

# The comparison of triceps-reflecting anconeus pedicle and olecranon osteotomy approaches in the treatment of intercondylar fractures of the humerus

Ibrahim Azboy, M.D.,<sup>1</sup> Mehmet Bulut, M.D.,<sup>1</sup> Cahit Ancar, M.D.,<sup>1</sup> Abdullah Demirtaş, M.D.,<sup>2</sup> Emin Özkul, M.D.,<sup>1</sup> Mehmet Gem, M.D.,<sup>1</sup> Hilmi Karadeniz, M.D.,<sup>3</sup> Hüseyin Arslan, M.D.<sup>1</sup>

<sup>1</sup>Department of Orthopaedics and Traumatology, Dicle University Faculty of Medicine, Diyarbakır, Turkey

<sup>2</sup>Department of Orthopaedics and Traumatology, Göztepe Training and Research Hospital, İstanbul, Turkey

<sup>3</sup>Department of Orthopaedics and Traumatology, Bahçelievler Medikal Park Hospital, İstanbul, Turkey

## ABSTRACT

**BACKGROUND:** This study aimed to evaluate the functional outcomes of patients with intra-articular distal humerus fractures treated with triceps-reflecting anconeus pedicle (TRAP) and olecranon osteotomy.

**METHODS:** Forty patients with intra-articular distal humerus fractures were retrospectively analyzed. TRAP approach was used in 22 patients (12 males, 10 females; mean age 37.8 years, range 17-70), and olecranon osteotomy in 18 patients (11 males, 7 females; mean age 35.4 years, range 18–62). Fractures were classified using the AO/ASIF classification. Functional results were evaluated with the Mayo elbow performance score (MEPS) and the Disabilities of Arm, Shoulder and Hand (DASH) questionnaire score.

**RESULTS:** The overall mean arc of elbow motion was 108° (range 70°–140°) in the TRAP group, whereas that of the olecranon osteotomy group was 98° (range 70°–115°). A significant difference was observed between the two groups in terms of overall mean arc of elbow motion ( $p=0.038$ ). There were no significant differences noted between the two groups in terms of mean MEPS and DASH scores ( $p=0.412$ ,  $p=201$ , respectively). The overall complication rate was 27.2% in the TRAP group and 55% in the olecranon osteotomy group.

**CONCLUSION:** TRAP is a successful approach in the treatment of intra-articular distal humerus fractures that provides better arc of elbow motion, reduces complications and reoperation rates.

**Keywords:** Distal humerus; internal fixation; intra-articular fracture; olecranon osteotomy; TRAP.

## INTRODUCTION

Intra-articular fractures of the distal humerus (AO type C) constitute 1% of all fractures in adults.<sup>[1]</sup> These fractures remain one of the most difficult fractures to treat.<sup>[2]</sup> Anatomic reconstruction of the articular surface and stable internal fixation are the key factors for successful functional outcomes.<sup>[3]</sup> Adequate exposure of the articular surface is a prerequisite

for anatomic reconstruction and stable fixation of these fractures.<sup>[4–6]</sup> To better visualize the articular surface, olecranon osteotomy,<sup>[7–9]</sup> Bryan-Murray (triceps reflecting),<sup>[10]</sup> triceps splitting (Campbell),<sup>[11]</sup> and triceps-reflecting anconeus pedicle (TRAP)<sup>[12]</sup> approaches have been used.

Olecranon osteotomy is the most frequently preferred surgical approach that provides excellent exposure.<sup>[13,14]</sup> However, olecranon osteotomy has disadvantages such as delayed union, nonunion, avascular necrosis, heterotrophic ossification, and prominent hardware.<sup>[7–9,14,15]</sup>

TRAP approach, as defined by O'Driscoll et al.,<sup>[12]</sup> is an alternative approach in these fracture patterns. This approach is a combination of modified Kocher and Bryan-Murray, mobilizes the triceps and anconeus muscle of the posterior humerus, and also provides adequate exposure of distal humerus. This approach avoids osteotomy, preserves nerve supplies of anconeus, and has no hardware related problems. On

Address for correspondence: İbrahim Azboy, M.D.  
Dicle Üniversitesi Tıp Fakültesi, Ortopedi ve Travmatoloji  
Anabilim Dalı, 21100 Diyarbakır, Turkey  
Tel: +90 412 - 248 80 01 E-mail: ibrahimazboy@hotmail.com

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the other hand, some disadvantages with this approach have been reported, such as limited exposure of the articular surface, longer duration of surgery, and weakness of the triceps muscle.<sup>[13,16]</sup>

The indications and superiority of these two techniques are a question of debate. In the literature, there are limited numbers of studies on this issue.<sup>[16,17]</sup> The current study aimed to compare the TRAP approach with olecranon osteotomy regarding their effects on the functional results of intra-articular distal humerus fractures treated with open reduction and internal fixation (ORIF).

## MATERIALS AND METHODS

Forty patients who were treated with ORIF with the diagnosis of adult distal humerus intra-articular fracture according to AO/ASIF classification<sup>[18]</sup> between 2006 and 2012 were retrospectively evaluated. TRAP approach was used in twenty-two patients (TRAP group; 12 males, 10 females; mean age 37.8 years, range 17–70 years), and olecranon osteotomy in eighteen patients (Olecranon osteotomy group; 11 males, 7 females; mean age 35.4 years, range 18–62 years). The preference of surgical approach was made by surgeon's discretion. According to AO/ASIF classification, there was a C1 fracture in six patients, C2 fracture in 15 patients, and C3 fracture in 19 patients (Table 1). According to the Gustilo-Anderson classification,<sup>[19]</sup> there was a Grade I open fracture in four patients and Grade II open fracture in 3 patients (Table 1). Patients with the following were excluded from the study; pathologic fractures, rheumatoid arthritis treated with corticosteroids for a long period of time, associated ipsilateral forearm fractures, functional loss prior to the fracture, and inadequate follow-up.

The mechanism of injury included sixteen patients of fall, three cases of traffic accidents, two cases of sports injuries, one case of firearm injury in TRAP group; and 10 patients of fall, seven cases of traffic accidents, and one case of sports injury in the olecranon osteotomy group. Six patients (15%) had accompanying fractures and two of them had concomitant head and thorax injury.

## Surgical Technique

All patients were prepared in the supine position and tourniquet was applied. A straight posterior longitudinal skin incision was used just lateral to the olecranon tip. Then, ulnar nerve was identified proximally and released distally.

In the TRAP group, the TRAP approach was used for exposure of the elbow which was described by O'Driscoll et al.<sup>[12]</sup> The anconeus muscle was subperiosteally separated from the ulna laterally, preserving the integrity of lateral collateral ligament complex and annular ligament. Along with the anconeus lateral side of the triceps, and then, the medial side were reflected from the olecranon (Fig. 1). While the triceps was removed from its insertion, the portion 1 cm distal to olecranon tip was marked with a drill to be used as a guide during closure. The posterior capsule was incised and the dissection was carried out proximally. The fragments were reduced with temporary K-wires. Parallel plating was performed in fourteen patients (63.6%) and orthogonal plating was performed in 8 (36.4%). Then, the triceps was reattached with interrupted number-2 Ethibond suture by using the drill-holes through the bone in the olecranon, and the wound was closed as usual.

In the olecranon osteotomy group, an apex distal, chevron-shaped osteotomy was preferred. The osteotomy was per-

**Table 1.** Data summary of patients

Parameters	TRAP (n=22)	Olecranon osteotomy (n=18)	p
Male/female ratio (no. of patients)	12/10	10/8	0.612
Mean age (year) (range)	37.8 (17–70)	35.4 (18–62)	0.791
Gustilo-Anderson classification (no. of patients)			0.782
Closed	18	15	
Type I open	2	2	
Type 2 open	2	1	
Type 3 open	0	0	
Mean time to surgery (day) (range)	3.8 (1–12)	3.1 (2–11)	
Mean follow-up (month) (range)	36 (16–74)	28 (14–72)	
AO/ASIF classification (no. of patients)			0.258
C I	4	2	
C II	8	7	
C III	10	9	

TRAP: Triceps-reflecting anconeus pedicle; OO: Olecranon osteotomy.



**Figure 1.** Intraoperative view of a patient after orthogonally plated olecranon fracture using TRAP approach in which olecranon fully skeletonized.

ous anterior transposition of the ulnar nerve was performed in these patients. Three senior authors (HA, MB, IA) performed the operations.

### Postoperative Care and Follow-up

Standard postoperative rehabilitation programme was used for ROM exercises applied by a physiotherapist for both groups. In both groups, a removable long arm splint was used for two weeks. Active assisted elbow movements were started on the second postoperative day. In the olecranon osteotomy, active elbow motion was started at two weeks postoperatively, whereas in the TRAP group, active elbow extension was prohibited until six weeks postoperatively to avoid undue stress on extensor mechanism repair. The patients were followed-up on the first, sixth and twelfth months after surgery.

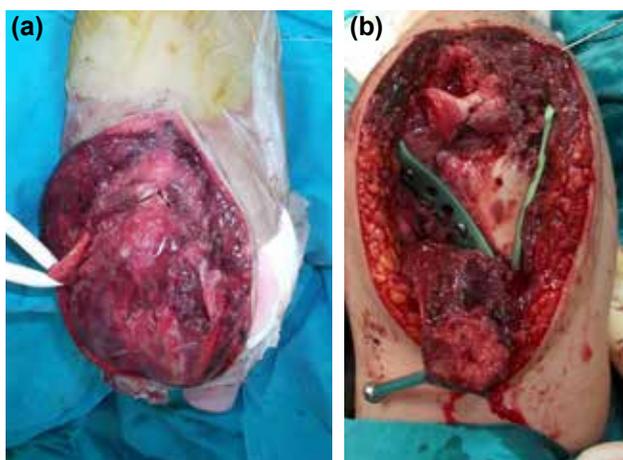
The patients were radiologically evaluated with anteroposterior and lateral radiographies until fracture union was fully observed. Triceps strength was graded according to the system given by Wolfe et al.<sup>[20]</sup> at the final follow-ups, the functional evaluation of the patients were carried out with goniometric measurement of the range of motion in the elbow joint, Mayo elbow performance score (MEPS),<sup>[21]</sup> and Disabilities of Arm, Shoulder and Hand (DASH) questionnaire.<sup>[22]</sup> The MEPS score is based on a 100-point scale which evaluates the pain relief, function, motion and stability of elbow. The MEPS falls in to four grades:  $\geq 90$ , Excellent; 75–89, Good; 60–74, Fair;  $< 60$ , Poor. Mean duration of follow-up of all patients was 34 months (range 14–78 months).

formed approximately 2 cm distal to the tip of olecranon (Fig. 2a). An oscillating saw was used to start osteotomy. An osteotome was used to complete osteotomy by levering the osteotome proximally. These maneuver results in cracking the subchondral bone and creates uneven surface that facilitates reduction. The posterior elbow capsule was then incised and the joint was reached (Fig. 2b). The fragments were reduced with temporary K-wires. Parallel plating was performed in thirteen patients (72%) and orthogonal plating was performed in 5 (28%). The proximal fragment of the olecranon was repositioned. Fixation was obtained with a tension band over a 1 cancellous screw, and the wound was closed as usual.

In the TRAP group, an iliac autograft was used in one patient for the bone defect in the supracondylar region. In twelve patients (30%) (7 and 5 patients in the TRAP and olecranon osteotomy groups, respectively) ulnar nerve was in contact with the medial plate in the cubital tunnel, hence subcutane-

### Statistical Analysis

Data were analyzed using the Statistical Package for Social Sciences 18.0 (SPSS Inc., Chicago, IL, USA) software. Statistical significance between variables of both groups were analyzed with student's t, chi-square, Fischer's exact, and Mann-Whitney U tests. A p value  $< 0.05$  was accepted as significant.



**Figure 2.** Intraoperative view of a patient shows apex distal, chevron-shaped osteotomy (a); after parallel plate application (b).

## RESULTS

Mean duration of follow-up was 36 months (range 16 to 74 months) in TRAP group, and 28 months (range 14–72 months) in the olecranon osteotomy group.

No significant differences were observed between the groups in terms of gender, age, type of fracture, time to operation, or presence of open or closed fractures ( $p < 0.05$ ). All fractures healed at the end of the follow-up period.

The overall mean arc of elbow motion was  $108^\circ$  (range  $70^\circ$ – $140^\circ$ ) in the TRAP group (Fig. 3), whereas that of the olecranon osteotomy group was  $98^\circ$  (range  $70^\circ$ – $115^\circ$ ) (Fig. 4). A significant difference was observed between the two groups in terms of overall mean arc of elbow motion ( $p = 0.038$ ) (Table 2). No patients had limitation of forearm



**Figure 3.** Preoperative X-rays (anteroposterior and lateral views) of the elbow shows intra-articular fracture of distal distal humerus (a, b); after orthogonal plate fixation using the TRAP approach, at 56 months of follow-up X-rays (anteroposterior and lateral views) shows fracture union (c, d); functional view of the patient (e, f).

pronation-supination. Range of motion improved in the first sixth months.

At the final control of the patients, mean MEPS was 85.9 (range 55–100) in the TRAP group, whereas that of the olecranon osteotomy group was 83.5 (range 55–100). Although mean MEPS was higher in the TRAP group, no significant difference was noted between the two groups ( $p=0.412$ ) (Table 2). Mean q-DASH score was 15.6 (range, 0–48) in the TRAP group, whereas that of the olecranon osteotomy group was 20.1 (range 4–57). Although mean q-DASH score was higher in the TRAP group, no significant difference was detected between the two groups ( $p=0.201$ ) (Table 2). No significant difference was found between the groups in terms of fixation technique preferred for distal humerus fracture when considering functional outcomes ( $p<0.05$ ).

### Complications

The overall complication rate was 27.2% in the TRAP group and 55% in the olecranon osteotomy group.

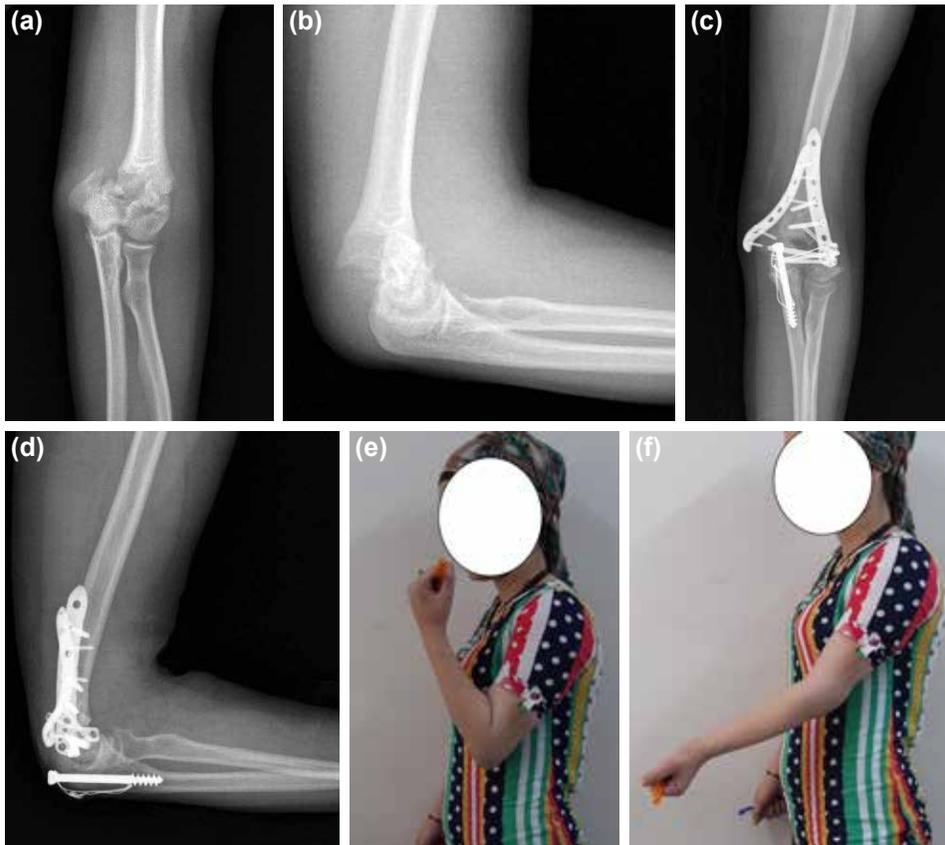
In the TRAP group, ulnar nerve paresthesia developed in two patients (9.1%), which resolved spontaneously in three months. Triceps muscle weakness was observed in two patients (9.1%). One patient (4.5%) had varus deformity 10 degrees, but without any interfering in elbow function. One patient (4.5%) developed deep infection at sixth month. The patient healed with debridement and antibiotic treatment. However, avascular necrosis developed in the follow-up and fair result was obtained in this patient. Triceps muscle rupture was not observed in any patient.

In the olecranon osteotomy group, implant irritation was ob-

**Table 2.** Mean arc of elbow motion and functional outcomes at latest follow-up

Parameters	TRAP (n=22)	Olecranon osteotomy (n=18)	p
Mean arc of elbow motion (range)	108 (70–140)	98 (70–115)	0.038
Mean DASH score (range)	15.6 (0–48)	20.1 (4–57)	0.201
Mean MEPS score (range)	85.9 (55–100)	83.5 (55–100)	0.412
Excellent, n (%)	10 (45.5)	6 (33.3)	
Good, n (%)	8 (36.4)	8 (44.4)	
Fair, n (%)	3 (13.6)	3 (16.7)	
Poor, n (%)	1 (4.5)	1 (5.6)	

TRAP: Triceps-reflecting anconeus pedicle; DASH: Disabilities of arm, shoulder and hand; MEPS: Mayo elbow performance score.



**Figure 4.** (a, b) Preoperative X-rays (anteroposterior and lateral views) of the elbow shows intra-articular fracture of distal distal humerus; (c, d) after parallel plate fixation using olecranon osteotomy approach, at 19 months of follow-up X-rays (anteroposterior and lateral views) shows fracture union; (e, f) functional view of the patient.

served in four patients (22%). After removal of the implants in the olecranon, the symptoms resolved in these patients. In two patients (11%), a delay in union of the olecranon osteotomy site was observed; however, union was achieved without need for additional surgery. Union was achieved in olecranon osteotomy site in other patients. Nonunion of distal humerus fracture was developed in one patient (5.5%) and a second surgery was performed. Union was achieved by harvesting iliac crest autograft and reosteosynthesis. Ulnar nerve paresthesia developed in two patients (11%) and resolved spontaneously in three months. Triceps muscle weakness was observed in one patient (5.5%).

## DISCUSSION

The current study revealed that the TRAP method is more successful than olecranon osteotomy in terms of overall mean arc of elbow motion ( $p=0.038$ ). When q-DASH scores and MEPS scores were examined, it was observed that the results were better for the TRAP group, but there were no statistically significant difference between the groups, ( $p=0.234$ ) ( $p=0.403$ ) respectively.

The main purpose in the treatment of intra-articular distal

humerus fractures is to achieve perfect anatomical restoration of the articular surfaces, maintain stable fixation and allow early full rehabilitation.<sup>[23,24]</sup> Perfect exposure of the fracture is a key factor that allows restoration of articular surfaces. Thus, many approaches were defined, such as olecranon osteotomy, triceps reflecting, triceps splitting, and TRAP approaches.<sup>[7,10-12]</sup>

Olecranon osteotomy provides the most extensive exposure of the distal humerus.<sup>[13]</sup> On the other hand, delayed union, nonunion, necessity of implant use to repair osteotomy, and prominent hardware that leads to a second surgery are among the disadvantages.<sup>[7-9,14,15,23,24]</sup> Furthermore, nerve supplies of the anconeus muscle might be damaged, as this muscle participates in the dynamic stabilization of the elbow joint, this may cause elbow instability.<sup>[23]</sup>

Wilkinson et al.<sup>[13]</sup> have compared the triceps split, TRAP, and olecranon osteotomy techniques in a cadaveric study. They have found that these techniques demonstrate the joint surfaces at a rate of 35%, 46%, and 57%, respectively. The authors have stated that the best exposure was achieved with the olecranon osteotomy approach (57%), but no statistically significant difference was detected between the TRAP

and olecranon osteotomy approaches. We should state that the exposure was better in the olecranon osteotomy group. However, we observed that increasing elbow flexion provides sufficient exposure in the TRAP group, which enables restoration of articular surfaces and stabilization of fracture. Therefore, we believe that relatively less extensive visualization of the distal humerus is not an important drawback to the TRAP approach.

Triceps-elevating exposures were generally claimed with the weakness of extension or rupture of triceps.<sup>[26]</sup> Ozer et al.<sup>[17]</sup> have used TRAP approach in eleven patients with AO type C fractures. They have performed an isokinetic strength test of involved and uninvolved elbow. Peak torque deficits of the flexor and extensors on the operated and non-operated side were below 20%. They have found no significant impairment of elbow function. Pankaj et al.<sup>[16]</sup> have used TRAP approach in AO type C distal humerus fractures (n=40). They have reported that thirty-five patients (87.5%) had good triceps strength, four patients (10%) had fair strength, and one patient (2.5%) had poor strength with an extension lag of 10. In the current study, triceps rupture was not observed in any of the patients in which TRAP approach was performed. We found a decrease in the strength of the triceps in two and one patients in the TRAP and olecranon osteotomy groups, respectively. In a detailed examination of these patients, it was also observed that there was also weakness of the flexor muscles. We suggest that the muscle weakness may be related to the initial injury.

According to O'Driscoll et al.,<sup>[12]</sup> the ideal approach should provide adequate exposure, could be extended when required, should be as soft tissue dissection without osteotomy, the dissection should be in the plane between the nerve, all alternative surgical procedures should be applied with the same exposure, should allow early rehabilitation, and the possible revision should be performed with the same incision. The TRAP approach provides all these requirements.<sup>[12,16,17]</sup> They have reported that TRAP approach provides sufficient exposure for open reduction and internal fixation, and also allows early rehabilitation.<sup>[12,25]</sup> Furthermore, after TRAP exposure, there is a chance of total elbow prosthesis in the same session in cases in which the joint surface could not be restored.<sup>[12]</sup>

Restoration of elbow motion is one of the most important parameters in the treatment of intra-articular distal humerus fractures.<sup>[4–7]</sup> Athwal et al.<sup>[25]</sup> compared the TRAP (n=12) and olecranon osteotomy (n=17) approach in the treatment of type C distal humeral fractures. They found no significant difference between both groups in terms of flexion-extension arc, elbow flexion, elbow extension, pronation, supination, MEPS or DASH score. The authors stated that although they found no statistical difference between both groups, their subgroup analysis must be interpreted with caution because the study was not powered to detect such difference. In the

study by Ozer et al.,<sup>[17]</sup> range of motion in Type C1 and C2 (n=9, 82%) had an average of 116° (range 95–140), and Type C3 (n=2, 18%) fractures had an average of 85°. In the study by Pankaj et al.,<sup>[16]</sup> the average of range of motion was 118±7 degrees (range 80–140). In our study, the mean arc of motion was better in the TRAP group (108° [range 70°–140°]) when compared to the olecranon osteotomy group (98° [range 70°–115°]). The rate of type C3 fracture in our study was higher (45.4%, and 50% in the TRAP and olecranon osteotomy groups, respectively) than the study by Pankaj et al.<sup>[16]</sup> (20%) and Ozer et al.<sup>[17]</sup> (18%), which may explain relatively lower mean arc of motion in our study. In the TRAP group, we used intact olecranon as a template for anatomic reconstruction of the joint. Therefore, we suggest that the use of olecranon joint surface as a template may provide better humero-trochlear joint congruency which may explain the high mean arc of motion in the TRAP group. In addition, the MEPS and q-DASH scores of our study are in line with the literature.<sup>[16,17,25]</sup>

Olecranon osteotomy has been associated with a number complications, including delayed union<sup>[14]</sup> and 0% to 10% risk of nonunion.<sup>[8,27]</sup> It was suggested that union problems observed in olecranon osteotomies are mostly related to the transverse osteotomy technique (30%).<sup>[28]</sup> Chevron shaped osteotomy reduced these complication.<sup>[8,14,29]</sup> Chevron osteotomy increases contact surface that may promote healing, facilitate reduction and have inherent translational and rotational stability due to interlocking of the proximal and distal fragments.<sup>[8]</sup> A study by Sanchez-Sotelo et al.<sup>[30]</sup> have reported excellent and good results (79%) using chevron type osteotomy in the treatment of complex distal humeral fractures. In the current study, an apex distal, chevron-shaped osteotomy was preferred in the olecranon osteotomy group. Union was observed in all patients. Although delayed union was observed in two patients (11%), healing was obtained without surgical intervention.

The need for a second operation to remove the implants used to repair olecranon osteotomy has been considered as an important shortcoming to the olecranon osteotomy. The risk of requiring subsequent hardware removal has been reported as 13% to 30%.<sup>[3–8]</sup> Tak et al.<sup>[31]</sup> have used olecranon osteotomy in ninety-four patients and stated that all the unsatisfactory results (average and poor) were seen in those patients who developed complications related to the olecranon osteotomy (p=0.000, OR 103.2). In the current study, 22% of the patients had implant removal related to the symptom of implants used for olecranon osteotomy repair. In contrast, no patient had a second surgery in the TRAP group. Therefore, when considering a second surgery for implant removal, we suggested that the TRAP approach has a distinct advantage over the olecranon osteotomy approach.

The study has several limitations. Firstly, it is retrospective and comprises a relatively small number of patients. Secondly,

parallel or orthogonal plating was used for fixation of distal humerus fractures in both groups. Thirdly, we could not make a comparison between sub-groups of the distal humerus fractures e.g. comminuted or osteoporotic fractures. Finally, we could not use isokinetic tests to evaluate the muscle strength. Future studies consisting of specific age groups, homogeneous sub-group types, with similar degree of osteoporotic bone can reveal more accurate results on indications and effectiveness of the TRAP and olecranon osteotomy approaches. Although olecranon osteotomy provides the best exposure, the effect of olecranon osteotomy on the development of osteoarthritis is not well-known. It should be evaluated in long term studies. We consider that the benefit of improved articular exposure must thus be weighed against this relatively high complication rates.

TRAP technique is superior to olecranon osteotomy in terms of average arc of elbow motion. We suggest that the TRAP approach is a successful alternative approach in the treatment of intra-articular distal humerus fractures that reduces reoperations and complications rates.

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ORİJİNAL ÇALIŞMA - ÖZET

## İnterkondiler humerus kırıklarının tedavisinde triseps reflektng pedikül ve olekranon osteotomisi yaklaşımlarının karşılaştırılması

Dr. İbrahim Azboy,<sup>1</sup> Dr. Mehmet Bulut,<sup>1</sup> Dr. Cahit Ancar,<sup>1</sup> Dr. Abdullah Demirtaş,<sup>2</sup> Dr. Emin Özkul,<sup>1</sup> Dr. Mehmet Gem,<sup>1</sup> Dr. Hilmi Karadeniz,<sup>3</sup> Dr. Hüseyin Arslan<sup>1</sup>

<sup>1</sup>Dicle Üniversitesi Tıp Fakültesi, Ortopedi ve Travmatoloji Anabilim Dalı, Diyarbakır

<sup>2</sup>Göztepe Eğitim ve Araştırma Hastanesi, Ortopedi ve Travmatoloji Kliniği, İstanbul

<sup>3</sup>Bahçelievler Medikal Park Hastanesi, Ortopedi ve Travmatoloji Kliniği, İstanbul

**AMAÇ:** Eklem içi humerus alt uç kırıklarının tedavisinde triseps-reflektng ankoneus pedikül (TRAP) ve olekranon osteotomisi yöntemlerinin fonksiyonel sonuçları karşılaştırıldı.

**GEREÇ VE YÖNTEM:** Eklemi içi humerus kırığı olan 40 hasta geriye dönük olarak incelendi. Bunlardan 22 hastaya (12 erkek, 10 kadın; ortalama yaş 37.8 yıl dağılım 17–70) TRAP, 18 hastaya (11 erkek, 7 kadın; ortalama yaş 35.4 yıl dağılım 18–62) olekranon osteotomisi uygulandı. Kırık sınıflaması AO/ASIF sınıflamasına göre yapıldı. Fonksiyonel sonuçlar Mayo dirsek performans skoru ve Kol, Omuz ve El Engellilik (DASH) skoru ile değerlendirildi.

**BULGULAR:** Triseps-reflektng ankoneus pedikül grubunda dirsek eklem hareket açıklığı ortalama 108° (dağılım 40°–140°) iken olekranon osteotomisi grubunda ortalama 98° (dağılım 70°–115°) bulundu. Eklem hareket açıklığı bakımından iki grup arasında istatistiksel olarak anlamlı fark bulundu ( $p=0.038$ ). Her iki grup arasında DASH ve MEPS puanı bakımından istatistiksel olarak anlamlı fark saptanmadı ( $p=0.412$ ,  $p=201$ , sırasıyla). Komplikasyon oranları TRAP grubunda %27.2 iken olekranon osteotomisi grubunda %55 bulundu.

**TARTIŞMA:** Triseps-reflektng ankoneus pedikül yöntemi, olekranon osteotomisine göre dirsek eklem hareket açıklığını sağlamada daha başarılıdır. Ayrıca TRAP yöntemi komplikasyon oranlarını ve yeniden ameliyat gereksinimini azaltmaktadır.

**Anahtar sözcükler:** Eklemiçi kırık; humerus alt uç; internal tespit; TRAP; olekranon osteotomisi.

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