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Surgical treatment of acute coronoid process fractures

Akut koronoid kırıklarının cerrahi tedavisi

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Amaç: Erken dönemde cerrahi olarak tedavi edilen tip 2-3 koronoid kırıklarının sonuçları değerlendirildi ve sonucu etkileyen etmenler araştırıldı.

Çalışma planı: Çalışmaya, deplase koronoid kırığı nedeniyle açık redüksiyon ve internal fiksasyon ile tedavi edilen 13 erkek hasta (ort. yaş 35; dağılım 17-53) alındı. Regan-Morrey sınıflamasına göre kırıklar dokuz hastada tip 2 (%69.2), dört hastada tip 3 (%30.8) idi. Dokuz hastada koronoid kırığına dirsek çıkığı, radius başı kırığı, olekranon kırığı veya bağ yaralanması eşlik etmekteydi. Hastalar yaralanmadan itibaren ortalama 2.3 gün (dağılım 1-7 gün) sonra ameliyat edildi. Fonksiyonel değerlendirmede Mayo dirsek performans skoru (MDPS) kullanıldı. Radyografik artroz bulguları Broberg-Morrey ölçütlerine göre değerlendirildi. Ortalama takip süresi 44.1 ay (dağılım 12-96 ay) idi.

Sonuçlar: On hastada (%76.9) fonksiyonel dirsek eklem hareket aralığı (EHA) elde edildi. Son kontrolde ortalama dirsek EHA 110.7° (dağılım 85°-130°), önkol rotasyonları 134.2° (dağılım 120°-155°) bulundu. Parçalı koronoid kırığı veya eşlik eden dirsek yaralanmaları olan üç hastada EHA daha düşüktü. Hastaların hiçbirinde instabilite saptanmadı. Ortalama MDPS 86.5 (dağılım 75-100) idi; dört hastada (%30.8) mükemmel, dokuz hastada (%69.2) iyi sonuç elde edildi. İzole veya tek parça koronoid kırığı olan dört hastada mükemmel sonuç alınırken (MDPS 98.8), parçalı kırığı veya eşlik eden bağ ve kemik yaralanmaları olan hastalarda fonksiyonel skor daha düşük bulundu. Yedi hastada (%53.9) posttravmatik artrit bulguları saptandı; bu hastalarda MDPS ortalaması 81.4 idi. Fonksiyonel sonucu mükemmel olan hastalarda artrit bulgularına rastlanmadı. Tüm hastalar yaralanma öncesi aktivite düzeylerine dönebildi.

Çıkarımlar: Koronoid kırıkları, çoklu dirsek yaralanmalarının en önemli kısmıdır. Kırığın parçalı olması, eşlik eden kemik veya bağ yaralanmaları ile posttravmatik artrit varlığı fonksiyonel sonucu olumsuz etkilemektedir.

Anahtar sözcükler: Dirsek eklemi/yaralanma/cerrahi; kırık tespiti; radius kırığı/cerrahi; ulna kırığı/cerrahi.

Objectives: This study was designed to assess the results of surgical treatment for type 2-3 coronoid process fractures and to identify factors that might influence the outcome.

Methods: Thirteen male patients (mean age 35 years; range 17 to 53 years) were treated with open reduction and internal fixation for displaced coronoid fractures. According to the Regan-Morrey classification, the fractures were type 2 in nine patients (69.2%), and type 3 in four patients (30.8%). Nine patients had associated injuries (elbow dislocation, radial head or olecranon fractures, and/or ligamentous injuries). The mean duration to treatment was 2.3 days (range 1 to 7 days). Functional results were assessed according to the Mayo elbow performance score (MEPS), and signs of arthritis were assessed according to the Broberg-Morrey criteria. The mean follow-up was 41.1 months (range 12 to 96 months).

Results: A functional range of motion of the elbow joint was achieved in 10 patients (76.9%). The mean elbow range of motion was 110.7° (range 85° to 130°) and the mean forearm rotation was 134.2° (range 120° to 155°). Three patients who had comminuted fractures and associated elbow injuries had decreased range of motion. None of the patients exhibited signs of instability. The mean MEPS was 86.5 (range 75 to 100). The results were excellent in four patients (30.8%; the mean MEPS 98.8) having isolated or noncomminuted coronoid fractures, and good in nine patients (69.2%) with comminuted fractures and/or associated bone or ligament injuries. Post-traumatic arthritis was detected in seven patients (53.9%) whose mean MEPS was 81.4. Patients with an excellent functional result did not develop arthritis. All the patients returned to preinjury activity levels.

Conclusion: Coronoid fractures are the most important component of complex elbow injuries. The presence of comminuted fractures, associated bone and ligament injuries, and post-traumatic arthritis affect the outcome adversely.

Key words: Elbow joint/injuries/surgery; fracture fixation; radius fractures/surgery; ulna fractures/surgery.

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The elbow is an inherently stable joint, primarily as a result of the ulnohumeral bony articulation. Most of the type 2-3 fractures of the coronoid make the ulnohumeral articulation unstable by disrupting its congruent architecture and damaging soft tissue stabilizers, which are inserting on the ulnar coronoid process.[1-3] Regan and Morrey classified these fractures into three types according to the height of the coronoid involved.[4] With this system, type 1 indicates a fracture involving the tip of the coronoid process, type 2 indicates a fracture involving less than 50% of the coronoid process, and type 3 indicates a fracture involving more than 50% of the coronoid process. Most recently, O'Driscoll et al.[5] introduced a classification system of coronoid fractures based on anatomic location of the fracture fragments. Fractures are classified into tip fractures, anteromedial fragment and basal fractures. Identifying the anteromedial fractures is a key element of this classification system. Several options exist for the fixation of the coronoid fractures, including plate fixation, lag screws (cannulated), threaded K wires and transosseous sutures or wires through the ulna. A hinged external fixator can be used for preservation or reconstruction of the fixation. Inadequate treatment can lead to instability, rapid progress of posttraumatic arthritis and stiff elbow. The goal of the treatment is to prevent displacement caused by deforming forces.[5-7] The purpose of our study is to determine the clinical outcomes following surgical treatment of bony and ligamentous injuries in type 2-3 coronoid process fractures, and to identify features that may predict outcome.

Materials and methods

Between January 1999 and February 2006, thirteen consecutive skeletally mature patients (thirteen elbows) were seen in whom displaced coronoid process fractures had been operated upon at our hospital. All patients were male with a mean age of 34.9 years (17-53 years). Six patients had injured their dominant right arm, while the left side was affected in seven of the patients. The mechanism of injury included four falls from standing height, four high-velocity falls from a height, three sports injuries and two traffic accidents. According to the Regan Morrey radiologic classification system, nine patients were classified as type 2, and four patients as type 3. According to the O'Driscoll et al. classification system , five patients were classified as anteromedial subtype 2 fractures, four patients were tip fractures subtype 2 and four patients were classified as basal fractures. There were no open fractures, vascular or neurologic complications encountered. Standard roentgenogram and computed tomography were performed on all patients before the operation to evaluate the articular involvement and fracture configuration. In recent patients, three-dimensional computed tomography was also performed. Patients were subcategorized by the number of fragments and involvement of the articular surface. O'Driscoll et al. clearly identified and described distinct features of anteromedial facet fractures for that reason especially anteromedial facet fractures determined. Existence of two or more fragments indicated a comminuted fracture, and one or two fracture fragments indicated a noncomminuted fracture. Eight patients had noncomminuted fractures and five had a coronoid fracture with communition. Of these eight noncomminuted fractures, one patient had anteromedial facet involvement. Four of five comminuted fractures had anteromedial facet involvement. There were four isolated coronoid fractures without associated fractures or ligament injury, which causes instability or dislocation. Eight patients were associated with elbow dislocations, and of these dislocations, five had additional radial head fractures, three had additional olecranon fractures and two had only medial ligament instabilities without any fracture. All patients were examined for ligament instability in the emergency room, in the operation theatre under general anesthesia, and after fixation. Reproducing the actual subluxation or dislocation, clunk that occurs with reduction and misalignment of the elbow joint or subluxation of the radius-ulna from the humerus, determining under real time fluoroscopy with varus-valgus stress force were called marked instability. If there were ligament injuries causing marked instability, surgical exploration and repair was performed. These examinations and surgical explorations showed that six patients had variable type ligament injuries; two lateral, two medial and two medial-lateral ligament injuries. At lateral side, humeral avulsion injuries of the lateral collateral ligament complex proximally beneath the common extensor tendon origin and at the medial side, avulsion injuries from humerus were determined with surgical exploration. Common extensor muscle tendon origin injuries were also determined by surgical exploration at the lateral side. To prevent additional soft tissue damage, surgical exploration was not performed in cases where there was no marked instability. Five of the nine Regan Morrey type 2 fractures had ligament injuries that caused instability (55.5%), and one of four Regan Morrey type 3 fractures

had ligament injuries that caused instability (25%) determined after fracture fixation. All coronoid fractures were treated with open reduction and internal fixation. The fixation method was determined by the fragment configuration and which part of the coronoid has fractured. For comminuted fractures, plate fixation was preferred. For screw fixation, adequate bone stock and large pieced fractures were preferred. The largest fragment that was available to fix was used. Seven coronoid fractures were fixed with specifically designed plates (Acumed, Oregon, U.S.); one fixation was performed using a dynamic compression plate and screws; four were performed using cannulated screws (Synthes, Pennsylvania, U.S.) and one was performed using cortical screws. All ligament ruptures were repaired with suture anchors (Mitek Surgical Products, Massachusetts, U.S.). Additional radial head and olecranon fractures were treated with open reduction and internal fixation with screws and plates. In one case, there was an elbow dislocation, comminuted radial head and severely comminuted coronoid fracture. In this case, only lateral incision was used. The radial head was excised and used as a structural graft to reconstruct the coronoid process. There was no longitudinal instability determined under real time fluoroscopy at the time of operation. For that reason we did not use a prosthetic radial head. For postoperative stability, the patient used a hinged, extension blocked elbow splint for four weeks and therapy program has started with the supervision of therapist. The patients were reviewed and examined after a minimum 12 months (range 12-96 months; mean, 44.1 months). At the final follow-up, all patients were examined for pain, range of motion, stability and function. Pain was determined subjectively for daily activities and heavy work. Elbow flexion-extension and forearm pronation-supination were measured with a goniometer and recorded for each patient. Instability was determined with a posterolateral rotatory apprehension test and the varus-valgus stress test. Creating apprehension in the patient and the reproduction of a sense that the elbow is about to dislocate were deemed instability. Patient were evaluated for daily activities such as combing hair, feeding, performing hygiene, wearing a shirt and wearing shoes. These parameters were marked and recorded for each patient and The Mayo Elbow Performance Score (MEPS) was used for functional assessment. The final determination included standard anteroposterior and lateral radiographs for assessment of the fracture union, joint congruity, degenerative changes and heterotopic ossification. Radiographic signs of arthrosis were rated according to system of Broberg and Morrey.[8]With this system, a normal elbow is Grade 0, an elbow with slight joint-space narrowing with minimum osteophyte formation is Grade 1, an elbow with moderate joint-space narrowing and moderate osteophyte formation is Grade 2, and an elbow with severe degenerative change and gross destruction of the joint is grade 3. Examination and radiographs protocol was approved by the human research committee at our institution. All procedures were performed by the principal investigator. The patients were operated upon within 2.3 days on average (1-7 days) after injury. In one patient, surgery was delayed for nearly a week because the patient had applied to another hospital first and after that, came to our hospital. Closed reduction for dislocated elbows was performed under sedation in the emergency room. Operations were performed with anterior incisions in two patients, medial incisions in four patients, lateral in two patients, medial and lateral in three patients, and posterior and lateral in two patients. Indications for incisions were determined with respect to type, configuration and localization of fracture which were evaluated in preoperative roentgenography and tomography. Surgical exploration was performed if ligamentous injury caused marked instability, which is determined with examination under general anesthesia and after fixation. These injuries were treated with suture anchors and used local tissue only. Repair of the injured structures restored stability and concentric reduction was achieved in all the patients. A hinged external fixator was not required for any of the patients. Wounds were closed in layers and sterile dressing was applied. A well-padded, long-arm posterior plaster splint was applied to the elbow at 90 degrees of flexion with the forearm in neutral rotation to protect the ligament repair and coronoid. On the second day after the operation, the drain was removed and passive elbow motion was begun and continued when changing the dressing, under supervision. Sutures and posterior splint were removed together within ten to fifteen days depending on the patient's healing capacity. When the splint was removed, patients were evaluated by the principal investigator and physiotherapist. A hinged, extension blocked elbow splint was applied if there were additional serious soft tissue injuries and if the patient could have residual instability; otherwise a sling was applied and a passive, active-assisted range of motion exercises, including elbow flexion-extension and forearm rotation, was initiated under supervision. Restriction of extension, especially terminal 30 degrees and

Figure 1.(a) A 53 year-old man fell from standing height and had a coronoid fracture with elbow dislocation and medial collateral ligament instability. **(b)** There was an anteromedial coronoid fracture without comminution. **(c, d)** Elbow dislocation was reducted under sedation. Coronoid fracture was fixed with plates and medial collateral ligament was repaired with suture anchore. **(e, f)** At 25 months follow-up, functional arc of motion was obtained without complications. The Mayo Elbow Performance Score was excellent.

permissions were explained to each patient to protect fixation when they were discharged from hospital. Roentgenographic control was done after four weeks and if there was evidence of fracture union, unrestricted active elbow motion and forearm rotation were encouraged. After six weeks, active muscle-strengthening exercises were initiated.

Results

At the final control, the mean arc of elbow flexion-extension was 110.7 (85-130 degrees) degrees and the mean arc of forearm supination-pronation was 134.2 (120-155 degrees) degrees. The functional arc of motion was achieved in ten of the thirteen patients. Three patients who had comminuted fractures or associated ligamentous and terrible triad injuries had less favorable range of motion (average elbow flexion-extension 86.6 degrees and forearm supination-pronation 125 degrees.). Concentric reduction was achieved in eight dislocated elbows. Of these dislocations, five were unstable after reduction. It was difficult to determine any instability before the operation. According to intraoperative exa-

mination and observation at dissection, there were six ligament injuries causing instability in varying degrees. Ligamentous injuries were treated for primary repair with suture anchors. At the final radiographic evidence and clinical examination, all patients had maintained a concentric reduction of the elbow joint and did not have any objective or subjective instability signs. The fractures had united in all patients, except one, whose coronoid was reconstructed with the radial head, and this patient had a less favorable range of motion and MEPS (75). The patients who constituted the working group did not need secondary surgeries. The average score on the MEPS was 86.5 (range, 75-100). According to the categorical ratings, there were four excellent and nine good results. Nine patients had mild pain with heavy work. Four isolated or noncomminuted coronoid fractures had excellent functional results according to MEPS (average MEPS was 98,75). Three patients who had a less favorable functional score according to MEPS had comminuted fractures or associated injuries including terrible triad injuries (average MEPS was 75). Patients who had less favorable results according to MEPS had lateral side injuries, such as lateral collateral ligament injuries or radial head fractures. Patients who had excellent results according to MEPS had no lateral side injuries that caused marked instability; even when the medial collateral ligament had been injured in one patient. (Fig. 1). All patients returned to pre-injury activity level and work. No operative neurovascular complications or infections after surgery were encountered. One patient had heterotopic ossification at the final follow up but it did not cause any significant restrictions in the elbow articulation, and functional elbow range of motion was obtained. According to the Broberg and Morrey radiographic classification system, seven patients had signs of posttraumatic arthritis. There were Grade 1 in four patients, Grade 2 in two patients, and Grade 3 in one patient. Four patients who had excellent results according to MEPS and isolated or noncomminuted coronoid fractures had no posttraumatic arthritis signs on the roentgenographic examination. The average functional score of the patients who had signs of arthritic changes was 81.4.

Discussion

The coronoid process of the ulna is a significant element for elbow stability and forms an anterior buttress with the radial head to prevent posterior dislocation of the elbow. [1-3,6] There are several biomechanic and anatomic cadaver studies that have addressed the role of the coronoid process in elbow stability against axial, posterolateral rotatory or varus loads. [2-9,12] Certain structures which have a significant role in elbow stability are inserting on the coronoid process. The anterior bundle of the medial collateral ligament, lateral collateral ligament complex, anterior elbow capsule and brachialis muscle are inserting on the coronoid process and tend to be injured by complex elbow injuries including coronoid fracture. Besides these structures, the medial collateral ligament and lateral collateral ligament complex are primary soft-tissue contributors to elbow stability. [13] Today, we consider virtually any coronoid fracture to have had an associated collateral ligament injury, even if only a strain.[15] Ring and Jupiter [6] state that when the coronoid is fractured at the base, the ligaments are often preserved, because failure occurs through the bone rather than the ligament.[1] In our study, there were five of the nine Regan Morrey Type 2 fractures that had ligament injuries that caused instability (55.5%) and one of four Regan Morrey Type 3 fractures had ligament injuries that caused instability (25%) determined after fracture fixation. The smaller fractures may tend to be associated with ligament injuries, as Ring and Jupiter stated. Ligamentous injuries seen in association with coronoid fractures have been described previously and lateral collateral ligament injury is the most important part of these types of injuries.[11,14,16,17] McKee et al., addressed characteristic lateral soft-tissue injury patterns and, with other authors, stated that repair of these lateral soft-tissue structures should be an integral part of the surgical strategy.[14,18,20] In our series, we found four lateral ligament injuries and we repaired them with suture anchors. Patients who had lateral collateral ligament injuries had less favorable range of motion and MEPS; otherwise, there were no lateral collateral ligament injuries associated with the patients who had excellent results. Lateral collateral ligament injuries are the most important part of the soft-tissue injuries which are associated with coronoid fractures and which influence the outcome negatively. Recent studies stated that the Regan Morrey classification, which is based on fragment size alone, may be too simplistic and inadequate to address fractures of the coronoid.[5,21,22] The importance of the anteromedial facet fractures of the coronoid process was clearly addressed [21,23] and Doornberg and Ring recognized that various elbow injury patterns are associated with specific types of coronoid fractures.[24] The Regan and Morrey classification system is based on the fragment size on the lateral radiograph and does not consider fragment configurati-

on. In addition, anteromedial fractures and specific fracture types cannot be adequately evaluated with this system. Today, many studies state that the Regan Morrey classification system is inadequate, but it is still most widespread and simple system. The O'Driscoll et al.[5] classification system needs a computed tomography scan and is more complex than Regan Morrey. In addition, we believe that the O'Driscoll classification system needs evaluation with intraobserver and interobserver comparison study, especially for subtypes. We classified coronoid fractures according both classification systems (Table 1) but we analyzed our data with the Regan Morrey classification system because of its prevalence. We noted that the coronoid fragment is bigger than it appears on the radiograph and x-ray examination doesn't indicate the true fracture configuration. For a more detailed investigation of the fracture configuration, computed tomography examination, three-dimensional scans if possible, should be performed. Computed tomography examination also helps the surgeon when determining the incision site and judgment regarding the hardware to use for fixation. Therefore computed tomography and a three-dimensional scan is a valuable investigation and should be performed in these patients. The coronoid fracture is the most important part of complex elbow injuries and the initial focus must be on the coronoid fracture. [18,20,25] However, they usually occur in associated injuries. These injuries should be considered as important negative prognostic factors. Jeon et al. [25] stated that comminution of the fracture fragment and associated soft-tissue injuries are considered unfavorable factors for the functional outcome. In our study, less favorable results were related with comminuted fractures or associated injuries including terrible triad injuries, whereas isolated or noncomminuted coronoid fractures had excellent results according to MEPS. Acceptable clinical outcomes are related not only to the successful rigid internal fixation of the coronoid fracture, but depend on the severity of the primary injury and especially the associated injuries. These injuries must be addressed and treated surgically with coronoid fractures at the same stage. Late reconstruction is difficult and will lead to complications.[5-7,18] Posttraumatic stiffness and elbow instability are well known complications in complex elbow fractures. In our patients, we did not encounter instability and a functional arc of motion was achieved in ten of the thirteen patients. In the three remaining patients, daily activities were not affected seriously and MEPS was good. We think that secure fixation of the coronoid, addressing all associated injuries with early surgical treatment and early mobilization prevent these complications. Arthritic changes may occur in complex elbow fractures even when a concentric reduction is achieved. These changes develop more rapidly especially when the joint is not reduced.[6,19,20] In our study, concentric reduction of the joint and rigid fixation of the coronoid process were achieved in all patients and seven of the thirteen patients (53.8%) had posttraumatic arthritic signs on roentgenographic evaluation. These signs were encountered a minimum of 19 months postoperatively. Six of seven patients who had arthritic changes had associated ligamentous and bony injuries. We state that arthritic changes may develop rapidly even when the joint is reduced and this change depends on not only the concentric reduction and rigid fixation of the coronoid process, but also the severity of the primary injury. Four patients who had excellent results according to MEPS had no signs of arthritic changes and the average of the functional score of the patients who had signs of arthritic changes is 81.4. Therefore arthritic change is an important factor influencing the functional outcome. Rigid fixation is difficult and may be unachievable for comminuted coronoid fractures if the fragments are too small. In this circumstance, the coronoid may be reconstructed with a well-fashioned structural graft from the radial head, ilium and olecranon as an autograft or allograft. [26,28] In our study, one coronoid fracture was reconstructed with a radial head autograft. At 96 months follow-up, the radial head autograft was not radiologically united and a less favorable range of motion and MEPS had resulted. However, this patient has no instability and marked restriction of daily activities. He returned to work with mild pain. Coronoid reconstruction with a structural bone graft may be a useful option for the untreatable or deficient coronoid process, but it has not yielded predictable outcomes. Coronoid fractures can be managed with an external fixation. Several authors have reported satisfactory results using hinged fixators in the setting of chronic instability after failure of bony or ligamentous repair. [6,7,18,20,29] Hinged external fixation is also indicated for severe comminuted coronoid fractures not amenable to internal fixation in acute settings. If instability persists after principal fixation and repair, application of an articulated external fixator may be a useful adjunctive treatment. External fixation was not required for any patients in this study. If all elements of the pathology are addressed and treated securely, in most of the cases external fixation is not essential for these fractures in acute

settings, except for severely comminuted coronoid fractures. Heterotopic ossification is commonplace after traumatic elbow injuries. Indomethacin or irradiation can be used as prophylaxis against heterotopic ossification.[15,19] We did not use prophylactic agents for heterotopic ossification. One patient had heterotopic ossification at 74 months follow-up and surgical intervention was not required. Coronoid fracture is the most important part of complex elbow injuries. Evaluation and surgical intervention should start with the coronoid, although all elements of the pathology should be addressed and treated at the same stage in acute settings. Secure fixation of the coronoid and proper treatment of associated injuries have a positive effect on the outcome.

References

1. Ablove RH, Moy OJ, Howard C, Peimer CA, S'Doia S. Ulnar coronoid process anatomy: possible implications for elbow instability. Clin Orthop Relat Res 2006;(449):259-61.
2. Closkey RF, Goode JR, Kirschenbaum D, Cody RP. The role of the coronoid process in elbow stability. A biomechanical analysis of axial loading. J Bone Joint Surg [Am] 2000;82:1749-53.
3. Morrey BF, An KN. Stability of the elbow: osseous constraints. J Shoulder Elbow Surg 2005;14(1 Suppl S):174S-178S.
4. Regan W, Morrey B. Fractures of the coronoid process of the ulna. J Bone Joint Surg [Am] 1989;71:1348-54.
5. O'Driscoll SW, Jupiter JB, Cohen MS, Ring D, McKee MD. Difficult elbow fractures: pearls and pitfalls. Instr Course Lect 2003;52:113-34.
6. Ring D. Fractures of the coronoid process of the ulna. J Hand Surg [Am] 2006;31:1679-89.
7. Tashjian RZ, Katarincic JA. Complex elbow instability. J Am Acad Orthop Surg 2006;14:278-86.
8. Broberg MA, Morrey BF. Results of delayed excision of the radial head after fracture. J Bone Joint Surg [Am] 1986; 68:669-74.
9. Beingessner DM, Dunning CE, Stacpoole RA, Johnson JA, King GJ. The effect of coronoid fractures on elbow kinematics and stability. Clin Biomech 2007;22:183-90.
10. Hull JR, Owen JR, Fern SE, Wayne JS, Boardman ND 3rd. Role of the coronoid process in varus osteoarticular stability of the elbow. J Shoulder Elbow Surg 2005;14:441-6.
11. Okazaki M, Takayama S, Seki A, Ikegami H, Nakamura T. Posterolateral rotatory instability of the elbow with insufficient coronoid process of the ulna: a report of 3 patients. J Hand Surg [Am] 2007;32:236-9.
12. Schneeberger AG, Sadowski MM, Jacob HA. Coronoid process and radial head as posterolateral rotatory stabilizers of the elbow. J Bone Joint Surg [Am] 2004;86:975-82.
13. Terada N, Yamada H, Seki T, Urabe T, Takayama S. The importance of reducing small fractures of the coronoid process in the treatment of unstable elbow dislocation. J Shoulder Elbow Surg 2000;9:344-6.
14. McKee MD, Schemitsch EH, Sala MJ, O'Driscoll SW. The pathoanatomy of lateral ligamentous disruption in complex elbow instability. J Shoulder Elbow Surg 2003;12:391-6.
15. Regan WD, Morrey BF. Coronoid process and Monteggia fractures. In: Morrey BF, editor. The elbow and its disorders. 3rd ed. Philadelphia: W. B. Saunders; 2000. p. 396-408.
16. Olsen BS, Sojbjerg JO, Dalstra M, Sneppen O. Kinematics of the lateral ligamentous constraints of the elbow joint. J Shoulder Elbow Surg 1996;5:333-41.
17. Josefsson PO, Johnell O, Wendeberg B. Ligamentous injuries in dislocations of the elbow joint. Clin Orthop Relat Res 1987;(221):221-5.
18. Papandrea RF, Morrey BF, O'Driscoll SW. Reconstruction for persistent instability of the elbow after coronoid fracture-dislocation. J Shoulder Elbow Surg 2007;16:68-77.
19. Pugh DM, Wild LM, Schemitsch EH, King GJ, McKee MD. Standard surgical protocol to treat elbow dislocations with radial head and coronoid fractures. J Bone Joint Surg [Am] 2004;86:1122-30.
20. Ring D, Jupiter JB, Zilberfarb J. Posterior dislocation of the elbow with fractures of the radial head and coronoid. J Bone Joint Surg [Am] 2002;84:547-51.
21. Doornberg JN, Ring DC. Fracture of the anteromedial facet of the coronoid process. J Bone Joint Surg [Am] 2006; 88:2216-24.
22. Doornberg JN, van Duijn J, Ring D. Coronoid fracture height in terrible-triad injuries. J Hand Surg [Am] 2006;31:794-7.
23. Sanchez-Sotelo J, O'Driscoll SW, Morrey BF. Medial oblique compression fracture of the coronoid process of the ulna. J Shoulder Elbow Surg 2005;14:60-4.
24. Doornberg JN, Ring D. Coronoid fracture patterns. J Hand Surg [Am] 2006;31:45-52.
25. Jeon IH, Oh CW, Kyung HS, Park BC, Kim PT, Ihn JC. Functional outcome after operative treatment of eight type III coronoid process fractures. J Trauma 2005;59:418-23.
26. Chung CH, Wang SJ, Chang YC, Wu SS. Reconstruction of the coronoid process with iliac crest bone graft in complex fracture-dislocation of elbow. Arch Orthop Trauma Surg 2007;127:33-7.
27. Moritomo H, Tada K, Yoshida T, Kawatsu N. Reconstruction of the coronoid for chronic dislocation of the elbow. Use of a graft from the olecranon in two cases. J Bone Joint Surg [Br] 1998;80:490-2.
28. Van Riet RP, Morrey BF, O'Driscoll SW. Use of osteochondral bone graft in coronoid fractures. J Shoulder Elbow Surg 2005;14:519-23.
29. Ring D, Hannouche D, Jupiter JB. Surgical treatment of persistent dislocation or subluxation of the ulnohumeral joint after fracture-dislocation of the elbow. J Hand Surg [Am] 2004;29:470-80.