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ORIGINAL ARTICLE

The olecranon osteotomy provides better outcome than the triceps-lifting approach for the treatment of distal humerus fractures

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Abstract
Introduction Intra-articular distal humeral fractures can be approached in a variety of ways. The purpose of this study is to evaluate and compare the functional outcomes of two approaches: approach with olecranon osteotomy and triceps-lifting approach for the treatment of intra-articular distal humeral fractures.
Methods This study shows a consecutive series of 54 intra-articular distal humeral fractures of 54 patients who were treated with open reduction and internal fixation with anatomic plating. Lateral plating was performed in 10 (45.5 %) patients, and medial and lateral parallel plating was performed in 12 (54.5 %) patients in olecranon osteotomy group, while lateral plating was performed in 8 (25 %) patients, and medial and lateral parallel plating was performed in 24 (75 %) patients in triceps-lifting group.
Results Mean follow-up was 38.3 months for olecranon osteotomy group and 41.4 months for triceps-lifting group. Functional outcomes according to MAYO elbow score and extension-flexion motion arc values were significantly better in olecranon osteotomy group ($p < 0.05$).
Conclusion Approach with olecranon osteotomy provided better functional outcomes than triceps-lifting approach. Additionally, intra-articular distal humerus fractures can be safely treated with olecranon osteotomy which provides more control over the elbow joint and better visualisation and allows early postoperative rehabilitation.
Level of evidence IV.

Keywords Intraarticular · Humerus · Fracture · Approach · Elbow

Introduction

Intra-articular distal humerus fractures are rarely observed in adults, and the incidence of such fractures varies with age and gender [1]. Given that osteoporosis is an important risk factor for complex distal humerus fractures and that the average lifespan is increasing, the incidence of these fractures has increased in the last two decades [2, 3].

Comminuted intra-articular distal humerus fractures account for 1 % of all fractures [4]. Because of the complex anatomical structure of the region and difficulty in fracture typing, these fractures are difficult to treat with a lack of a clear rehabilitation protocol after treatment and satisfactory functional outcomes [4, 5]. The main goal of treatment is to obtain anatomical reduction of the joint and produce an elbow joint that allows early mobilisation and is functional following fixation [5, 6].

Besides the fracture type, age, gender, implant choice and surgical approach all affect the treatment outcomes of distal humerus intra-articular fractures [7]. Approaches for these types of fractures include olecranon osteotomy, triceps lifting (Campbell's approach), triceps splitting and triceps sparing [8, 9].There are inherent advantages and disadvantages to each approach [9]. Triceps-sparing approach has limitations in exposure and extensibility [8]. Triceps-splitting approach limits exposure to the intra-articular humeral fractures [9]. The accepted approach is olecranon osteotomy

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because it provides good command of the surgical site, provides the best understanding of the joint problem and has minimal impact on the extensor muscle mechanism [5, 10]. In cases where olecranon osteotomy is insufficient to control the fracture line in comminuted intra-articular distal humerus fractures with metaphyseal fracture extension, triceps lifting (Campbell's approach) has also been used [8, 11]. We hypothesise that the surgical approach used affects the functional outcomes in comminuted intra-articular distal humerus fractures and also we hypothesise that approach with olecranon osteotomy provides better functional outcomes than triceps lifting. In this study, we aimed to compare the midterm functional outcomes in patients with complex distal humerus fractures who were treated using two different surgical approaches.

Materials and methods

Twenty-two patients who were treated with olecranon osteotomy and thirty-two patients who were treated with triceps lifting for comminuted distal humerus fractures between 2006 and 2011 were retrospectively reviewed. The patients were operated by 4 surgeons (1 professor and 3 attending surgeons) in two different hospitals. Surgery types were chosen by two surgeons according to their experience. The patients were called to the final controls, and mean follow-up durations were set. Patients with a minimum of 1-year follow-up were included to the study. Twenty-two of the thirty patients who underwent olecranon osteotomy were reached and enroled as group 1. Thirty-two of the 40 patients who underwent surgery using triceps lifting were reached and enroled as group 2.

Patients who had additional systemic diseases (diabetes mellitus, hypertension and cerebrovascular disease), did not regularly attend follow-ups, required intensive care monitoring pre- or postoperatively were excluded from this study.

Of the patients in group 1, 11 (50 %) were female and 11 (50 %) were male, and the mean age was 49.3 years. Group 2 consisted of 14 (43.8 %) female and 18 (56.2 %) male patients with a mean age of 46.2 years. Nine (40.9 %) of the 22 patients in group 1 had left-sided fractures, and 13 (59.1 %) of the patients had right-sided fractures. In group 2, 11 (34.4 %) of the fractures were left-sided and 21 (65.6 %) were right-sided. In group 1, distal humerus fractures had occurred due to simple falls in 8 (36.4 %) patients, falling from a height in 4 (18.2 %) patients, falling during sports in 5 (22.7 %) patients and traffic accidents in 5 (22.7 %) of the patients. In group 2, the fractures had resulted from simple falls in 15 (46.9 %) patients, traffic accidents in 8 (25 %) patients, falling from a bicycle in 2 (6.3 %) patients, falling from a height in 5 (15.5 %) patients and an assault in 2 (6.3 %) of the patients. All of the fractures were classified using the AO classification. In group 1, the fracture type was B3 in 7 (31.8 %) patients, C1 in 6 (27.3 %) patients, C2 in 6 (27.3 %) patients and C3 in 3 (13.6 %) patients. In group 2, fractures were evaluated as B2 in 4 (12.5 %) patients, B3 in 1 (3.1 %) patient, C1 in 8 (25 %) patients, C2 in 11 (34.4 %) patients and C3 in 8 (25 %) patients. Open fractures were observed in 2 patients from group 1 and 3 patients from group 2.

All patients in this study received surgical treatment under general anaesthesia with tourniquet application and prophylactic intravenous administration of a first-generation cephalosporin at a dose of 3 mg/kg.

All of the patients were preoperatively informed about the fracture type, surgical approach and the possible peri- or postoperative complications. Signed informed consent forms were obtained from all of the patients.

Surgical technique

The mean duration between the injury and surgical treatment was 4.7 days (1–14) in group 1 and 5.3 days (1–18) in group 2. Surgical treatment of patients with open fractures was performed within the first 24–48 h. All of the patients underwent open reduction and internal fixation in line with the AO principles. The ulnar nerve was transposed to the anterior of the elbow joint in both groups.

In the olecranon osteotomy approach to the elbow joint, layers were passed following a posterior elbow incision. The ulnar nerve was protected by loosening it from the surrounding tissues. Then, an inverted V-shaped Chevron osteotomy was performed 2 cm distal to the olecranon tip, and the joint was reached (Fig. 1). The fragments were reduced, and restoration of the joint was transiently provided with K-wires. Joint integrity was created by fixation over the K-wire. Lateral plating was performed in 10 (45.5 %) patients, and medial and lateral parallel plating was performed in 12 (54.5 %) patients. The site of the olecranon osteotomy was fixed with a tension band or 1 cancellous screw (Fig. 2).

In triceps lifting to the elbow joint, a posterior elbow incision was made, and the ulnar nerve was then exposed and protected. The triceps muscle was detached from the attachment site and lifted in a "V" form with the fascia loosened proximally, and the muscular portion was split up to the condyles (Fig. 3). The fracture line was visualised and transiently fixed with K-wires, and lateral plating was performed in 8 (25 %) patients and medial and lateral parallel plating was performed in 24 (75 %) patients. The triceps muscle was sutured to its anatomical location using a 1.0 absorbable suture (Fig. 4).

Postoperative follow-up

Postoperatively, the arms of all patients were placed in long-arm splints, for 2 weeks in group 1 and for 3 weeks in

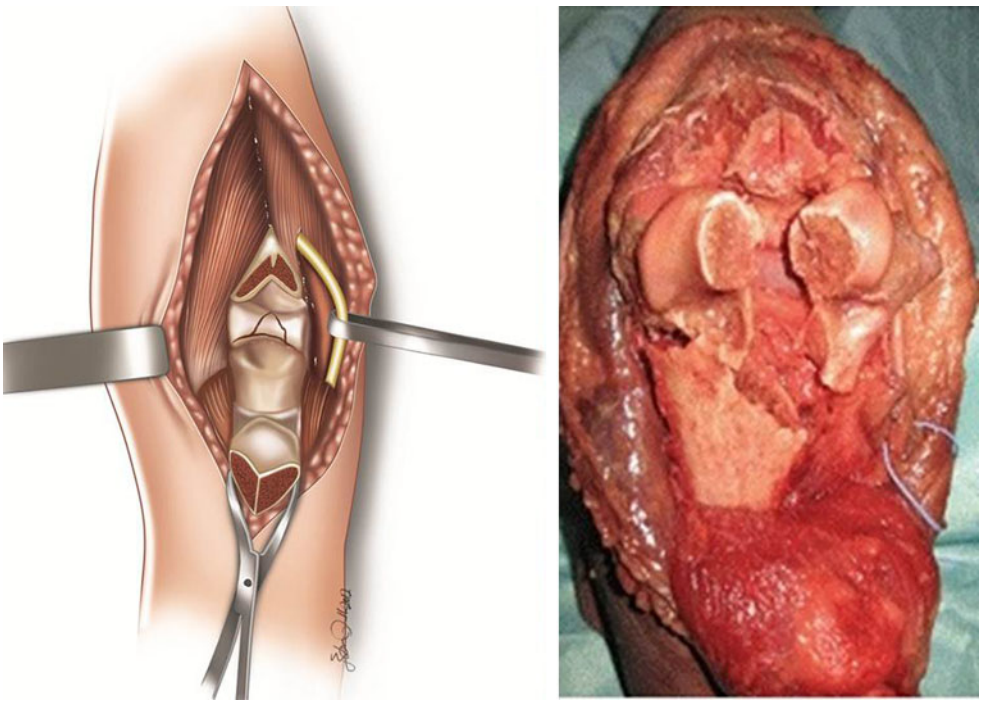

Fig. 1 Illustration of olecranon osteotomy approach

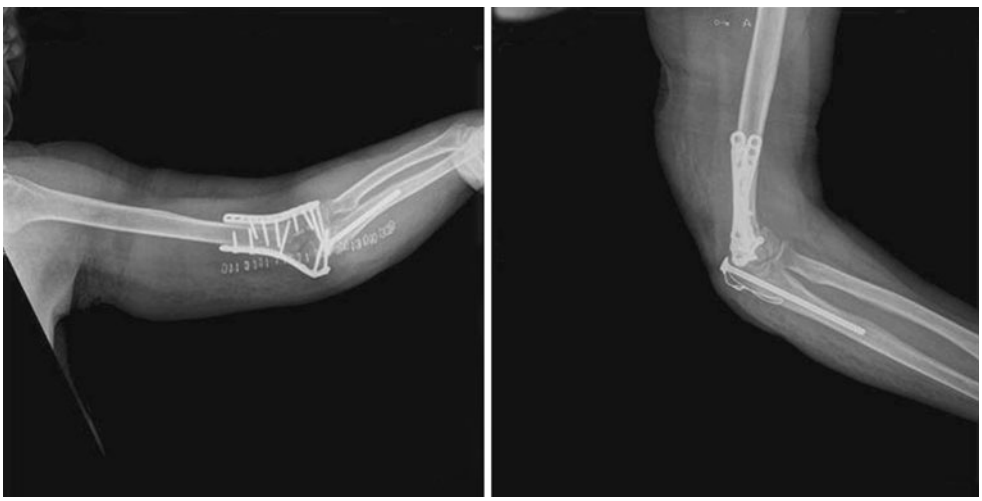

Fig. 2 Postoperative X-ray of the olecranon osteotomy

group 2. Sutures were removed at the end of the second week. After removal of the splint, all patients were given hinged elbow orthoses with an adjustable angle. The range of the motion was set free, allowing the patients to perform both active and passive elbow movements. Orthosis use was discontinued at the end of the sixth week. A rehabilitation programme was continued, and the elbow joints were radiologically evaluated with anteroposterior and lateral imaging until the union was fully observed. Functional evaluation of the patients at the final control was carried out with goniometric measurement of the range of motion in the elbow joint, MAYO and q-DASH (quick-Disabilities of Arm, Shoulder & Hand) scores. Patients were given indomethacin 75 mg/day for heterotopic ossification for 6 weeks and prophylactic antibiotic therapy (cefazolin 40 mg/kg/day) during the first 3 postoperative days.

Statistical analysis

Analysis of the data was performed using SPSS 11.5 (Statistical Package for Social Sciences) software. Descriptive statistics were expressed as the means ± standard

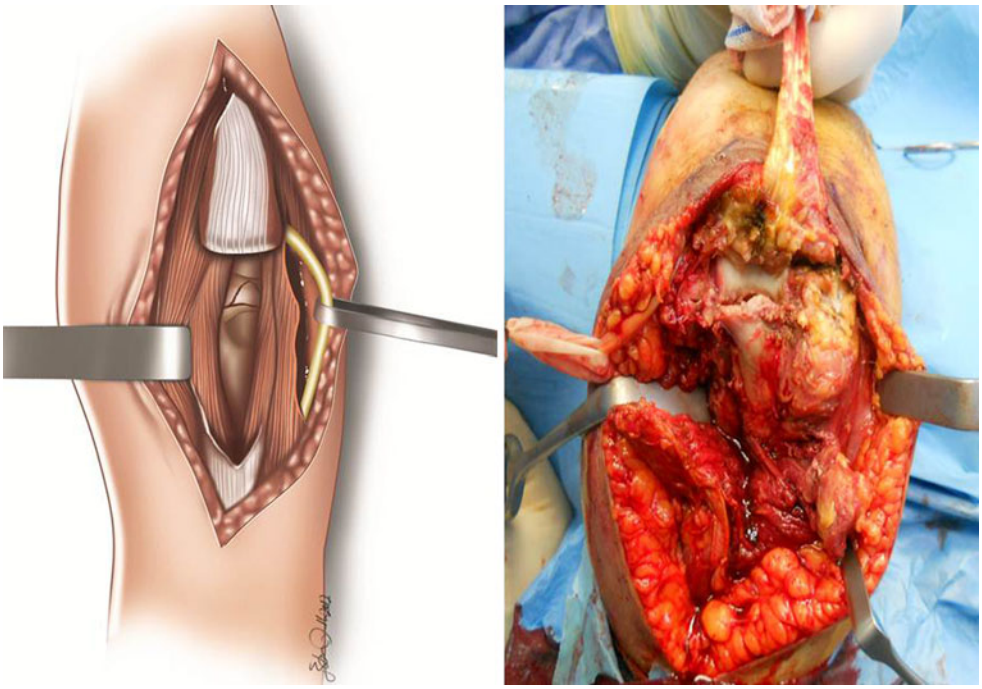

Fig. 3 Illustration of triceps-lifting (Campbell's) approach

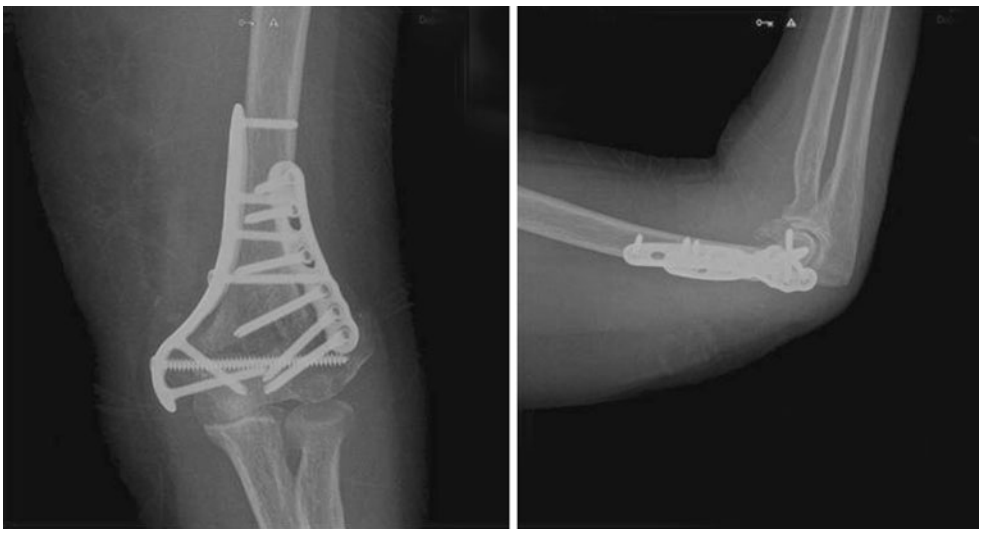

Fig. 4 Postoperative X-ray of the triceps lifting (Campbell's approach)

deviations for continuous variables, while nominal variables were expressed as % values and case numbers. Statistical significance between continuous variables with a normal distribution was analysed with the Student's *t* test, and the significance between the groups in terms of gender, complications and implants used was evaluated using Pearson's chi-square test. The existence of the fractures was analysed between the groups using Fisher's exact test. $p < 0.05$ was considered statistically significant.

Results

Patients were first evaluated in terms of their demographics. No significant differences were observed between the groups in terms of gender ($p = 0.651$) and age ($p = 0.422$). Differences in fracture types could not be evaluated because of a nonhomogeneous distribution between groups. The mean follow-up duration was 38.3 months (range 13–60 months) in group 1 and 41.4 months (range

12–69 months) in group 2. All fractures were healed at the end of the follow-up period. The results in group 1 according to MAYO scoring were excellent in 10, good in 8, fair in 3 and poor in 1 patient, with a mean MAYO score of 85 ± 13.2. The results in group 2 were excellent in 6, good in 14, fair in 7 and poor in 5 patients, with a mean score of 76.7 ± 13.4. The mean MAYO score was significantly different between the groups ($p < 0.05$). The mean q-DASH score was 16.6 ± 17.2 in group 1 and 23.2 ± 13.4 in group 2, but this difference was not significant ($p = 0.117$). The mean MAYO and q-DASH scores are shown in Fig. 5 with their corresponding p values.

In the final controls of the patients, the mean elbow flexion was found to be 99.3 ± 11.6°, and the limitation of elbow extension was 13.4 ± 9.3° in group 1, while these values were 88.8 ± 12.3 and 22.3 ± 11.1°, respectively, in group 2. These were significantly different ($p < 0.05$) (Fig. 6).

During surgery, lateral plating was performed in 10 (45.5 %) patients, and medial and lateral parallel plating was performed in 12 (54.5 %) patients in group 1, while lateral plating was performed in 8 (25 %) patients, and medial and lateral parallel plating was performed in 24 (75 %) patients in group 2. No significant difference was observed between the groups in terms of the type of implant ($p = 0.117$).

The mean complication rate was (50 %) in group 1 and (40.6 %) was in group 2 (Table 2). In group 1, ulnar nerve paraesthesia was found in two patients (spontaneously resolved), while heterotopic ossification was found in 1 patient, superficial infection in one patient (treated with superficial wound debridement and antibiotic therapy), elbow joint stiffness in two patients (resolved after physiotherapy for 6 weeks) and nonunion at the osteotomy site in two patients. A second surgery was performed in two patients with nonunion. Union was achieved at the end of 8 weeks by grafting with an autograft harvested from the iliac wing and reosteosynthesis. In group 2, ulnar nerve paraesthesia was found in three patients (spontaneously resolved in two patients and symptoms regressed in 1 patient after the ulnar nerve was released), heterotopic ossification in two patients and elbow joint stiffness in three patients (elbow motions improved in two patients following 6 weeks of physiotherapy, while ROM did not change in one patient). No significant difference was found between the groups in terms of complications ($p = 0{,}369$).

Gender, age, fracture type, existence of additional fractures, preferred implant type and complication rates of the two groups are summarised, along with the statistical outcomes, in Table 1.

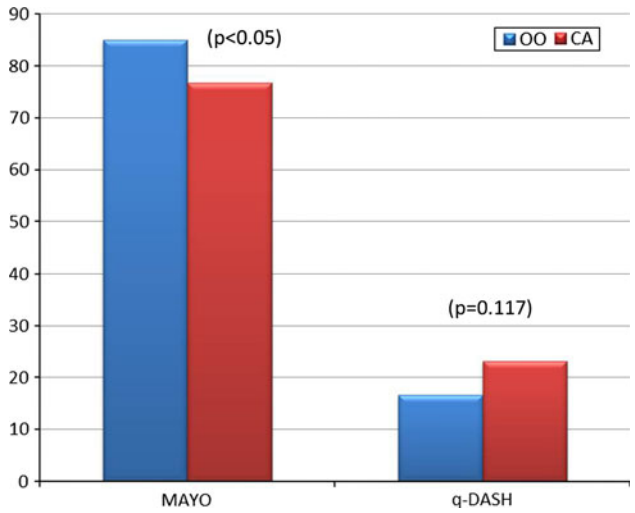

Fig. 5 A comparison of MAYO and q-DASH scores between the groups is provided, along with the corresponding p values. The mean MAYO score was significantly higher in the patients who underwent OO (olecranon osteotomy) compared with those who underwent CA (Campbell's approach) ($p < 0.05$). No significant difference was found between the groups in terms of the mean q-DASH score ($p = 0.117$)

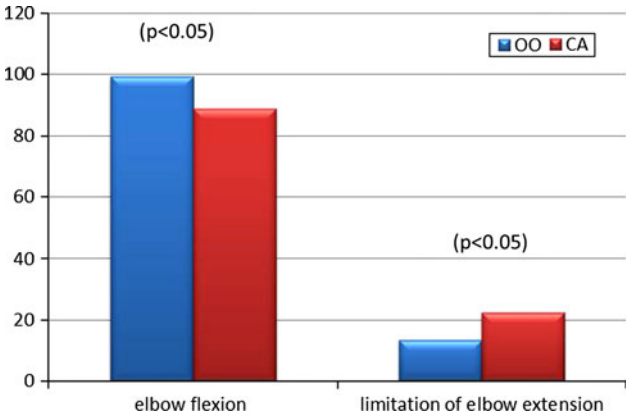

Fig. 6 The mean elbow flexion and mean limitation of elbow extension are shown along with their corresponding p values. The differences in the values of both mean elbow flexion and limitation of elbow extension between groups were significant ($p < 0.05$). *OO* olecranon osteotomy, *CA* Campbell's approach)

Discussion

In our study, we evaluated 54 elbows of 54 patients with B and C type intra-articular distal humerus fractures according to AO classification. With the evaluation according to MAYO elbow score and q-DASH score, we achieved increasing results in all of our patients. We compared the functional outcomes in 2 subgroups according to surgery type with olecranon osteotomy approach and triceps-lifting approach. We achieved significantly better functional outcomes according to MAYO elbow score and better extension and flexion elbow motion arc with the olecranon osteotomy approach which allows early rehabilitation. We reported similar complication rates in both groups (Table 2).

Table 1 Comparison of the olecranon osteotomy (group 1) and Campbell's approach (group 2) approaches in terms of age, gender, type of fracture, existence of additional fractures, type of implant and postoperative complication rates (with *p* values) in the patients with comminuted distal humerus fractures

	Olecranon osteotomy	Campbell's approach	*p* Values
Gender	11 females (50 %)	14 females (43.8 %)	0.651
	11 males (50 %)	18 males (56.2 %)	
Age (years)	Mean 49.3 (17–67)	Mean 46.2 (16–78)	0.422
Type of fracture	7 B3 (31.8 %)	4 B2 (12.5 %)	
	6 C1 (27.3 %)	1 B3 (3.1 %)	
	6 C2 (27.3 %)	8 C1 (25 %)	
	3 C3 (13.6 %)	11 C2 (34.4 %)	
		8 C3 (25 %)	
Existence of additional fracture	3 (13.6 %)	8 (%25)	0.493
Type of implant	Lateral plating in 10 patients (45.5 %)	Lateral plating in 8 patients (25 %)	0.117
	Lateral + medial plating in 12 patients (54.5 %)	Lateral + medial plating in 24 patients (75 %)	
Complication rate	11 (50 %)	13 (40.6 %)	0.369

The fracture type could not be evaluated statistically because of the nonhomogenous distribution and insufficient number of cases

Table 2 Complications and complication rates

	Ulnar Nerve paraesthesia	Heterotopic ossification	Superficial infection	Elbow joint stiffness	Nonunion	Malunion	Refracture
Group 1 (olecranon osteotomy) (50 %)	2 (9.1 %)	1 (4.5 %)	1 (4.5 %)	2 (9.1 %)	2 (9.1 %)	2 (9.1 %)	1 (4.5 %)
Group 2 (Campbell's approach) (40.6 %)	3 (9.4 %)	2 (6.3 %)		3 (9.4 %)		4 (12.5 %)	1 (3.1 %)

The restoration of functional capacity in the surgical treatment of comminuted distal humerus fractures depends on joint restoration, stable fixation and early rehabilitation [2, 12, 13]. Even if all of these criteria are optimally satisfied, several studies report that the results are not always satisfactory [2, 6, 14]. Therefore, other factors must also be emphasised in the surgical planning process to obtain the best results. The type of surgical approach is perhaps the most important of these additional factors.

The most commonly performed approaches in the operative repair of comminuted distal humerus fractures are a posterior incision followed by olecranon osteotomy, triceps splitting or triceps sparing and triceps lifting [2, 5–7, 10, 13, 15, 16]. In this study, we compared the postoperative long-term results between 22 patients who underwent olecranon osteotomy and 32 patients who underwent surgery using triceps lifting.

Both surgical techniques have distinct advantages and disadvantages. In patients who undergo olecranon osteotomy, control of the joint is better with a wide surface, and anatomical reduction and fixation of osteochondral fragments are easier [9, 16, 17]. However, olecranon osteotomy carries a nonunion risk of 1–10 % [17–19]. This rate has been observed to decrease with Chevron osteotomy, which provides a wider contact surface [4, 7]. In this study, the effect of nonunion in olecranon osteotomy could not be evaluated because of the limited number of cases. In addition, implants used for osteosynthesis in the olecranon osteotomy may be painful and require later removal [14, 19]. A disadvantage of the triceps-lifting approach is that the elbow joint must be kept immobile in a flexed position at 90° for at least 3 weeks postoperatively to allow healing of the extensor muscle group and restoration of the extensor muscle mechanism [20, 21].

Ulnar nerve neuropraxia is one of the most common complications encountered after surgical treatment of comminuted fractures near the elbow [3, 5, 6]. This complication is caused by perioperative manipulation of the nerve, failure to loosen enough flexor carpi ulnaris fascia and the formation of fibrous tissue around the ulnar nerve following postoperative immobilisation of the elbow joint [22]. In this study, ulnar nerve paraesthesia was observed in two patients from group 1 (resolved spontaneously) and 3 patients from group 2 (spontaneously resolved in two patients and symptoms regressed in one patient after the ulnar nerve was released).

Another complication observed following fracture in the elbow region is heterotopic ossification in 3–20 % of cases

[15, 21–23]. The clinical manifestation of this complication is heat increase and loss of function with pain and swelling. Heterotopic ossification does not require surgery unless it limits elbow movements enough to hinder daily activities. The administration of 75 mg indomethacin twice a day hindered the transformation of precursor cells to osteoblasts in the process of heterotopic ossification [23]. Similarly, in this study, we administered 150 mg of indomethacin daily for almost 3 weeks, beginning immediately after the surgery. Nevertheless, this complication was encountered in one patient in group 1 and two patients in group 2. We believe that the time between fracture and surgery affected the formation of heterotopic ossification because the patients who had complications were those who underwent operation later than the patients without heterotopic ossification.

The surgical treatment of distal humerus fractures is quite challenging because of the complex anatomical structures in the affected region, difficulty in reduction, insufficiency of the implants used in osteosynthesis and close proximity to many neurovascular structures. Functional results were reported to be worse with an increase in the number of fragments. The most important fracture group consists of type B and C intra-articular fractures [3, 5, 12, 15]. In this study, type of fractures could not be evaluated because of the nonhomogeneous distribution between the groups, but excellent and good results in terms of MAYO and q-DASH scores were observed in patients with type B2-3 and C1 fractures.

One of the most important criteria affecting the outcomes of surgical treatment is early surgical treatment and anatomical fixation [14, 24]. Delayed surgical treatment causes a contracture in the soft tissue and hinders the recovery of functional capacity, leading to poor results [24]. In this study, we carried out the surgical treatment in a mean of 4.7 (1–14) days in group 1 and 5.3 (1–18) days in group 2. No significant difference was found between the groups in terms of waiting time for surgery ($p = 0{,}351$). In terms of functionality, excellent to good results were obtained in patients operated on within the first 48–72 h after injury.

The age of the patient can significantly affect the postoperative results of surgically treated distal humerus fractures [25]. Chen et al. defined an extension of 22.9° in the patients who underwent triceps lifting and were 60 years of age or older. They also demonstrated that triceps lifting caused poor results in patients older than 60 years, whereas it had no significant effects on the functional results in those less than 60 years old, especially in patients younger than 40 years [17]. In our study, the loss of extension observed after performing triceps lifting was found to be 22.3°, which is consistent with the literature. Differences in the limitation of extension between the two groups were statistically significant in favour of group 2 ($p < 0{,}005$).

The choice of surgical approach is crucial for the ease of surgical treatment and insertion of the implants. However, creating a wide operative site is not possible because the region is rich in neurovascular tissue. Anterior, posterior, medial and lateral incisions were described in the surgical treatment of adult distal humerus fractures. The medial or lateral approach can be used to treat fractures with single-column involvement that is unrelated to the joint. Currently, the posterior incision is the most accepted approach in cases related to the joint that involve both columns because this approach protects the neurovascular structures, provides the widest field of view for the surgeon, allows for anatomical reduction and enables early motion. With the posterior incision, better control of the medial and lateral columns is obtained, and a wider view is provided for the surgeon during the plating process. We preferred the posterior approach in all of our patients. Recent studies have shown that the most reliable choice for preserving the anatomy of the medial and lateral columns and providing stable fixation is osteosynthesis with double plates [25]. In this study, osteosynthesis with isolated lateral plating or with lateral and medial double-plating was preferred. No significant difference was found between the two implant options ($p = 0.117$).

Besides the surgical technique and implant type, another factor affecting functional results is postoperative rehabilitation. Despite the lack of clear protocols on this subject, programmes designed to facilitate elbow motion in the early period following surgery have been shown to yield better outcomes, and long-term immobilisation has been shown to be one of the causes of poor functional results [5, 6, 13]. In this study, the arms of the patients in group 1 were placed in long-arm splints, and the splints were removed after a mean of 2 weeks postoperatively. We began joint movements as soon as the fixation method used for olecranon osteotomy was rigid. Patients in group 2 were rehabilitated following the splint by keeping the elbow in 90° of flexion for 3 weeks. We believe that enabling elbow movements beginning early after the surgical treatment of comminuted fractures around the elbow is crucial for achieving good results and that olecranon osteotomy provides advantages in this respect.

The range of motion required for the elbow joint to function normally is in the range of 30–130° [4, 7]. The primary objective of everything from the preferred surgical approach, implant choice, effort to achieve anatomical reduction and early rehabilitation following fractures is to regain the range of motion in this joint and restore functional capacity. In this study, the range of the joint was evaluated in the final postoperative follow-up appointment, which resulted in a mean elbow flexion of 99.3 ± 11.6° and a mean limitation of extension of 13.4 ± 9.3° in group 1. These values were 88.8 ± 12,3 and 22.3 ± 11.1° in

group 2, respectively, and were significantly different from those in group 1 ($p < 0.005$). We believe that range of motion values for the elbow joint was significantly greater in the patients in whom olecranon osteotomy was performed due to their ability to be rehabilitated in the early period following surgery and the lower amount of damage incurred to the extensor mechanism.

Our study has several limitations. It has all the limitations associated with retrospective analysis of existing data. In particular, comparisons could not be made between groups as a result of nonhomogeneous fracture severity. Small number of patients with short follow-up period was included to our study. Finally, results were evaluated with scoring systems not with objective functional tests.

In our study, we concluded that olecranon osteotomy provided better functional outcomes than triceps lifting and intra-articular distal humerus fractures can be safely treated with olecranon osteotomy which provides more control over the elbow joint and better visualisation and allows early postoperative rehabilitation.

Conflict of interest All participating authors declare conflict of interest.

References

1. Rose SH, Melton LJ, Morrey BF (1982) Epidemiologic features of humeral fractures. Clin Orthop 168:24–30
2. Gupta R, Khanchandai P (2002) Intercondylar fractures of the distal humerus in adults: a critical analysis of 55 cases. Injury 33(6):511–515
3. Ring D, Jupiter JB (2000) Fractures of the distal humerus. Orthop Clin North Am 31(1):103–113
4. Jupiter JB, Morrey BF (2000) Fractures of the distal humerus in adults. In: The elbow and its disorders. WB Saunders, Philadelphia, pp 293–329
5. Kinik H, Atalar H, Mergen E (1999) Management of the distal humerus fractures in adults. Arch Orthop Trauma Surg 119(7–8): 467–469
6. Holdsworth BJ, Mossad MM (1990) Fractures of the adults distal humerus. Elbow function after internal fixation. J Bone Joint Surg Br 72(3):362–365
7. Jupiter JB, Neff U, Holzach P et al (1985) Intercondylar fractures of the humerus. An operative approach. J Bone Joint Surg Am 67(2):226–239
8. Ziran BH, Smith WR, Balk ML et al (2005) A true triceps-splitting approach for treatment of distal humerus fractures: a preliminary report. J Trauma 58(1):70–75
9. Archdeacon MT (2003) Combined olecranon osteotomy and posterior triceps splitting approach for complex fractures of the distal humerus. J Orthop Trauma 17(5):368–373
10. Coles CP, Barei DP, Nork SE et al (2006) The olecranon osteotomy: a six year experience in the treatment of intraarticular fractures of the distal humerus. J Orthop Trauma 20(3):164–171
11. Morrey BF (2000) Surgical exposures of the elbow. In: The elbow and its disorders. WB Saunders, Philadelphia, pp 109–134
12. Ring D, Jupiter JB, Gulotta L (2003) Articular fractures of the distal part of the humerus. J Bone Joint Surg Am 85-A(2):232–238
13. John N, Rosso R, Neff U et al (1994) Operative treatment of distal humerus fractures in the elderly. J Bone Joint Surg Br 76(5):793–796
14. Huang TL, Chiu FY, Chuang TY et al (2005) The results of open reduction and internal fixation in elderly patients with severe fractures of the distal humerus: a critical analysis of the results. J Trauma 8(1):62–69
15. Gofton WT, Macdermid JC, Patterson SD et al (2003) Functional outcome of AO type C distal humeral fractures. J Hand Surg Am 28(2):294–308
16. Cheung EV, Steinmann SP (2009) Surgical approaches to the elbow. J Am Acad Orthop Surg 17(5):325–333
17. Chen G, Liao Q, Luo W et al (2011) Triceps-sparing versus olecranon osteotomy for ORIF: analysis of 67 cases of intercondylar fractures of the distal humerus. Injury 42:366–370
18. Ring D, Jupiter JB (1999) Complex fractures of the distal humerus and their complications. J Shoulder Elbow Surg 8(1):85–97
19. Hewins EA, Gofton WT, Dubberly J et al (2007) Plate fixation of olecranon osteotomies. J Orthop Trauma 21(1):58–62
20. Schildhauer TA, Nork SE, Mills WJ et al (2003) Extensor mechanism-sparing paratricipital posterior approach to the distal humerus. J Orthop Trauma 17(5):374–378
21. Ek ETH, Goldwasser M, Bonomo AL (2008) Functional outcome of complex intercondylar fractures of the distal humerus treated through a triceps-sparing approach. J Shoulder Elbow Surg 17(3):441–446
22. Daniels L, Worthingham C (1986) Muscle testing: technique of manual examination. WB Saunders Co., Philadelphia
23. Douglas K, Cannada LK, Archer KR et al (2012) Incidence and risk factors of heterotopic ossification following major elbow trauma. Orthopaedics 35(6):815–822
24. Ali AM, Hassanin EY, El-Ganainy AE et al (2008) Management of intercondylar fractures of the humerus using the extensor mechanism-sparing paratricipital posterior approach. Acta Orthop Belg 74(6):747–752
25. Patterson SD, Bain GI, Mehta JA (2000) Surgical approaches to the elbow. Clin Orthop 370:19–33