



Treatment results of pseudarthrosis of the humeral shaft by open reduction and internal fixation with dynamic compression plating

Humerus diyafiz psödoartrozlu olgularda dinamik kompresyon plağı ile açık redüksiyon ve internal fiksasyon uygulamasının sonuçları

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Amaç: Humerus diyafiz psödoartrozu nedeniyle dinamik kompresyon plağı kullanılarak açık redüksiyon ve internal fiksasyon uygulanan olgularda tedavi sonuçları değerlendirildi.

Çalışma planı: Çalışmaya, aseptik humerus diyafiz psödoartrozu tanısıyla dinamik kompresyon plağı kullanılarak açık redüksiyon ve internal fiksasyon ile tedavi edilen 18 hasta (12 erkek, 6 kadın; ort. yaş 41; dağılım 22-68) alındı. İlk tedavi olarak yedi hastada konservatif, 11'inde cerrahi yöntemler denenmişti. İlk tedavi ile plak vida uygulaması arasında geçen süre ortalama 12.2 ay (dağılım 5-46 ay) idi. Bütün olgularda radial sinir eksplorasyonu ve otojen kortikospongioz greftleme aynı anda yapıldı. Fonksiyonel sonuçlar Stewart-Hundley ölçütlerine göre değerlendirildi. Olgular ortalama 38.8 ay (12-78 ay) süreyle izlendi.

Sonuçlar: Bir olgu dışında tüm olgularda (%94.4) ortalama 5.5 ay (3-8 ay) sürede kaynama sağlandı. Stewart-Hundley ölçütlerine göre, 14 olguda (%77.8) iyi, üçünde (%16.7) orta, birinde (%5.6) kötü sonuç elde edildi. Ameliyat sonrası erken dönemde iki olguda gözlenen radial sinir paralizisi ameliyattan sonra üçüncü ve beşinci aylarda kendiliğinden iyileşti. İki olguda orta derecede refleks sempatik distrofi gelişti.

Çıkarımlar: Humerus diyafiz psödoartrozunun dinamik kompresyon plağı kullanılarak yapılan açık redüksiyon ve internal fiksasyon ile tedavisinde, uygun endikasyonlarda ve iyi bir cerrahi teknikte çok başarılı sonuçlar elde edilebilir.

Anahtar sözcükler: Kemik plağı; kırık fiksasyonu, internal; humerus kırıkları/cerrahi/komplikasyon/radyografi; psödoartroz/etyoloji/cerrahi; radial sinir/yaralanma.

Objectives: We evaluated the results of open reduction and internal fixation with the use of dynamic compression plating in patients with pseudarthrosis of the humeral shaft.

Methods: Eighteen patients (12 males, 6 females; mean age 41 years; range 22 to 68 years) with aseptic pseudarthrosis of the humeral shaft were treated by open reduction and internal fixation with the use of a dynamic compression plate following unsuccessful treatment with conservative (n=7) or surgical (n=11) methods. The mean interval between the initial and final treatments was 12.2 months (range 5 to 46 months). Exploration of the radial nerve and autogenous corticocancellous grafting were simultaneously performed in all the cases. Functional results were evaluated according to the Stewart-Hundley's criteria. The mean follow-up was 38.8 months (range 12 to 78 months).

Results: Union was achieved in all (%94.4) but one patient within a mean duration of 5.5 months (range 3 to 8 months). Functional results were good in fourteen patients (77.8%), fair in three patients (16.7%), and poor in one patient (5.6%). Radial nerve palsy that occurred in two patients during the early postoperative period underwent spontaneous recovery within three and five months, respectively. Mild reflex sympathetic dystrophy developed in two patients.

Conclusion: In selected patients with pseudarthrosis of the humeral shaft, the results of open reduction and internal fixation with the use of dynamic compression plating are excellent, provided that an appropriate surgical technique is employed.

Key words: Bone plates; fracture fixation, internal; humeral fractures/surgery/complications/radiography; pseudarthrosis/etiology/surgery; radial nerve/injuries.

Successful results can be achieved generally by conservative methods in the treatment of humeral shaft fractures. However, there are circumstances when surgical methods may be indicated, namely for unacceptable alignment, for fractures associated with no signs of healing, for patients who can not tolerate conservative treatment.^[1-11] Rates of pseudarthrosis between 0% and 13% have been reported which didn't depend on the treatment method.^[2,3,5,8] Although the prevalence of pseudarthrosis is between 0% 8% after the conservative method, it may be as high as 13% after operative treatment.^[2,3,5,8] It is more difficult to achieve successful results in the treatment of humeral pseudarthroses because it is not possible to benefit from compressive forces as in the lower extremities. Surgical methods are considered currently in the treatment of humeral pseudarthroses. If surgery is required, plates and screws, intramedullary nailing, various external fixators are generally used with or without bone grafting.^[2,3,5,7]

Compression plating, which is a classic method, was first used by Müller et al.^[12,13] In selected patents and indications with pseudarthrosis of the humeral shaft, it is a preferred method because of its high success rate when used by simultaneous autogenous corticocancellous grafting.

This study describes the results of open reduction and internal fixation done by the use of dynamic compression plate for the patients that were previously treated by conservative or surgical methods.

Patients and methods

In this study, we examined the results of 18 patients (12 men, 6 women; mean age 41; range 21-68) who were treated by open reduction and internal fixation with the use of DCP for humeral pseudarthrosis diagnosed radiologically and clinically. Broad DCP was used for all the patients except two cases who had thin humeral diaphysis. Exploration of the radial nerve and autogenous corticocancellous grafting were performed in all the cases. Etiology was traffic accident in eight patients; fall in six patients, sports injury in one and work-related accident in three patients. The initial treatment was conservative in seven and surgical in eleven patients (1 intramedullary nail, 3 external fixator, 7 plate-screws). Eleven fractures were in the

dominant arm in which 4 fractures had been treated conservatively and seven fractures by surgical methods. The mean surgical intervention number of the eleven patients was 1.36 (range 1 to 3). The implants of three patients in this group were taken off due to infection.

Infection was not encountered in any of the patients at the latest examination. Forward flexion of the shoulder averaged 130 degrees, abduction of the shoulder 135 degrees and the range of motion of the elbow 120 degrees. The time period from the initial treatment to our plating averaged 12.2 months (range 5 to 46 months). Pseudarthrosis was assessed by a clinical examination and AP-lateral radiographs. Pseudarthrosis was hypertrophic in five patients and atrophic in thirteen patients. Fractures were open in four and closed in 14 patients. The fracture line had been transverse in 11 cases, oblique in four, and spiroid in two. The fracture had been at the proximal third of the humeral shaft in two cases, at the middle third in fifteen, and at the distal third in one. Radial nerve exploration was performed by an anterolateral incision for pseudarthrosis in the proximal third of the humerus and by the lateral incision for the others. If the pseudarthrosis was situated in proximal part of the humeral shaft, the radial nerve was identified until it curved posteriorly in the embedded scar tissue due to the previous surgery. The implant material was dehiscent if it exists. The tip of the bone fragments was vitalized and the medullary canals of both fragments were opened. The insertion of the deltoid muscle was detached from the proximal humerus in order to apply the long plate. Decortication was performed for the callus regeneration and to create enough space for the plate, 0.5-1cm (range 0 to 4) shortening was done to achieve a full compression at the fracture sites. Compression plate was applied laterally in all patients. Broad DCP was preferred for the available anatomic structures. Fixation was secured with a minimum of four cortices on either side of the pseudarthrosis and generally with 6 or more cortices. (Figure 1 a-d, 2 a-d). Autogenous bone grafts from the anterior iliac crest were routinely used for all the patients. Axial compression for the transverse fractures and interfragmentary compression for the oblique fractures were performed. Subacromial bursa tissue was resected to release the scar tissue in the shoulder especially for

proximal type pseudarthrosis when the shoulder motion is restricted. The coracoacromial ligament is cut out, and contracted musculus subscapularis or pectoralis major was released. After a stable internal fixation and manipulation under general anesthesia, physiotherapy and early passive motion is started for the patients who had restricted shoulder motion and middle third's pseudarthrosis of the humeral shaft.

Capsule was released as an arthrolysis after the release of musculus brachialis and triceps for the patients who had very restricted elbow motion and pseudoarthrosis of the middle third of the humeral shaft. A well padded cast brace was used for the patients after the operation. On the third postoperative day, during the wound control, we started controlled active shoulder and elbow motion supervised

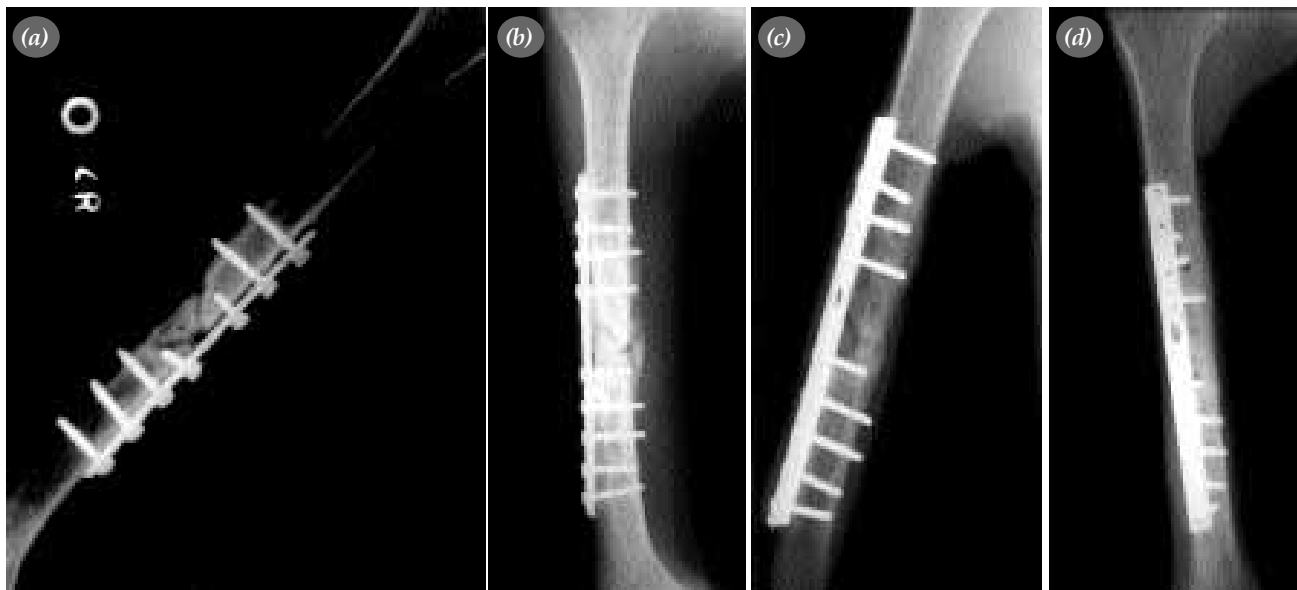


Figure 1. a) a preoperative radiograph of a humeral fracture of a patient with a history of 8 months which was treated with a plate implanted medially but not well stabilized because of an insufficient fixation. b) An early, postoperative radiograph of the same patient fixed with a dynamic compression plate implanted laterally and also autogenous corticocancellous grafts were used. c) Radiograph shows union 5 months after the operation. d) Radiograph taken 13 months postoperatively shows solid union.



Figure. 2 a) A radiograph of a patient who was treated with a cast conservatively b) A preoperative radiograph showed no union after the conservative treatment. c,d) AP and lateral radiographs, taken after open reduction and internal fixation with dynamic compression plating, demonstrating achievement of union.

Table 1. Functional results according to the Stewart and Hundley's^[14] criteria

Score	Pain	Limitation of elbow or shoulder mobility	Angulations
Good	No	< 20°	< 10°
Fair	after efforts or fatigue	20°-40°	> 10°
Poor	permanent	> 40°	Radiologic nonunion

by a physiotherapist. Physiotherapy is continued as long as the patients stayed at the hospital (averaging 7 days; range 5 to 26 days). Each time the cast braces were readapted. After the healing of the wound (averaged 3 weeks), the braces were abandoned and active or passive functional treatment was started. Simple actions were permitted to support the daily basic needs. Protective brace is used which did not preclude the shoulder and elbow motion for six weeks. At the latest follow-up the cases were questioned for objective and subjective evaluation. For subjective evaluation, pain and satisfaction of the patients were questioned. Radiological union and functional results were observed for objective evaluation. Union was accepted when the bone trabeculae bridging the pseudarthrosis line were seen on radiographs. Functional results were evaluated according to the Stewart-Hundley's criteria (Table 1) Mean follow-up was 38.8 months (range 12 to 78).

Results

Union was achieved in all but one patient within a mean duration of 5.5 months (range 3 to 8 months). The patient who did not achieve union had a chronic renal failure, he was old and obese, osteoporotic also he was treated with an external fixator initially and rigid fixation was not achieved at this first operation. Because the patient did not accept any other treatment method, he was followed by a brace. He was able to use this nondominant arm for the basic daily activities. At the latest follow up, 15 patients (83.3%) were satisfied with their present condition, and three patients (16.7 %) were not satisfied with the treatment method. Although union was achieved, four patients complained of pain. According to the Stewart-Hundley's criteria, functional results were good in fourteen patients (77.8%), fair in three patients (16.7%), and poor in one patient (5.6%). The poor result was in the patient in whom we couldn't achieve union. The

patient with the fair result had an elbow motion restriction with a 20-40 degrees. The other patient had a 20-40 degrees shoulder motion restriction, and on the lateral view there was an angulation of 10 degrees. In the third patient, there was a fatigue pain and it was relieving at rest.

Before referral to our clinic there were two cases of radial nerve palsy. One of them was followed up without an additional procedure. In this case, we observed that the radial nerve was compressed with a bony spur. Paralysis resolved completely after the release of the nerve. In the other case, intramedullary nailing was performed before. During the operation the neurosurgeons were consulted and then the fibrotic part of the radial nerve was excised and it was replaced with a sural nerve interposition. But there was not a complete healing of the nerve after the intervention, so we planned a tendon transfer in the future. On the other hand, we observed a radial nerve palsy after the operations in two cases in whom the nerves were intact before the operation. Radial nerve palsy underwent spontaneous recovery within three and five months, respectively. Besides these neurologic complications, a superficial infection healed after an antibiotherapy and a reflex sympathetic dystrophy resolved after a physiotherapy.

Discussion

It is difficult and troublesome to treat the pseudarthrosis of the humeral shaft. More than one surgical intervention can be needed to treat them by surgical methods. Success rate decreases with an increase in the number of surgical interventions and complications are higher. Patients that are prone to pseudarthrosis should be well-known to decrease the complication rate and the preferred surgical method should be well performed. The generally accepted factors for humeral shaft pseudarthrosis are those; fractures at the junction of middle and proximal

third humeral shaft, open and pathologic fractures, preexisting systemic diseases, obesity, chronic shoulder and elbow movement restriction, alcohol and smoking, and also osteoporosis. Technical errors of the surgical method and insufficient follow-up also increase the pseudarthrosis rate.^[1-8,15]

Rigid fixation is not always achieved in all patients by ORIF with the use of a plate and screws.^[16] Various methods are advocated especially for older, osteoporotic, badly qualified bones, also for those who are operated more than one. ORIF method can be performed by the use of onlay or intramedullary grafts combined with a locked compression plate adapted to the Schuhli nuts or a blade plate in osteoporotic patients. Trotter and Dobozi^[17] tried to strengthen the plate and screw fixation by a bone cement inserted into the medulla. But this method has disadvantages of disturbing the medullary circulation and leakage of the bone cement into the pseudarthrosis line which may affect the healing in a negative way. Kassab et al^[18] used locking nuts with plate and screw fixation in osteoporotic patients to increase the rigidity of fixation. Wright et al^[19] used screws by passing them through the autogenous or allogeneic fibula to improve the engagement and push out strengths of the screws to the bone in similar cases. Intramedullary nailing is advised for osteoporotic and comminuted fractures in which a broad incision and soft tissue dissection is needed to apply a plate and screws. And also it is advised for the cases in whom neurolysis is very difficult because of the embedded scar tissue.^[20] It is not always possible to achieve rotational stability and to close the nonunion gap by the use of intramedullary nails. Distraction occurs at the fracture sites even in applying intramedullary implants for fresh fractures. Subacromial impingement syndrome or elbow problems are encountered in the treatment of humeral shaft pseudarthrosis due to the technique of application in the entry site.

Modabber and Jupiter^[21] compared the results of plate-fixation and intramedullary nailing in the treatment of humeral pseudarthrosis. Disadvantages of plate fixation were, noncosmetic appearance due to the extensile approach, impaired periosteal circulation, possibility of iatrogenic nerve palsy, and blood loss. Advantages of this method were possibility of nerve repair because of direct exploration, simplici-

ty of applying the plate to each segment of the humeral shaft, and also possibility of bone grafting, debridement and resection of the pseudarthrosis site from a single incision in one operation.

Disadvantages of intramedullary nailing are; shoulder or elbow problems due to the application of the technique, possibility of iatrogenic nerve injury and fractures, impairment of endosteal circulation, spread of infection of the other sites of humerus, impossibility of performing the method in cases of humeral deformities, obstruction of the medullary canal, need of a second surgery for the extraction of the implant. Advantages are; this method is stronger biomechanically, preservation of periosteal circulation, less blood loss, application of the implant for away from the surgical incision. Although plate screw fixation has many disadvantages but union rates are higher in this method.^[6-8,22,24,25,28]

Many treatment methods are not available or are contraindicated in cases of infection. Debridement, excision of the necrotic tissue, irrigation and local antibiotherapy should be performed first. External fixators are performed in the presence of an infection. Torsional and shearing forces are effective on the humerus because it is not bearing a load. Today Ilizarov-type fixators are performed because they resist these forces and also gradual axial compression and/or distraction is possible with this type fixator.^[9] External fixators have an advantage of less blood loss and it is possible to correct the deformity and shortness simultaneously. Development of joint movement restriction is prevented during the treatment period. But this method has many disadvantages. Neurovascular injury and pin tract infection may occur with this method. It is difficult to perform the method and also refractures may occur after the extraction of the fixator.^[4,5] It must not be the first choice when there is a risk of radial nerve injury, intolerance of the patient and the surgeon is not acknowledged and experienced with the system. It must be preferred in these situations: If the scar disease is high due to the old operations, bone loss is much, and also if there is an angulated deformity and infected pseudoarthrosis. Patient intolerance with this method and the failure of the other methods in cases of segment transport as shortness, led the surgeons to search for new methods. Ring et al^[29] treated the humeral nonunions by the use of waved plates

and corticocancellous autografts. Jupiter^[30] also used medial plate application combined with fibula grafts and was successful in this method.

Up to date plate and screw fixation is the most preferred method for the treatment of humeral shaft pseudarthroses. When compared with other methods, plate and screw application has a high rate of union. Rosen^[7] treated 25 patients with nonunions of the humeral shaft by ORIF with the use of compression plate and bone graft for the atrophic nonunions. He achieved union in 24 of the 25 cases and declared that union is available in 95% of the nonunions of the humeral shaft if one follows the AO/ASIF principles of open reduction and stable internal fixation. Barquet et al^[28] reported 24 cases undergoing union in periods averaging 6 months after performing ORIF and corticocancellous grafting with the use of a broad DCP for 25 patients of having aseptic pseudarthrosis of the humeral shaft. As a complication there was one patient with a radial nerve lesion that underwent healing 12 weeks after the operation. Marti et al^[31] treated 51 patients with a protocol of careful radial nerve exploration, autogenous corticocancellous bone grafting and application of a 4,5 millimeter DCP. In their series, they achieved union in 50 cases and also they had a complete consolidation in all of the cases after one year. 23 patients were treated by conservative methods and 28 were treated by surgical methods before.

In our study 17 of 18 patients achieved union with an average of 5.5 months. Initial treatment was operative in 11 cases. We also preferred autogenous corticocancellous grafting in all cases. We consider that the difference in union achievement time in two series depends on the various numbers of conservative or operative treatment methods before.

The primary cause of the humeral shaft pseudoarthrosis is the insufficient surgical technique. The success of ORIF method with the use of DCP is best achieved by the fact that the rules of osteosynthesis technique is strictly obeyed and sufficient stabilization is reached. Broad DCP should be preferred in surgical practices. Narrow DCP can be used especially in the narrow humeral shaft or if the patient is woman. To enhance the stability, the screws must be fixed in different directions instead of providing a parallelism between them.^[13] A minimum of four cortices on both sides of the

pseudarthrosis site should be engaged by the screws and it may also be five or six too.^[6,31] Healy et al^[8] made an analysis of successful and unsuccessful results for nonunions treated by plate-screw fixation. Unsuccessful platings averaged 2.1 above and below the nonunion but successful plating averaged 6.8(distally 7.1). In our study we applied broad DCP in 16 patients (88.9%) and narrow DCP in two patents (11.1%). We also used a minimum of four screws and preferable five or more screws on both sides of the nonunion. Ellipsoid holes of the DCP enables the screws to be engaged in different directions depending on the quality of the bone and also prevents new screws being directed into the older holes formed by the previous screws. Also stabilization may be improved by purchasing the corticocancellous graft and on the other cortex of the bone. Some authors offer a two plate construct because one-plate construct does not provide sufficient stabilization. Rubel et al^[32] showed in an experimental study that a two plate construct provides a more stiff stability biomechanically and also decreases the micromotion at the pseudarthrosis site. However, a two-plate fixation has a limited practise because it requires an extensible dissection, increases the risk of infection and osteoporosis in humeral bone. Beyond the healing of pseudarthrosis of the lower extremities, equalization of the bone length is also recommended. However, 4-5 cm difference in two upper extremities is accepted in the treatment of humeral pseudarthrosis of the shaft. No functional or cosmetic morbidity occurs. Shortening of the bone as necessary to achieve apposition and compression of the two diaphyseal bone is accepted. The amount of compression is important because humerus does not carry a load. The best amount of compression to achieve union of the humeral shaft pseudarthrosis is best provided by the method of ORIF with the use of DCP. We did not shorten the humeral bone over 4cm.

Physiotherapeutic rehabilitation can be started earlier after a stable fixation performed by a good surgical technique. Restriction of the shoulder and elbow movement associated with the conventional methods can be prevented with this method. In our study, functional results were good in four, fair in three and poor in one patient. As a well-done stabilization has a good effect on achieving union and also permits earlier rehabilitation. So patients obtaining function-

al gains feel better. Progress in osteopenia associated with immobility and decrease in muscle tone can be prevented especially in older patients.

Radial nerve injury after the treatment of humeral shaft pseudarthrosis is reported as 3-29 % in the literature. This rate ranged from 2% to 4% after ORIF method. In our study, it was 2%. Because a great amount of nerve injuries are neuropraxia or axinotimesis; spontaneous recovery is achieved in 90% of them. Neurolysis of radial nerve performed by a broad exposure enables the surgeon to solve mechanical problems that cause the injury. In one of the patients, radial nerve injury was treated by excision of a cortical spur. Infection rate decreases by atraumatic handling of the soft tissues even a broad exposure is used. A superficial infection treated by an antibiotherapy was observed in one of our patients. Deep infection occurred in none of the patients. It is difficult and troublesome to treat the pseudarthrosis of the humeral shaft. As the number of surgical interventions increase, the success rate decreases. The surgical application should be performed after the evaluation of the patient, the pseudarthrosis and choice of the appropriate method. The primary cause of the unsuccessful outcome is the inability to perform a good and correct surgical technique. It is also true for humeral fractures. And also performing surgical procedures without a minimum number of operations decreases the success rate. ORIF by the use of a DCP provides many procedures to be performed from a single incision in one operation. In selected patients without osteoporosis and infection; this method is excellent provided that a good surgical technique is employed.

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