articular surface faced posteriorly, causing it to appear to be in the upside down position (Fig. 2-B). Closed reduction was accepted in six patients, two of whom obtained satisfactory ratings. Late rotational displacement by the subscapularis led to limited range of motion and discomfort in the four other patients treated by closed methods (Table II). Open reduction, wire-loop fixation, and cuff repair resulted in good ratings in three patients. Spotty avascular changes in the head were the rule, but the cir-

Figs. 2-A, 2-B, and 2-C: Anteroposterior roentgenograms showing the difficulties encountered in closed reduction of fracture-dislocations.

Fig. 2-A: Anterior three-part lesion shown while traction was applied under anesthesia. The subscapularis, attached to the head, prevented its being reduced.

Fig. 2-B: Same type of fracture-dislocation as that shown in Fig. 2-A following closed reduction. The head appears to be upside down because the subscapularis has rotated it so that the articular cartilage faces posteriorly.

Fig. 2-C: Increased displacement and brachial plexus symptoms following three attempts to reduce an anterior four-part lesion by manipulation.
### TABLE III

**Operative Results of Eighty-six Fractures and Fracture-Dislocations**

<table>
<thead>
<tr>
<th></th>
<th>Open Reduction (Forty-three)</th>
<th>Prosthesis (Forty-three)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Patients</td>
<td>Excellent (90 units)</td>
</tr>
<tr>
<td>Three-part</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group IV</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>Group V</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>VI anterior</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>VI posterior</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>Four-part</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fracture</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>VI anterior</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>VI posterior</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>13</td>
</tr>
</tbody>
</table>

Figs. 3-A, 3-B, and 3-C: Group IV three-part fracture in which the greater tuberosity is detached allowing the subscapularis to rotate the head inward, causing the articular surface to face backward.

- **Fig. 3-A:** Preoperative anteroposterior roentgenogram showing the typical rotatory displacement.
- **Fig. 3-B:** Photograph made in the operating room showing the biceps tendon (forceps) overlying the greater tuberosity fragment and the cuff tear at the rotator interval. Skin hooks are on the edge of the subscapularis tendon which is causing the articular surface to face posteriorly.
- **Fig. 3-C:** Showing the anatomical repair of the lesion shown in Figs. 3-A and 3-B by approximating the tuberosities with a wire loop and repair of the rotator-cuff defect. The subluxation disappeared as the muscles regained tone.
calculation, derived from the lesser tuberosity, was adequate to prevent resorption of the head (Fig. 6-C). One of the two failures of open reduction was due to a postoperative wound infection in a patient who had been in traction for two weeks prior to surgery and the other to loss of fixation in a patient treated with screw fixation (Table III). Prosthetic reconstruction was performed in six patients, two of whom had glenoid fractures and whose shoulders had been dislocated for over two months. The results were: four satisfactory, one unsatisfactory, and one failure (Table III). The failure was due to a large glenoid-rim fracture and persistent subluxation (Fig. 8-B). The unsatisfactory result was caused by a broken wire that permitted the greater tuberosity to displace (Fig. 8-A).

*Group VI, Posterior*

In eight posterior fracture-dislocations the greater tuberosity remained attached to the head and a severe rotational deformity was present through the surgical neck. Four of the patients had been injured during electroshock therapy.

Closed reduction was attempted in six patients with success in only one patient, who obtained an excellent result. Incomplete reduction was accepted in one other patient who had non-union at the surgical neck (Table II). Open reduction was performed in four patients. The anterior deltopectoral approach was used and the head was relocated by leverage with a flat instrument. The results were:

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**Figs. 4-A, 4-B, and 4-C:** Group-V three-part fracture in which the lesser tuberosity is detached allowing the external rotators to rotate the head externally, causing the articular surface to face anteriorly.

**Fig. 4-A:** Preoperative anteroposterior roentgenogram showing rotatory displacement.

**Fig. 4-B:** Photograph made in the operating room to show the articular surface presenting just beneath the clavicular fascia. The skin hook is on the lesser tuberosity. This appearance has suggested the term *false fracture-dislocation.*

**Fig. 4-C:** Excellent wire loop repair of the lesion shown in Figs. 4-A and 4-B by approximating the tuberosities and shaft and repairing the rotator-cuff defect.

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two excellent, one satisfactory, and one failure (Table III). The failure was due to non-union following Rush-nail fixation (Fig. 6-A). A prosthesis was used in two lesions, one of which had been repeatedly manipulated and was several weeks old. The other had been undiagnosed for four months. Both patients eventually achieved satisfactory ratings (Table III).

Four-Part Fractures and Fracture-Dislocations

Four-Part Fracture

Nineteen fractures with displacement of both tuberosities were encountered. In each patient the articular segment was displaced laterally, out of contact with the glenoid, and was detached from a source of blood supply.

Closed reduction was attempted in twelve patients, five of whom later came to surgery. None of the reductions were good because retraction of the tuberosity persisted, and it was not possible to obtain good contact for the articular fragment. Nevertheless, closed treatment was continued in seven patients, resulting in four non-unions at the surgical neck, one complete resorption of the humeral head, and two disabling malunions, each with significant humeral-head necrosis (Table II). Five open reductions were performed, and the results in all were rated failure. Each effort to obtain contact between head and tuberosities so that the articular fragment might become revascularized failed (Fig. 7-B). The head was removed in one patient and resorbed in three. One patient had a postoperative wound infection (Table III). A prosthesis was used with reconstruction of the tuberosity and cuff in seven patients (Fig. 11). The results were one excellent and six satisfactory (Table III).

Group VI, Anterior

There were thirty-one subcoracoid fracture-dislocations in which both tuberosities were detached from the articular segment (Fig. 2-C). The tuberosities were usually retracted, but in twelve patients they were held in approximation by the rotator cuff.
Figs. 6-A, 6-B, and 6-C: Depicting errors of fixation at open reduction of three-part fractures.

Fig. 6-A: Axillary roentgenogram made two years after Rush-nail fixation of a three-part posterior fracture-dislocation, showing non-union.

Fig. 6-B: Anteroposterior roentgenogram of a non-union in a Group IV three-fragment lesion that had been fixed with Kirschner wires and without repair of the rotator cuff.

Fig. 6-C: Anteroposterior roentgenogram of a three-part anterior fracture-dislocation made two years after open reduction. Good approximation of the tuberosities and a good cuff repair was obtained but the wire loop did not secure the shaft, resulting in delayed union.

Closed reduction was attempted in twenty-three and accepted in four patients. When the tuberosities were held together by the intact cuff, they seemed to prevent relocation of the head. When they were retracted, it was not possible to obtain adequate bone contact for the head. Manipulation appeared to contribute to neurological symptoms in five patients (Fig. 2-C). All four lesions treated by closed methods resulted in failure, two due to resorption of the head and two due to non-union (Table II). Open reduction was performed in five patients (Fig. 5). It was difficult to maintain contact between the fragments, and the head was discarded during two operations. All five results are classified failures because of discarded or avascular heads (Table III, Fig. 7-A). Twenty-two patients were treated by prosthetic replacement. The results were three excellent, eighteen satisfactory, and one failure (Table III). The failure was due to a postoperative wound infection.

**Group VI, Posterior**

In six patients the head was dislocated posteriorly and was detached; both tuberosities were retracted.
Closed reduction was attempted without success in three patients (Table II). Three lesions treated by open reduction resulted in failure because of avascular necrosis (Table III). The results were rated satisfactory in three patients in whom a prosthesis was used (Table III).

Complications

There were no significant systemic complications. Five patients had sustained their injuries during electroshock therapy for psychoses, seven were alcoholic, one had epileptic seizures, two had multiple injuries, and seven had pending litigation. None of these problems proved an overwhelming deterrent to recovery. Local complications are summarized in Table IV.

Infection: Three postoperative wound infections occurred. Two followed open reductions that had been delayed. One followed prosthetic replacement and was promptly controlled by removal of the prosthesis and the administration of local and systemic antibiotics. All resulted in failure.

Fig. 7-A

Figs. 7-A and 7-B: Complications of open reduction in four-part lesions.

Fig. 7-A: Anteroposterior roentgenogram made two years after open reduction of a four-part fracture-dislocation which failed because of resorption of the head.

Fig. 7-B: Anteroposterior roentgenogram made one year after failure of Rush-nail fixation for a four-part fracture showing avascular necrosis, non-union of the head, and tuberosity retraction, indicative of a large rotator-cuff defect.
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Figs. 8-A through 8-D: Complications of prosthetic replacement, illustrated by anteroposterior roentgenograms.

Fig. 8-A: Result rated failure because a broken wire allowed the tuberosity to retract on the seventh day after operation.

Fig. 8-B: Failure to reconstruct a four-month-old anterior fracture-dislocation with a large glenoid-rim fracture.

Fig. 8-C: Roentgenogram made with the arm at the side four years after delayed surgery for a fracture-dislocation complicated by myositis ossificans.

Fig. 8-D: Same patient as shown in Fig. 8-C with the arm overhead, demonstrating that adequate range had been attained four years after the complication.

Non-union: There were sixteen established non-unions at the surgical neck of which nine followed closed treatment, six a hanging cast (Fig. 1-C), and two overhead traction. Distraction appeared to be a causal factor. Six non-unions followed open reduction of three-part fractures that were inadequately internally fixed (Figs.

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Illustrating the method of exploring acute fractures. The defect in the rotator interval is developed proximally, avoiding injury to the blood supply of the head which enters bone in the vicinity of the bicipital groove and tuberosities.

6-A and 6-B). Non-union of the head segment was present in most patients with avascular necrosis (Fig. 7-B).

Avascular necrosis: Collapse of the articular surface occurred in only two of thirty three-part lesions treated by open reduction (Table IV). Of thirteen patients with four-part lesions treated by open reduction, however, the head was discarded in five and resorbed in six (Fig. 7-A).

Malunion: Rotatory displacement in three-part fractures could not be controlled by closed methods (Figs. 1-A, 1-B, 2-A, and 2-B). The result usually included
significant discomfort and loss of external rotation and abduction. One patient with fixed retraction of the greater tuberosity and malunion of the glenoid (Fig. 8-B) and another with loss of fixation of the tuberosities (Fig. 8-A) accounted for two of the failures of prosthetic replacement (Table IV).

Neurom'ascular: Ten patients were first seen with neurological deficits, involving the axillary and median nerves in four, axillary and radial nerves in two, ulnar nerve in two, and all three in two. Repeated efforts at closed reduction was thought to have increased these symptoms in several patients (Fig. 2-C). Deficits persisted in four patients, one of whom received an unsatisfactory rating (Table IV).

Transitory subluxation: This was common after all types of treatment (Fig. 3-C). It disappeared as the muscles regained tone.

Myositis ossificans: Pericapsular bone formation occurred after all three methods of treatment: three after closed reduction, five after open reduction, and six after prosthetic replacement (Figs. 8-C and 8-D). Predisposing factors seemed to be soft-tissue injury as in fracture-dislocations, repeated manipulation, and delayed reduction beyond seven days.

Failure of metal: There was no instance of dislocation or loosening of the stem of a prosthesis. The wire loops fragmented in one patient, between two and nine years after surgery, but caused no discomfort.

Over-all Results

The results of closed reduction, open reduction, and prosthetic replacement are summarized in Tables II and III. A minimum of one year was required for reasonable recovery and, in general, the results improved with time.

Closed treatment appeared inadequate for active patients in either group. It produced satisfactory ratings in only three of thirty-nine patients with three-part lesions and consistently failed in thirty-eight patients with four-part displacements.

Open reduction was performed in thirty patients with three-part displacements and appeared effective. There were eleven failures but these were largely due to technical errors (Figs. 6-A and 6-B). Suture fixation of the tuberosities and cuff repair yielded satisfactory or excellent results in 86 per cent (Fig. 10). Severe necrosis with resorption of the head rarely occurred. Patients with four-part lesions, however, had uniformly poor results because the head had been discarded or resorbed.

Prosthetic replacement was used in thirty-two patients with four-part displacements (Fig. 11). The typical result was satisfactory but imperfect and the recovery period was prolonged. The average numerical rating was 82 units. There were few complications. These results in patients with four-part lesions were quite superior to those of either closed or open reduction.

Operative Technique

During the course of this study, some techniques were found to be of value and some problems and errors in technique became apparent.

1. Anteroposterior and lateral roentgenograms of the upper end of the humerus are essential preoperatively in planning the procedure and avoiding unnecessary tissue damage.

2. Reconstruction is difficult and delay beyond two weeks renders it more difficult because of fixed retraction of the tuberosities, formation of cicatrix, deposition of pericapsular bone, and softening of the fragments.

3. The preoperative pain in the shoulder reduces the efficacy of skin preparation, and the injured tissue invites infection. It is important that the skin be cleaned scrupulously under anesthesia and that adherent plastic drapes be used.
4. The deltopectoral approach with detachment of the anterior 7.6 centimeters of the deltoid from clavicle is preferred. Acromionectomy or inadequate reattachment of the deltoid is especially disabling.

5. After division of the clavipectoral fascia, the wound should be irrigated free of clots and the tendon of the long head of the biceps should be used as a guide to the interval between the greater and lesser tuberosities (Fig. 3-B).

6. Injury to the blood supply of the head and the anterolateral artery can be avoided by developing the interval defect in the rotator cuff (Fig. 9). In doubtful cases the interval should be explored before a final decision to discard the head is made.

7. At open reduction, fixation by two strong buried wire loops is much more efficient than by screws, nails, or Kirschner wires. After the tuberosities are secured together and to the shaft, the rotator cuff is repaired (Fig. 10).

8. If a prosthesis is used (Fig. 11), a tight fit of the stem within the medullary canal is essential. Four stem sizes are currently available, each with appropriate drill specifications. The articular surface must be positioned so as to face in 30 degrees of retroversion to provide stability against dislocation. The fragments of the tuberosities are approximated beneath the prosthesis with two wire loops and the rotator cuff is then repaired.

9. Adhesions can be minimized by the use of assisted external rotation exercises. These are started at about four days after surgery and progress as rapidly as the repair permits, working initially for range and much later for strength.

10. Patients should be warned preoperatively of the protracted course of rehabilitation, and later they should be encouraged by their surgeon to have confidence and take pride in their accomplishments.

Discussion

During the period required to collect this series, more than 1500 proximal humeral fractures were seen in our clinic. This figure does not, however, accurately portray the prevalence of the severe multifragment injuries among injuries to the proximal end of the humerus since many in the series were referred from other hospitals. The majority of patients who sustained these disabling fractures were healthy individuals in their active years. Therefore, although these injuries are uncommon, they pose a significant problem.

The classification used may seem cumbersome, but it seems much more representative of the actual type of lesion encountered than the oversimplified classifications of the past. For the purpose of evaluating therapy, at least, our classification has proved useful. For example, if the over-all results after open reduction are compared with those of Knight and Mayne, there were 44 per cent satisfactory results in this series of forty-three procedures as compared with 46 per cent satisfactory results in twenty-six procedures in the series of Knight and Mayne. Yet when the technically good open reductions in our three-part fractures are considered, the results were excellent or satisfactory in 86 per cent. It is not possible to separate this group from Knight and Mayne's series. Thus, it is possible now to recognize the value of open reduction in the various types of fracture and to detect its deficiencies in the four-part fracture.

Summary

A study of 117 three-part and four-part displaced proximal humeral fractures, followed for from one to sixteen years, is presented. The ages of the patients averaged 55.3 years. Treatment began with closed reduction in seventy-seven patients, the result of which were accepted in thirty-one. Open reduction was done in forty-three
patients, and prosthetic replacement in forty-three patients. Their results were rated by a numerical system. Closed reduction was found inadequate for active, healthy patients in either group. This was because of uncontrollable rotatory displacement in three-part fractures and avascular necrosis of the detached head in four-part fractures. Most of the poor results of open reduction in three-part displacements were due to errors in reduction or fixation while those in four-part displacements were due to avascular necrosis of the head. It was concluded that the preferable method for three-part fractures was open reduction and that for four-part fractures was prosthetic replacement. Using these indications, the typical result was satisfactory but imperfect and many months were required for maximum recovery. Surgical errors and technique are discussed.

References