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Comparison of plate-screw fixation and intramedullary fixation with inflatable nails in the treatment of acute humeral shaft fractures

Akut humerus cisim kırıklarının cerrahi tedavisinde plak vida ile şişebilen intramedüller çivi yöntemlerinin karşılaştırılması

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Amaç: Akut humerus cisim kırıklarının cerrahi tedavisinde dinamik kompresyon plağı ve şişebilen intramedüller çivi yöntemlerinin sonuçları karşılaştırıldı.

Çalışma planı: Çalışmada humerus cisim kırığı nedeniyle plak vida veya şişebilen intramedüller çiviyle tedavi edilen hastalar arasından yaş, cinsiyet, yaralanma ciddiyeti ve humerus kırık tipi eşleştirilmiş 34 hasta (20 kadın, 14 erkek; ort. yaş 36.4; dağılım 18-62) (36 kırık) değerlendirildi. Her bir yöntemle 18 kırık tedavi edildi. Humerus cisim kırıkları AO sınıflandırmasına göre, açık kırıklar Gustilo-Anderson'a göre sınıflandırıldı. Omuz fonksiyonları 6. ve 12. aylarda Constant skoru ile, dirsek fonksiyonları Mayo dirsek skoru ile değerlendirildi. Tüm hastalara ameliyat sonrası 12. ayda Kısa-Form 36 (Short-Form 36, SF 36) uygulandı. İki tedavi grubu ameliyat süresi, ameliyattaki kan kaybı, kaynama süresi, komplikasyonlar, omuz ve dirsek fonksiyonları açısından karşılaştırıldı.

Sonuçlar: Ortalama ameliyat süresi şişebilen intramedüller çivi grubunda daha kısa (25.3 dk ve 66.1 dk; p<0.001), kan transfüzyonu ihtiyacı daha az bulundu (p=0.001). Constant omuz ve Mayo dirsek puanları iki grupta 6. ve 12. aylarda benzer bulundu. İmplant yetmezliği sadece plak vida grubunda üç olguda görüldü. Kaynama sorunu yaşanan beş olgunun üçü plak vida, ikisi şişebilen intramedüller çivi grubundandı. Plak vida uygulanan iki olguda yüzeyel enfeksiyon, iki olguda ameliyat sonrası geçici radiyal sinir paralizi görüldü.

Çıkarımlar: Şişebilen intramedüller çiviler akut humerus cisim kırıklarının cerrahi tedavisinde kaynama sorunlarını ve komplikasyonları artırmadan güvenle kullanılabilir.

Anahtar sözcükler: Kemik plağı; kırık tespiti, intramedüller; humerus kırığı/cerrahi.

Objectives: We compared the results of plate-screw fixation and intramedullary fixation with inflatable nails for the treatment of acute humeral diaphyseal fractures.

Methods: The study included 34 patients (20 females, 14 males; mean age 36.4 years; range 18 to 62 years) who were selected from patients treated with plate-screw fixation or inflatable intramedullary nails. The groups were matched for age, sex, severity of fracture, and the type of humeral fracture. Eighteen fractures were treated in each group. Classification of humeral fractures and open fractures were made according to the AO and Gustilo-Anderson systems, respectively. Functional evaluations were made at postoperative six and 12 months using Constant shoulder and Mayo elbow performance scores. All the patients were administered the Short-Form 36 (SF-36) questionnaire at 12 months. The two groups were compared with respect to operation time, perioperative need for blood transfusion, time to union, complications, and shoulder and elbow functions.

Results: The mean operation time was significantly shorter (25.3 min *vs* 66.1 min; p<0.001) and the need for blood transfusion was significantly less (p=0.001) with inflatable intramedullary nails. Constant shoulder and Mayo elbow scores did not differ significantly between the two groups. Implant failure was only encountered with plate-screw fixation in three patients. Union problems were observed in five patients (3 plate-screw, 2 intramedullary nail). Following plate-screw fixation, two patients developed superficial infection, two patients developed transient radial paralysis.

Conclusions: Inflatable intramedullary nails can be used safely in the treatment of acute humeral diaphyseal fractures without increasing union problems and complications.

Key words: Bone plates; fracture fixation, intramedullary; humeral fractures/surgery.

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Humeral diaphyseal fractures are commonly seen and comprise 1-3 % of all fractures.[1] Usually occurring as a result of indirect blunt trauma, these fractures can be treated conservatively with success rate approaching 98 %.[1] Despite of high success rate of conservative treatment, for cases with open fractures, pathologic fractures, bilateral fractures, simultaneous ipsilateral upper extremity fractures, multiple injuries, fractures associated with burns, neurovascular injuries necessitating surgical exploration and in patients that conservative treatment fails, surgical treatment becomes mandatory.[2-8] Literature review showed that plate and screws [2, 4, 7, 9] external fixation and intramedullary nails[3, 5, 7, 9-11] were used with similar success rates in the past.

Purpose of this study is to compare the results of inflatable intramedullary nails and compression plate-screw osteosynthesis in the surgical treatment of humeral diaphyseal fractures in two patient groups with similar trauma and demographic characteristics.

Patients and methods

In March 1999 a prospective protocol for humeral diaphyseal fractures was initiated in our clinic and patients were followed accordingly. For this study, records of 75 patients with humeral diaphyseal fractures, 2 cm inferior to surgical neck and 5 cm proximal to olecranon fossa, treated surgically were reviewed. All patients were treated by using either dynamic compression plates or inflatable intramedullary nails. Indications for surgical treatment in these patients were listed in Table 1. After excluding two patients with intensive care unit stay longer than one month, three with severe head trauma precluding active rehabilitation, eight with fracture extension to more proximal and distal regions, three with severe fracture comminution and two with inadequate follow up, data of 57 patients was included in the study. To neutralize the effects of fracture type, age, injury severity, associated diseases and associated skeletal injuries, 34 patients having similar features (20 females, 14 males, mean age 36,4 range; 18-62) with total of 36 humeral fractures were selected from each treatment group. Analyses were performed on these matched patient subgroups.

Severity of trauma was recorded as ISS in points. Fractures were classified according to AO. Open fractures were graded according to Gustillo-Anderson. Surgeries were performed by four orthopaedic specialists who completed learning curves for predetermined fixation methods and patients were randomized to surgeons. Plate-screw fixations were performed by using anterolateral approach to humerus and 4, 5 mm dynamic compression plates with 4, 5 cortical screws were applied. After open reduction with minimal soft tissue stripping possible, at least six cortices were hold at the either end of the major fragments. All intramedullary nail fixations were performed in antegrade fashion. Reduction closed reduction was attempted; if it has not been achieved closely, mini open reduction was performed. Nails in pre-inflation diameters of 6, 7 and 7, 4 mm and 22 to 24 cm in length were used according to preoperative evaluations. Locking screws were used in two cases with

Table 1. Indications of surgical treatment according to treatment groups

Indication	DCPS	IIMN	*Total*	*%*
Inability to obtain reduction	4	5	9	25
Loss of reduction	4	3	7	19
Severe obesity	2	1	3	8
Associated extremity fractures	3	2	5	14
Bilateral humeral fractures	1	1	2	6
Multiple trauma	2	4	6	17
Open fracture	2	2	4	11
Total	18	18	36	100

DCPS: dynamic compression plate and screw

IIMN: inflatable intramedullary nail

Table 2. Distribution of fractures according to AO and Gustillo-Anderson

	DCPS		IIMN		*Total*	
Fracture Type	Number	%	Number	%	Number	%
AO						
12 A1.2	3	8.3	2	5.6	5	13.9
12 A2.2	2	5.6	1	2.8	3	8.3
12 A3.2	5	13.9	7	19.5	12	33.4
12 B1.2	2	5.6	3	8.3	5	13.9
12 B2.2	4	11.1	4	11.1	8	22.2
12 C1.1	1	2.8	-		1	2.8
12 C2.2	1	2.8	1	2.8	2	5.6
Gustillo-Anderson						
I	1	2.8	2	5.6		8.3
II	1	2.8	–			2.8

DCPS: dynamic compression plate and screw

proximal diaphyseal involvement. Operative time was recorded from anesthesiologists' sheets. Amount of bleeding was measured as blood filled surgical sponge count, based on an assumption of each sponge carries 20 milliliters of blood. Blood transfusions were recorded as units if used. Arm sling was applied in all patients and shoulder, elbow, wrist active motions initiated when tolerated. Control X-rays were obtained two weeks, six weeks postoperatively and monthly thereafter. Bridging of at least three cortices with clinically painless extremity was accepted as union. Active and passive shoulder and elbow motion was recorded monthly. Shoulder function was measured by using Constant Score at 6^{th} and 12^{th} months. Similarly elbow function was evaluated by using Mayo Elbow Score at the same time intervals. At the end of first postoperative year Short-Form 36 was applied to all patients to determine general health status.

Data was analyzed by using SPSS 13.0 software. Chi square test was used to compare ratios and percentages. To compare the means T test was used when the distribution is normal and Mann-Whitney U test when skewed. Correlation analysis and ROC (Receiver operating characteristic) curves were used when appropriate. Alfa value was accepted as 0,05.

Results

Mean ISS was 16,2 (range 8-24) in whole series. Surgery was performed at a mean of four days (1-21) after injury. Mean operative time was 45 minutes (range 15-110) and mean blood loss during surgery was 120 milliliters (range 40-240). Fractures united at a mean of 12 weeks (range 8-32) and mean follow up was 32 months (range 24-40).

In comparison of two groups our data showed no difference in; age, gender, trauma mechanism, mean ISS, fracture type according to AO and Gustillo Anderson (Table 2), time interval between injury and surgery, associated skeletal injuries, union time, additional procedures to obtain union and elbow and shoulder functional evaluation at the latest follow up. However, operative time, blood loss during surgery and blood transfusion need were significantly different between groups as shown (Table 3). Operative times were 66,1 and 25,6 minutes for plate and inflatable intramedullary nail groups respectively ($p<0,001$, t-test). Patients having operative time longer than56 minutes needed blood transfusion more frequently (sensitivity= 0,813, specificity= 0,800, $p<0,001$, ROC curve). Thirteen of 16 patients (%80) with operative time longer than 56 minutes needed blood transfusion. On the other hand, only four of 20 patients with shorter operative times had transfusion ($p=0,001$, Fischer Exact test). Odds for patients with operative time longer than the cut off value of 56 minutes was 17 regarding blood transfusion risk. Mean blood losses during surgery were 200 and 60 milliliters for plate and inflatable intramedullary nail groups respectively ($p<0,001$).

Table 3. Trauma and surgical data

	Overall		DCPS		IIMN		
	Mean	Range	Mean	Range	Mean	Range	*p*
Age years	36.4	18-62	33.3	18-49	39.4	26-62	0.086
Time between injury and surgery	4.1	1-21	3.7	2-7	4.5	1-21	0.510
ISS	15.7	9-24	16.7	11-24	14.7	9-22	0.165
Follow up months	32.1	24-40	32.7	24-40	31.4	27-38	0.395
Time to union weeks	11.9	8-32	12.1	8-16	11.7	8-32	0.821
Intraoperative blood loss (ml)	120	40-240	200	140-240	60	40-80	0.000
Operative time minutes	45.7	15-110	66.1	45-110	25.3	15-35	0.000
Blood transfusion units	0.25	0-1	0.50	0-1	0.0	–	0.000

DCPS: dynamic compression plate and screw.

Shoulder motions were decreased in all patients after the operation. Patients treated with inflatable intramedullary nail had better shoulder motions at the first four months. Later on all patients showed progressive improvement and after the fourth month there was no significant difference between the groups regarding shoulder motions. Constant scores at the 6th and 12th months were similar for both groups (Table 4). Elbow functional evaluations yielded similar results for both groups (Table 4). Similarly general health was not different between two groups at the end of the first postoperative year. Figure 1 and 2 shows fractures and follow-up functions of two patients treated with inflatable intramedullary nails.

Three implant failures observed in this series and all in plate group. Two broken plates were revised with replating and bone grafting and one loose plate screw construct was revised with inflatable intramedullary nailing. Two union problems detected in inflatable intramedullary nail group and one revised with exchange inflatable intramedullary nail and the other was observed only, since implant-fracture construct was stable and extremity was painless. Two infections were detected during study period; both were in plate group and superficial. Systemic antibiotherapy was all that needed for these patients. Transient postoperative radial nerve dysfunction was observed in two patients from plated group and resolved without any intervention. No neurovascular lesions observed in inflatable intramedullary nail

Table 4. Shoulder motions, shoulder and elbow functional evaluations and SF-36 results.

	Overall		DCPS		IIMN		
	Mean	Range	Mean	Range	Mean	Range	*p*
Shoulder flexion							
2nd month	94.6	75-120	86.9	75-100	102.2	90-120	0.000
4th month	113.1	80-140	105.6	80-120	120.6	100-140	0.000
6th month	133.3	100-150	135.6	100-150	131.1	100-150	0.271
Constant Score							
6th month	86.1	75-96	85.5	75-96	86.6	75-95	0.584
12th month	90.8	80-96	89.1	80-96	91.9	84-96	0.107
Mayo Score							
6th month	84.2	70-90	81.9	70-90	86.4	70-90	0.591
12th month	91.5	80-95	90.6	80-95	92.5	80-95	0.253
SF-36							
Physical functioning	66.7	60-75	66.8	62-75	66.6	60-75	0.855
Mental score	79.8	70-90	80.0	74-90	79.6	70-90	0.829
Total SF-36	72.1	68-76	72.4	68-76	71.8	68-76	0.394

DCPS: dynamic compression plate and screw.

group. We could not detect any angular malalingment in whole series. Rotational malalingment was not evaluated in our patients.

Discussion

Humeral diaphyseal fractures can successfully be treated both with conservative and surgical means. The most suitable treatment method for a given fracture should be decided after taking into consideration the healing potential of each fracture, patient status and method to be used individually.

Although there are many reports about the surgical treatment using plates, only few authors studied inflatable intramedullary nails in the treatment of humeral diaphyseal fractures.[10-12]

To our knowledge our study is the first one comparing inflatable intramedullary nails and plates in the surgical treatment of acute humeral diaphyseal fractures in a prospective manner.

Comparing plate with rigid intramedullary nail some authors reported similar good clinical results, provided that both methods properly applied.[6, 7, 13] Each method has its own advantages. Sparing of adjacent joints is one of the major advantages of plate and screw fixations. On the other hand, closed reduction is possible with nails providing more biological fixation.

During plating additional damage to soft tissues and vascularity are major concerns. Additionally, plate fixation takes longer operative time, increases intraoperative blood loss, endangers neighboring neurovascular structures and in osteoporotic bone stability is questionable.

Although operative time for plating is supposed to be longer than intramedullary nailing, our literature review revealed only one manuscript specifical-

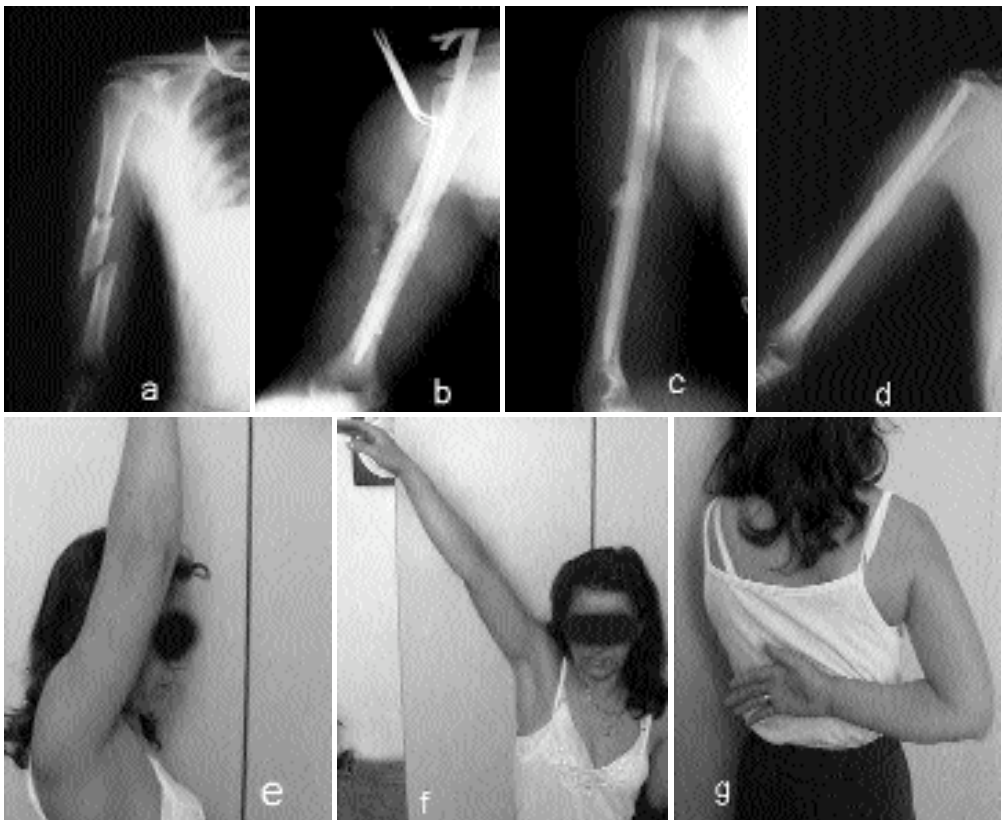

Figure 1. **(a)** 34 years old female with 12 C2 fracture preoperatively. **(b)** peroperative radiograph before nail inflation. **(c)** early postoperative and **(d)** 1 year postoperative radiographs. **(e, f, g)** at one year functional results with full shoulder range of motion.

ly mentioning operative time for plate osteosynthesis of humeral fractures and giving a mean time of 68 minutes.

Even in that report authors did not mention about how did they measured the operative time.[14] Similarly, we were unable to find any manuscript specifically reporting about the blood loss during plating of humeral diaphyseal fractures. In our opinion this study is the first comparing operative time and intraoperative blood loss of two different treatments with a predetermined prospective methodology.

Main drawbacks of intramedullary fixation for humeral fractures are their relatively higher nonunion rate and difficulty of the treatment of these surgical nonunions. Insufficient rotational stability of intramedullary nails was accepted as a reason for union problems.

Introduction of interlocking nails overcome this problem and raised the success rates of nails.[15] However, important concerns still remain. One of them is entry portal of the nail. Antegrade portal passes through rotator cuff and violates its integrity. If portal is located more medial than needed articular surface of humeral head may be damaged.

More lateral placement of portal may cause fractures at the proximal humerus. Additionally, if the proximal end of the nail protrudes excessively from

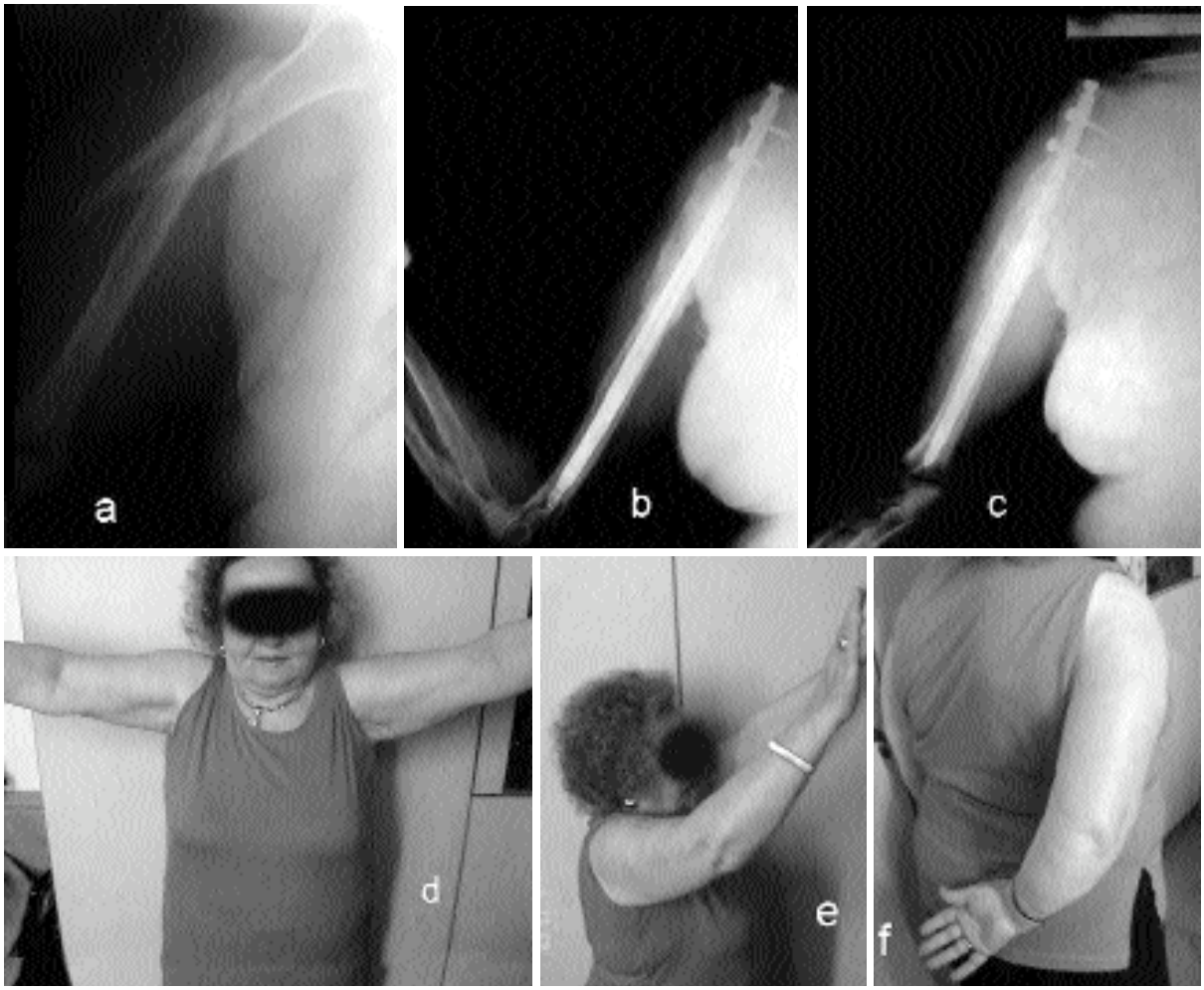

Figure 2. 62 years old female with 12 C1 fracture. **(a)** preoperative radiograph **(b, c)** radiographs at one year. **(d, e, f)** shoulder range of motions at one year. Motions were restricted but similar to the opposite unaffected side. Unseated end cap did not resulted additional functional limitations in this patient.

the bony surface it may cause subacromial impingement. In case of interlocking nails because of larger rigid diameter at the proximal end of the nail above mentioned risks are more likely.[16] Inflatable intramedullary nail with its smaller insertional diameter reduces these risks. Reduced diameter also provides easier advancement of the nail through medullary canal decreasing iatrogenic fracture comminution risk.

Although retrograde entry portal is advocated by some authors we still favor antegrade way since retrograde portal significantly weakens distal humerus facilitating fractures through this region.[17, 18] Inflatable intramedullary nails provide similar bending strengths with the interlocking nails, although their torsional stiffness is lower in vitro.[19]

Provided that proper nail diameter and length is used, similar clinical stability should be expected with the use of inflatable intramedullary nails. However, we do not advocate that, inflatable intramedullary nails can be used for all humeral diaphyseal fractures. Intraoperative stability testing after fixation is the major determinant of uneventful union.

Our results showed that inflatable intramedullary nail and plate screw fixation can be used with similar clinical results.

In conclusion, inflatable intramedullary nails can safely be used in the treatment of acute humeral diaphyseal fractures without increasing complication rates. Shorter operative times and less blood loss during operation are the advantages of inflatable intramedullary nails. In contrast to some reports, antegrade nailing did not interfere the shoulder functions in our patients and shoulder complaints were also observed in plated patients in the early postoperative period.

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