



The results of internal fixation of proximal humeral fractures with the PHILOS locking plate

Proksimal humerus kırıklarında kilitli plak PHILOS ile internal tespit sonuçları

Mehmet Fatih KORKMAZ, Neslihan AKSU, Abdullah GOGUS, Mursel DEBRE,¹
Ayhan Nedim KARA, Zekeriya Ugur ISIKLAR

*Istanbul Bilim University, Department of Orthopaedics and Traumatology; ¹Florence Nightingale Hospital,
Department of Orthopaedics and Traumatology*

Amaç: Humerus proksimal ve diyafiz kırıkları, osteoporotik hastalarda sık görülen ve cerrahisi komplikasyonlarla seyreden sorunlu kırıklardır. Çalışmamızda AO/ASIF grubu tarafından geliştirilen ve kilitli vidalarla sabit açılı stabilizasyon sağlayan yeni internal tespit sistemi PHILOS (Proximal Humeral Internal Locking System) ile tedavi edilen hastaların sonuçları değerlendirildi.

Çalışma planı: Çalışmaya, proksimal humerus kırığı nedeniyle PHILOS plak sistemiyle tedavi edilen 41 hasta alındı. Hastalar 65 yaş altı (grup A) ve 65 yaş veya üstü (grup B) olarak iki grupta değerlendirildi. Grup A'da 24 hasta (12 erkek, 12 kadın; ort. yaş 47, dağılım 24-64); grup B'de 17 hasta (4 erkek 13 kadın; ort. yaş 78, dağılım 67-90) vardı. Radyografik olarak tüm kırıklar AO/ASIF ölçütlerine göre sınıflandırıldı. Grup A ve B'de sırasıyla 10 hasta ve iki hastada deltopektoral girişim; 14 hasta ve 15 hastada deltooid split girişim uygulandı. Ortalama 15 ay (dağılım 6-28 ay) takip süresi sonunda her iki grubun fonksiyonel ve radyografik sonuçları değerlendirildi.

Sonuçlar: Constant omuz skoru grup A'da ortalama 95.0 (dağılım 74-100), grup B'de 92.8 (dağılım 72-100) bulundu ($p>0.05$). Deltopektoral ve deltooid split girişim uygulanan olgularda altıncı aydan sonra Constant skoru ve fonksiyonel açıdan fark saptanmadı. Hiçbir hastada kaynamama veya implant yetersizliği gözlenmedi. Komplikasyonlar şunlardı: Vidanın eklem içine girmesi ($n=1$), tüberkülem majus fragmanında deplasman ($n=1$) ile birlikte plağın oblik yerleşimi ($n=1$), yetersiz redüksiyon ($n=4$) ve başın varus pozisyonunda tespiti ($n=3$). Hiçbir olguda avasküler nekroz görülmedi.

Çıkarımlar: Kilitli vida plak sistemi, özellikle osteoporotik kırıkların tespitinde bugüne kadar kullanılan osteosentez yöntemlerinden, erken harekete izin vermesi ve implant yetersizliği olmaması nedeniyle üstündür.

Anahtar sözcükler: Kemik plağı; kemik vidası; kırık tespiti, internal/yöntem; humerus kırığı/cerrahi; omuz kırığı/cerrahi.

Objectives: Proximal and diaphyseal humeral fractures are common especially in the elderly, presenting as a challenging problem due to their high complication rates following surgical treatment. In this prospective study, we evaluated the results of patients treated with the PHILOS (Proximal Humeral Internal Locking System) locking plate, a new technique recently developed by the AO/ASIF.

Methods: Forty-one patients who were treated with the PHILOS plate for proximal humeral fractures were evaluated in two age groups. Group A included 24 patients (12 males, 12 females; mean age 47 years; range 24 to 64 years) younger than 65 years, and group B involved 17 patients (4 males, 13 females; mean age 78 years; range 67 to 90 years) at or above 65 years. Radiographically, all fractures were classified according to the AO/ASIF system. Surgery was performed with the deltopectoral approach in 10 and two patients, and with a deltooid split in 14 and 15 patients in group A and B, respectively. Functional and radiographic results were evaluated after a mean follow-up of 15 months (range 6 to 28 months).

Results: The mean Constant scores were 95.0 (range 74 to 100) and 92.8 (range 72 to 100) in group A and B, respectively ($p>0.05$). After six months of surgery, Constant scores and functional outcomes were similar in patients operated on with the deltopectoral approach or deltooid split. There was neither nonunion nor implant failure. Complications included intra-articular screw penetration ($n=1$), displacement of the greater tuberculum ($n=1$) with oblique placement of the plate ($n=1$), insufficient reduction ($n=4$), and varus displacement of the humeral head ($n=3$). No avascular necrosis was seen.

Conclusion: Locking plate system is superior over other means of fixation methods, particularly in osteoporotic fractures, because it allows early rehabilitation and does not result in implant failure.

Key words: Bone plates; bone screws; fracture fixation, internal/methods; humeral fractures/surgery; shoulder fractures/surgery.

Proximal fractures of the humerus constitute 5-8% of all humeral fractures^[1,2] Although more than 80% of these heal without surgical intervention, the rates of nonunion vary between %1 and 23% in displaced and nonimpacted fractures of the surgical neck. ^[1,3-5] These fractures are displaced in 20% of the cases and may coexist with other injuries.^[6,7] The aim of treatment in proximal humeral fractures is to attain a painless and simultaneously functional shoulder. This result depends on the age, medical condition, bone quality and expectations of the patient as well as a good evaluation of the current fixation techniques. Loosening or failure of the implant and nonunion are possible complications of surgery in humeral fractures. There is still no treatment that can be the golden standart in these fractures.^[8] Shoulder arthroplasty for proximal humerus fracture is effective in the elimination of pain, however the functional results are limited.^[9,10,11,12] Especially in comminuted fractures of the humerus that involve the trabeculae the functional results are not good. The factors which negatively affect the functional results after fracture have been studied. In comminuted osteoporotic fractures where the trabeculae are also fractured, the placement of the prosthesis in the appropriate height and position, establishment of trabecular stability and repair of the rotator cuff may be difficult. These difficulties negatively affect the functional success of the prosthesis.^[11,12] In order to decrease the high complication rates of proximal humeral fractures, the AO/ASIF group developed the PHILOS (The Proximal Humeral Internal Locking System) plate (Synthes, Stratec Medical ltd, Mezzovico Switzerland), an internal fixation system that enables angled stabilization with multiple interlocking screws. In this study, the results of 41 patients with proximal humeral fractures who were treated with internal fixation using PHILOS plate in our hospital between September 2005 and July 2007 are analyzed. Functional evaluation was carried out using Constant shoulder scale. The functional results were investigated in this plate, which early results are being reported in the literature.

Material and method

Between September 2005 and December 2007, a total of 64 patients underwent surgical treatment with PHILOS plate system. Forty one patients who had longer than 6 months follow up and who fulfilled the inclusion criteria were taken into the study.

Inclusion criteria: 1. Closed proximal humerus frac-

ture (AO/ASIF bifocal, unifocal, intraarticular). 2. Fractures not treated with conservative means (inadequate position, osteoporotic fracture, patients who did not accept conservativie treatment) 3. Patients older than 18 years. Exclusion criteria: 1.Pathologic fractures 2. Patients with primary or metastatic tumors (one patient who had enchondroma was not included) 3. Fractures with nonunion. In four patients older that 65, there were associated fractures in the contralateral femur diaphysis, ipsilateral femur diaphysis fracture, ipsilateral intraarticular humerus distal edge fracture and distal radius fracture, and ipsilateral distal radius fracture. The patients (n=41) were separated into two groups, below age 65 (Group A), and above age 65 (Group B). In group A, there were 24 patients (12 males, 12 females; mean age 45.66, range 24-64). In group B, there were 15 patients (4 males, and 13 females; mean age: 77.73, range 67-90). In order to completely analyse the fractue type AP and transthoracic lateral imaging was used, and CT scans were used only in selected cases. Using X-rays, all fractures were classified according to AO/AIF classification (Müller et al, 1990) (Table 1). Computer tomography was used only in selected cases to evaluate the extension to the articular surface and to evaluate the amount of major tuberculum displacement in comminuted fractures. All operations were controlled using fluoroscopy. After a mean follow up period of 14.68 (6-28) months the functional and radiologic results of both groups were assessed. In the surgical treatment of proximal humeral fractures, most surgeons prefer the deltopectoral approach due to their education and habits. The deltoid splitting approach is a good choice especially in comminuted fractures or where the trabecular fragments are displaced. We used both approaches. The patients were positioned in the beach chair position. Ten patients in Group A underwent deltopectoral approach and 14 underwent deltoid split approach. Two patients in Group B underwent deltopectoral approach and 15 underwent deltoid split approach. In proximal femur

Table 1. The classification of fractures according to AO/ASIF.

	Below age 65 (Group A)	Above age 65 (Group B)
1.1 A.1	–	–
1.1 A.2	7	5
1.1 A.3	1	3
1.1 B.1	9	7
1.1 B.2	2	1
1.1 C.1	4	–



Figure 1. 64 year old male patient. The fracture is 1.1.B.1 according to AO classification. Preoperative (a) and postoperative (b) X rays (deltoid split approach is used). (c) Postoperative joint range of motion is shown (Constant score: 96).

fractures, after the fracture site was exposed, reduction was enabled with a K wire under fluoroscopy and with ethibond sutures passed through the rotator cuff tendons. The PHILOS plate was positioned lateral to the bicipital groove and distal to the major tuberculum, and the correct position was checked with fluoroscopy. The tubercular fragments and rotator cuff tendons were fixed using sutures passing from these structures and the plate. Finally, fracture reduction and screw length were assessed with fluoroscopy. Preoperative and postoperative images of our cases are shown in Figures 1,2,3.

In 5 patients who underwent deltoid split approach, the axillary nerve was seen to be compressed between fracture fragments and was released. None of the patients had hypoesthesia in the axillary nerve dermatome prior to surgery. None of these patients developed axillary nerve paralysis after the operation. There were 3 patients who had valgus impaction, 2 underwent deltoid split and 1 underwent elevation and grafting with the deltopectoral approach. After fracture fixation, shoulder AP and neutral position X rays were taken as the shoulder was internally rotated, externally rotated and neutral. The limit of shoulder movement was controlled

for the presence of impingement. Following stabilization with PHILOS, the shoulder was immobilized with a shoulder-arm sling for 2-3 days. Subsequently, passive motion exercises were initiated with 90° abduction and ante flexion. Active pendular and circular motions of the arm were prescribed. Active assisted and passive exercises were used during the first two weeks, and 3 weeks later active motion was started. On the 3rd postoperative week, daily activities were allowed. After the postoperative control on the 6th week, subsequent visits were organized on the 3rd, 6th, 12th and in patients with longer follow up, annually. Regular X rays were obtained to control the plate position and healing. The range of motion in the shoulder joint was recorded. The patients were evaluated with the Constant score^[13] on the postoperative 6th week, 3rd and 6th months. At the end of 6 months, none of the patients showed any signs of implant loosening. The functional results between the two groups were compared using student's t test (95% confidence interval). $p < 0.05$ was accepted as significant.

Results

After a mean follow up of 14.68 (6-28) months, radiological and functional evaluations were made. Preope-



Figure 2. 51 year old male patient. The fracture is 1.1.B.1 according to AO classification. Preoperative (a) and postoperative (b) X rays (deltopectoral approach is used) (c) postoperative joint range of motion is seen (Constant score: 98)

ratively, all patients had normal motor function of all 3 parts of the deltoid muscle and intact sensory function of the axillary nerve. Axillary nerve and deltoid muscle functions were evaluated meticulously in the postoperative clinical examination. Complications like suprascapular or axillary nerve injury or deltoid weakness were not encountered. None of the patients developed nonunion or implant failure. During follow up, intraarticular screw placement was seen in 1 patient (Figure 4), displacement in major tuberculum fragment was seen

in 1 case, displacement in major tuberculum fragment along with oblique placement of the plate was seen in 1 case (Figure 5). Inadequate reduction was seen in 4 cases (Figure 6). In three cases, as an early postoperative complication, it was seen that the head was fixed in the varus position (Figure 7). None of the patients developed avascular necrosis, superficial or deep infection. None of the scars required revision. The deltoid muscles were weak initially, however returned to normal after reha-

Table 2. The distribution of postoperative complications according to age and type of treatment

	Deltopectoral approach		Deltoid splitting approach	
	Age <65 (n=10)	Age ≥65 (n=2)	Age <65 (n=14)	Age ≥65 (n=15)
Inadequate reduction	2	2	–	–
Displacement in major tuberculum fragment and/or oblique placement of the plate	1	–	–	1
Intraarticular migration of the screw due to collapse of the head	1	–	–	–
Varus fixation of the head	–	–	1	2



Figure 3. 38 year old male patient. The fracture is 1.1.C.1 according to AO classification. Preoperative (a) and postoperative (b) X rays (c) Deltoid split incision scar. (d) Postoperative joint range of motion is shown (Constant score: 100)

bilitation. In all shoulders, the suprascapular nerve was functional, and normal power was demonstrated after rehabilitation. In the final evaluation, the Constant shoulder score was 95.04 (74-100) and 92.75 (72-100) in patients below and above age 65, respectively, and this difference was not significant ($p>0.05$). There was no significant difference between the groups with respect to range of motion in the joint. In patients below age 65 and who were operated with the deltopectoral approach, 2 had inadequate reduction, 1 had displacement of the major tuberculum and oblique placement of the plate, 1 case had intraarticular migration of the screw due to collapse of the head. In patients above age 65 and who were operated with deltopectoral approach, 2 had inadequate reduction. In patients below age 65 and operated with deltoid split, 1 had varus fixation of the head. In patients above age 65 and who were operated with deltoid split, 2 cases had fixation of the head in varus, 1 had displacement in major tuberculum. In the follow up after the 6th month, there were no significant differences between the deltopectoral and deltoid split groups with respect to Constant score and function.

Discussion

Fractures of the proximal humerus can be treated conservatively in old or young patients if the bone quality is sufficient and the fracture is nondisplaced. Open reduction and internal fixation should be preferred in patients who will not comply with conservative management, who have comorbidities or osteoporotic and open fractures. In the 1980s, T-plates and 1/3 tubular plates were the preferred fixation material in proximal humerus fractures.^[14,15] Plate osteosynthesis was replaced with minimal osteosynthesis.^[8,14] Numerous techniques for minimal osteosynthesis including K wires applied with open or percutaneous technique, cerclage or tension band application with wire or PDS (polydioxanone suture), screws, cannulated screws, and intramedullary nails.^[8,16-18,19-21] Also numerous techniques including prosthetic replacement, double tubular plates, Polarus nails (Acumed, Inc., Beaverton,OR), Plan Tan humerus fixator plate (Plan Tan Medizintechnik GmbH, Lambrechtshagen, Germany) are described.^[22-24] Minimal invasive methods such as closed reduction and percutaneous pinning require good bone quality,



Figure 4.(a) 60 year old female patient. She has a 1.1.B.1 fracture according to AO classification. A-Preoperative X ray. (b) The patient was operated with the deltopectoral approach. Early postoperative X ray shows that the screw heights are good. During follow up the proximal screws were not loosened, however the proximal head fragment collapsed, causing the screws to dislodge into the joint cavity. (c) These screws were changed 5 mnths later with deltoid split approach. The defect in the head fragment was grafted with allograft. Postrevision X ray is shown. (d) Range of motion after revision surgery is shown (Constant score: 74).

fractures with minimal fragmentation, and compliant patients.^[25] The results of this method are poor in elderly patients with osteoporosis.^[26] Early rehabilitation and early motion was not possible in this age group. Several complications have been reported with the traditional methods of open reduction and internal fixation, including loosening or failure of the plates and

screws, nonunion, malunion, migration of the nails, rotator cuff injury and impingement syndrome.^[15,23,24] In osteoporotic individuals, the risk of implant loosening and failure is higher due to poor bone quality.^[24,27] Excellent results began to be reported after the introduction of the PHILOS plate, a new internal fixation system developed by the AO/ASIF group for the

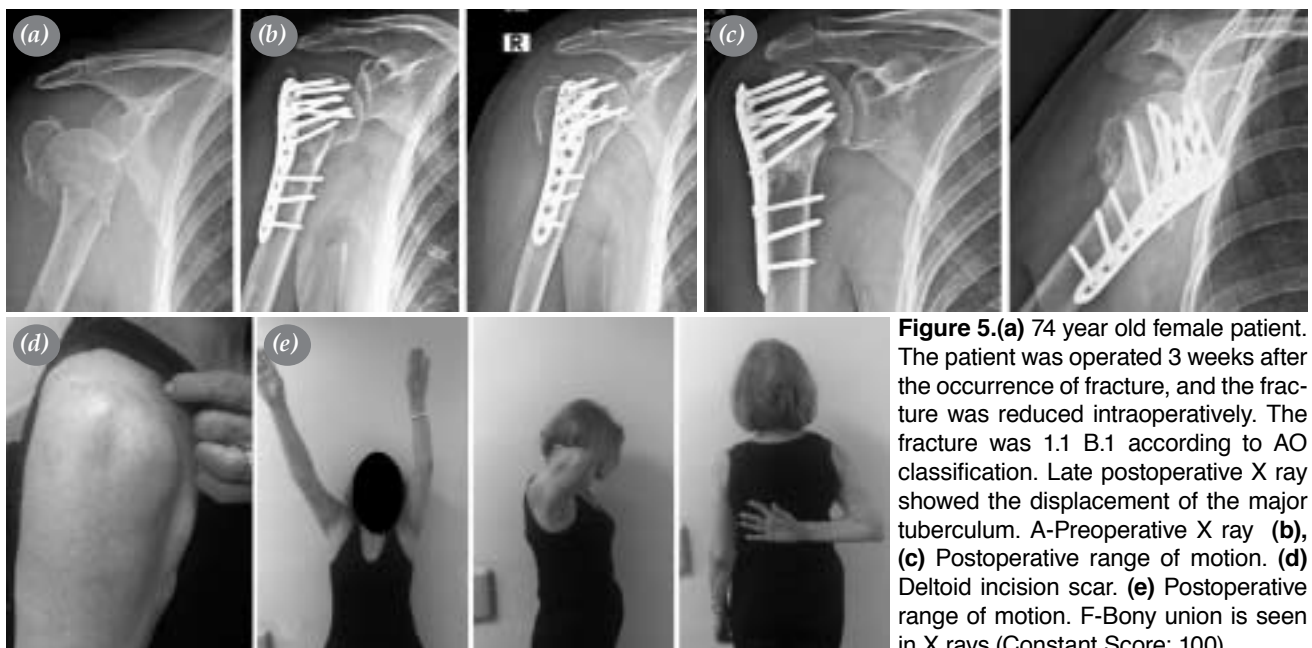


Figure 5.(a) 74 year old female patient. The patient was operated 3 weeks after the occurrence of fracture, and the fracture was reduced intraoperatively. The fracture was 1.1 B.1 according to AO classification. Late postoperative X ray showed the displacement of the major tuberculum. A-Preoperative X ray (b), (c) Postoperative range of motion. (d) Deltoid incision scar. (e) Postoperative range of motion. F-Bony union is seen in X rays.(Constant Score: 100)



Figure 6. (a) Preoperative X ray of a 62 year old male patient with 1.1.C.1 fracture according to AO classification. (b) Early postoperative imaging after deltopectoral approach revealed that the major tubercle was displaced, the head was in varus, and the plate was placed obliquely. (c) Late postoperative X rays shows healing of the fracture (d) The deltopectoral incision scar (e) Range of motion of the patient (Constant score 93).

treatment of proximal humerus fractures which enables angled fixation using multiple interlocking screws.^[28, 29] The screws in the humeral head are locked to the plate and cannot move backwards, a significant advantage in osteoporotic bones. It also enables the placement of screws in different directions (converging or diverging). The low profile minimizes the risk of impingement.^{[30-}

^{33]} Koukakis et al. reported early results in a series of 20 patients, and stated that the design of the plate achieves stable fixation, yields good results, and prevents failure.^[32] In a series of 25 cases, Charalambous et al. reported that in 20 of the cases, the fractures united, and none of the patients required a revision due to implant failure or nonunion. Five cases required revision due to

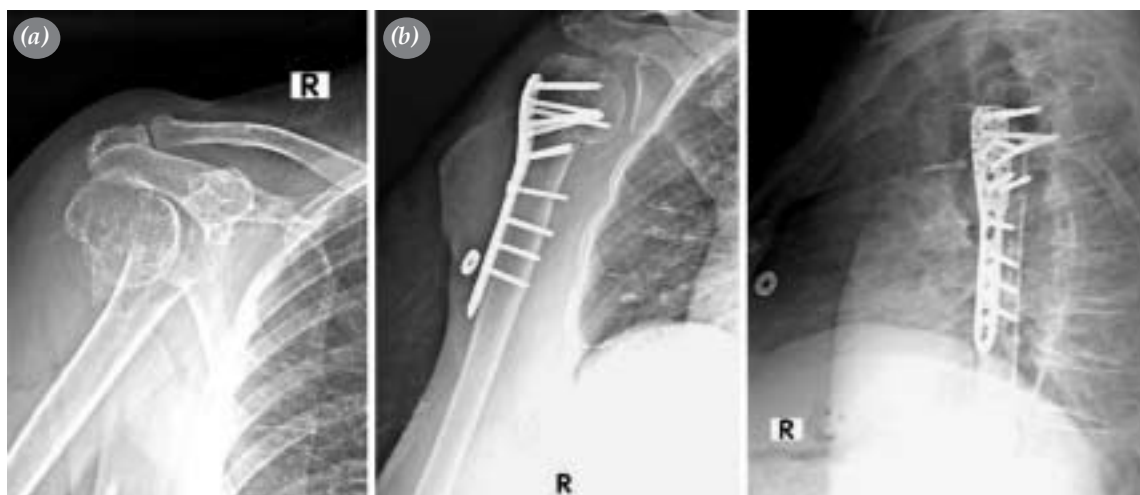


Figure 7. Case example of the fixation of the head in varus position. (a), Preoperative (b) Postoperative X rays.

nonunion or implant failure. The head screw entered the glenohumeral joint in 4 cases, loosened in another 4 and extruded, and the plate fractured in 1 case. They stated that PHILOS is an effective system in providing stabilization in these fractures, however cautioned against the potential complications of the implant.^[33] Siffri et al compared the angled plate and interlocking plate fixation in a biomechanical study performed on cadavers and synthetic models. The studies on synthetic humerus showed that the torsional stability of the angled and interlocking plates were similar. In the cadaver humeral neck model, interlocking plate system provided greater torsional stability in periodic loading, however the bending stability of both plates were similar.^[34] The use of screws located on the 4th and 5th level when there is no medial support, and reduction using indirect minimal invasive methods when the bone fragments of the medial support is adequate is one of the most critical points of this system. In proximal humerus fractures, the protection of the inferomedial support is critical in the preservation of reduction. It is important in stabilizing the medial column that the lower interlocking screws directed superiorly must pass through the inferior aspect of the proximal fracture fragment. In comminuted fractures, failure to achieve adequate medial column support may result in early reduction loss and failure.³⁵ In our patient group, the primary reason for not encountering plate or screw failure or nonunion is our meticulous adherence to this technical principle from the beginning of this prospective study. Bone grafts or synthetic materials used for bone defects, e.g. calcium phosphate cement (Norian, SRS) is used in a limited number of patients. Among these 4 patients, 3 are valgus impacted fractures and the other is a proximal humeral enchondroma who is excluded from the study. We do not advocate use of bone grafts except for valgus impacted displaced fractures and postreduction major bone defects. The advantage of deltoid splitting surgical approach is the easy access to supraspinatus, infraspinatus and teres minor. This approach gives better exposure of the major tuberculum fragment that is displaced posterosuperiorly and the head fragment. In cases with valgus impaction, elevation and grafting can be applied more anatomically. This incision also allows the release of the axillary nerve impinged in the fracture line. Our study showed that if the axillary nerve is protected, there will not be a postoperative axillary nerve dysfunction. In the deltopectoral approach, there is greater risk of injury as the deltoid muscle is retrac-

ted laterally. In the deltoid split approach, there is very little risk of injury to the axillary nerve when it is under the retractor. The axillary nerve can also be compressed by the retractor if care is not taken. The nerve is directly within sight in deltoid split approach, therefore has a lower risk of injury. Particularly in AO/ASIF Type B and C fractures, the deltoid split approach allows 270 degree control of the proximal humerus, reduction with sutures passing through the tubercular fragments and rotator cuff tendons and fixation with plates. The deltoid split approach that is applied simultaneously with axillary nerve exploration is a useful surgical technique that does not risk deltoid muscle function and axillary nerve. We are now conducting more comprehensive studies on this approach and comparison with deltopectoral approach. PHILOS plate is made of titanium, and therefore lighter than other implants. It has a good biocompatibility. The locking screw and plate system is a reliable internal fixation method for all age groups, if attention is paid to technical details and the tubercular fragments are reduced with sutures fixed to the plate. Easy applicability, biologic property due to the lack of interference with blood supply of the humeral head, no requirement to shape the plate and the achievement of stabilization at constant angles are the benefits of this plate. All screws and the plate move as a single structure. Complications related to the plate are very few, therefore it is possible to avoid most of the complications of traditional plating. In the treatment of osteoporotic fractures, it is superior to other osteosynthesis techniques since it allows early motion and there is no implant insufficiency. We therefore believe that the PHILOS plate is a good internal fixation material in the osteosynthesis of proximal humerus fractures in patients above age 65. Another aspect of this study is that all patients in this group were operated by 2 orthopedics attendings who were trained on the use of this plate, and when the surgeon is experienced on all technical details and the anatomic approaches it is possible to state that complication rates will be lower than the number reported in the literature. We believe that the reason for high Constant scores in this group is related to adequate surgical technique, good follow up and rehabilitation.

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