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Outcome following olecranon osteotomy versus paratricipital approach for complex intra-articular (AO 13-C) fracture of distal humerus: a prospective comparative study

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Background: The paratricipital approach is a relatively new approach in a complex intra-articular fracture of distal humerus (AO13-C). The aim of this study was to ascertain this approach compared with the olecranon osteotomy approach. Also, we aimed to investigate whether advancing age and surgical delay yield a poor outcome.

Materials and methods: Between 2011 and 2015, 51 adult patients with closed AO 13-C–type fractures were included in the study and divided into 2 groups, that is, paratricipital approach (PT) group and olecranon osteotomy (OO) group. Patients were treated by 2 senior trauma surgeons. They were prospectively analyzed for outcome and complications. Mayo elbow performance score (MEPS) was used to evaluate the outcome.

Results: Of the total 51 patients (mean age, 41.6 years), 27 patients were in the PT group and 24 in the OO group. There was no difference in arc of motion ($P = .513$) and MEPS ($P = .127$) as well as complication rate (χ^2 statistic $= 0.36$, $P = .54$). However, specifically in the type C3 fracture, the PT group had a poor outcome for arc of motion ($P = .002$) and MEPS ($P = .019$) compared with the OO group. Also, age and surgical delay had a weak, negative correlation with arc of motion and MEPS. The association between age and surgical delay against arc of motion was statistically significant ($P = .005$ and .01, respectively).

Conclusions: The PT approach and the OO approach can be used alternatively for AO 13-C1 and -C2 fractures with similar outcomes. However, in type C3, the PT approach yields a poor outcome in comparison with the OO approach.

Level of evidence: Level II; Prospective Cohort Design; Treatment Study

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Keywords: Complex distal humeral fracture; surgical approach; paratricipital; olecranon osteotomy

Restoring elbow anatomy and stable bicolumnar fixation after complex intra-articular distal humerus fractures is well described now.[7,11,17] Accordingly, the exposure technique becomes crucial to evaluate the fractures. These complex fractures are usually approached from the

Institutional Review Board approval was not required for this prospective cohort study.

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posterior side, and various approaches are described that provide extensive exposure for distal humerus.[4] Approaches such as triceps-reflecting anconeus pedicle, triceps reflecting (Bryan and Morrey's approach), and triceps splitting (Campbell's approach) have been described in the literature with pros and cons of each.[4,16] The olecranon osteotomy (OO) approach, which provides maximum articular surface visualization, gives better command on fracture fragments, and has minimal consequences on the extensor mechanism, is often employed for such fractures.[5] But the OO approach has potential complications such as nonunion, delayed union, and hardware issues.[20,5] Alonso-Llames,[2] in 1972, described the triceps-sparing approach with medial and lateral windows for supracondylar fracture in children that was further reshaped by Schildhauer et al[19] to approach intra-articular fractures of distal humerus in adults. The major benefit with this is that the integrity of triceps muscle is not disturbed, permitting early active range of motion (ROM) and avoiding osteotomy and hardware concerns. So far, there is limited literature on the paratricipital approach (PT), as described by Schildhauer et al.[19] To the best of our knowledge, there is no study that compares the PT approach with the OO approach. So, this study was undertaken to evaluate the PT approach in comparison with the OO approach, in terms of the functional outcome and complication. We postulated that the surgical approach employed has an impact on the final results. Also, we hypothesized that advancing age and delay in surgery after injury would yield a poor outcome.

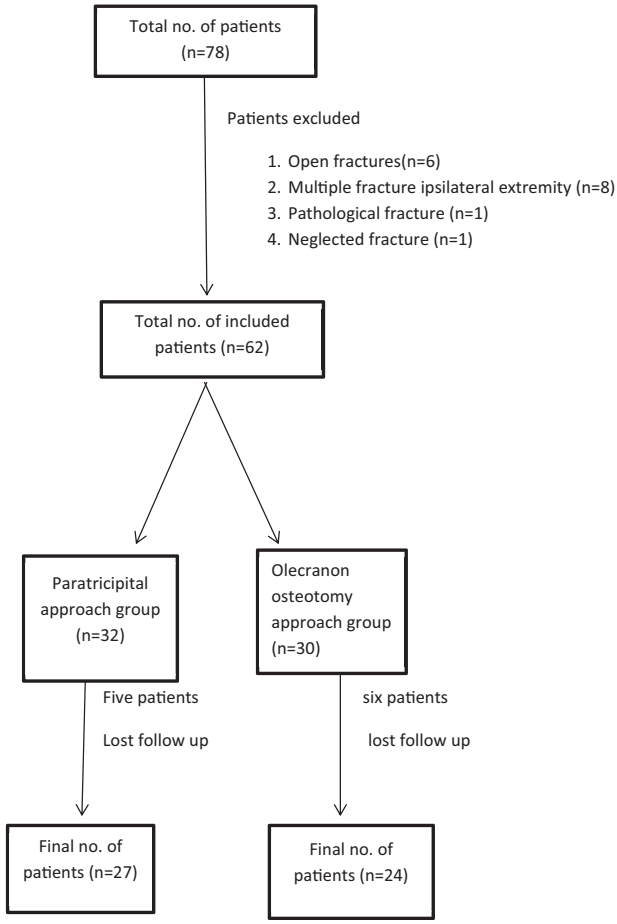


Figure 1 Methodology for study.

Materials and methods

This prospective comparative study was performed in the Orthopaedic Department, GSVM Medical College, Kanpur, India, from July 2011 till September 2015 after the ethical committee and departmental review board approval. We initially identified 78 patients admitting to the hospital with a comminuted intra-articular fracture of distal humerus (AO 13-C), of whom 16 patients were excluded (Fig. 1). All patients were operated by 2 senior trauma surgeons. As per the trauma units they were admitted into (with 1 unit having expertise in the PT approach and the other in OO), the patients were divided into 2 groups, that is, the PT group and the OO group. Five patients (5/32 patients) in the PT group and 6 patients in the OO group (6/30 patients) lost to follow-up early and were excluded. Patients with a minimal 12 months of follow-up were included. The final number of patients in the PT group was 27 (male = 14, female = 13) with a mean age of 40 years, and the final number in the OO group was 24 (male = 15, female = 9) with a mean age of 41 years. Of 27 patients in the PT group, 19 (70.3%) were right sided and 8 (29.7%) were left sided. In the OO group, 14 (53.8%) of 24 patients were right sided and 10 (46.2%) were left sided. In the PT group, injury occurred because of motor vehicle accident in 12 patients (44.4%), simple fall in 8 patients (29.6%), fall from height in 3 patients (11.1%), and fall from bicycle in 4 patients (14.8%). In the OO group, fracture occurred in 13 patients (54.2%) in motor vehicle accident, falling on ground in 5 patients (28.8%), falling from bicycle in 3 patients (12.5%), assault in 1 patient (4.2%), and fall from height in 2 patients (8.3%). On classifying these injuries, type C1 fracture was observed in 18 patients (PT = 13, OO = 5), type C2 was observed in 15 patients (PT = 8, OO = 7), and type C3 was observed in 18 patients (PT = 6, OO = 12).

Surgical fixation was done under general anesthesia in the lateral decubitus position with arm support and hemostasis achieved using tourniquet in all patients. Prophylactic antibiotic (cefuroxime 1.5 g) was given in all cases. Signed informed consent was taken from all patients about fracture type, approach used, and possible complications.

Surgical technique

A midline posterior incision was used with a slight lateral bent on the olecranon tip to avoid the weight-bearing zone. The ulnar nerve was identified first, and then the release of the ligament of Struthers and medial intermuscular septum was done to transpose the ulnar nerve. Anterior transposition of the ulnar nerve was done in all cases in our series. All fractures were fixed as per AO principles using bicolumnar plating.

In the OO approach, an interval was created between the medial intermuscular septum and the triceps. Also, the triceps was lifted from the posterior aspect of the humerus to create a lateral window. Chevron shape osteotomy of ulna was done with apex

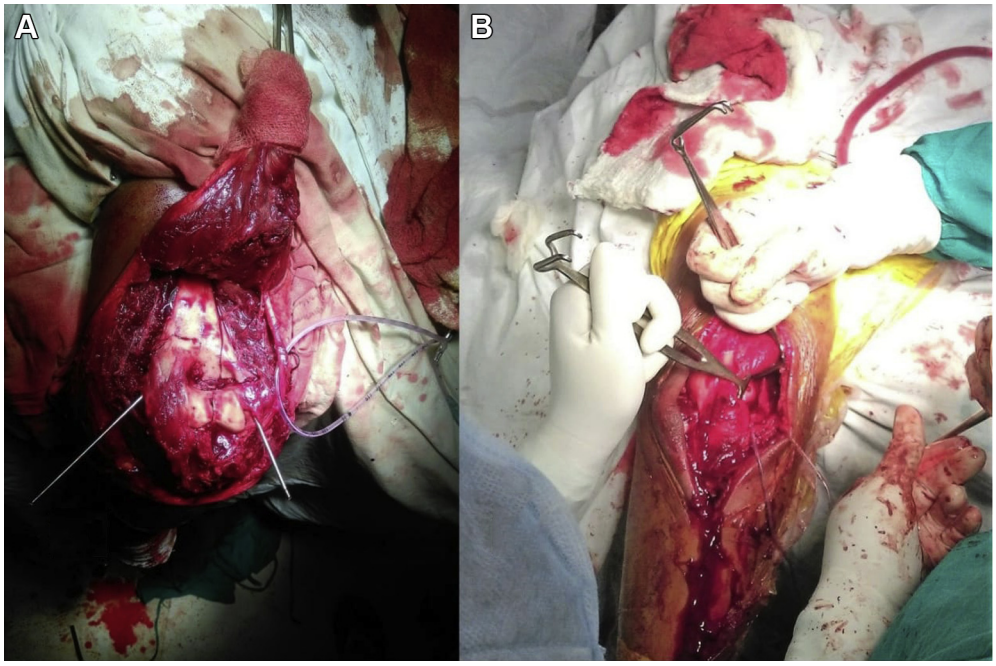


Figure 2 (**A**) Olecranon osteotomy approach with the olecranon fragment tied with a saline-soaked gauge piece. (**B**) Paratricipital approach with medial and lateral windows. The ulnar nerve was identified first and isolated in both approaches.

distally at approximately 2 cm from the olecranon tip. Osteotomy first started with a thin oscillating saw, and then the subchondral bone and articular surface were fractured with thin osteotome. Dissection extended proximally as required and olecranon fragment wrapped with a saline-soaked gauge piece sutured proximally (Fig. 2, *A*). This completed the exposure of fracture. The osteotomy site was fixed with two 1.8-mm (0.072″) smooth K wires that perforate the anterior cortex distal to the coronoid process and were stabilized with an 18-gauge wire in accordance with tension band wire principles. K wires' tips were bent at the triceps insertion and impacted the bone.

In the PT approach, dissection was done on the medial side along the intermuscular septum posterior border to expose the posterior-medial border of the humerus. After creating a medial window, the posterior lateral humerus was approached by lifting the lateral border of the triceps from the lateral intermuscular septum. Dissection was carried out proximally as required, but if more proximal dissection was required, radial nerve was identified and retracted. Whole triceps muscle was elevated along the posterior surface of the humerus by connecting these 2 windows (as described by Schildhauer et al[19]). This exposed the posterior humeral shaft and fractured fragments (Fig. 2, *B*). Fracture reduction was done after clearing the debris by direct and indirect manipulation under fluoroscopy guidance.

Postoperative

The wound was closed under the negative suction drain, which was removed after 48 hours. The elbow was immobilized at 90° for initial 2 days. After drain removal, ROM exercises were encouraged. ROM exercises were gradually increased aiming to achieve elbow flexion up to 90° by the end of 2 weeks and full ROM by 6 weeks. Patients were regularly followed up at 6 weeks, 12 weeks, and thereafter every 3 months for radiological and functional assessment.

Outcome measurement

ROM was measured manually using a goniometer. Functional assessment was done using Mayo Elbow Performance Score (MEPS). Radiological assessment was done using x-rays in follow-up visits. An articular step-off of >2 mm or a malalignment of >5° in any plane was considered as malunion.

Statistical analysis

Data were summarized as mean and standard deviation. Continuous variables were compared using a 2-tailed Student's *t*-test and categorical data were compared using the χ^2test and Fisher's *z* test. The Pearson correlation coefficient test was used to assess strength, and Spearman's Rho test and a 2-tailed *P* value were used for statistical significance of correlation. $P < .05$ was considered for the level of significance, for all analysis (SPSS version 22; IBM, Armonk, NY, USA).

Results

There was no statistically significant difference in the 2 groups' demography (Table I). The mean duration of follow-up for the PT group was 21 months (range, 12-28 months) and 28 months (range, 22-35 months) for the OO group. All fractures were healed primarily including the osteotomy site in both groups (Fig. 3).

Table I Comparison of the paratricipital (PT) approach group and the olecranon osteotomy (OO) approach group in terms of age, gender, fracture type, and complications

Parameter	PT approach group (n = 27)	OO approach group (n = 24)	Remark
Gender	Male = 14 Female = 13	Male = 15 Female = 9	Fisher's z test statistic value = 0.513 Difference of gender for 2 groups was nonsignificant at $P < .05$
Age	Mean age = 39.92 ± 13.28 yr Range, 22-62 yr	Mean age = 41.41 ± 13.14 yr Range, 20-65 yr	Statistic evaluation done using Student's t-test. t value = 0.59, $P = .55$. Difference for age in 2 groups was nonsignificant at $P < .05$
Fracture type	Type C1 = 13 Type C2 = 8 Type C3 = 6	Type C1 = 5 Type C2 = 7 Type C3 = 12	χ^2 statistic = 5.46, $P = .06$. The difference was not significant at $P < .05$
Complications	9 (33.3%) 2, hardware prominence 2, ulnar nerve injury 5, stiffness	11 (45.8%) 5, hardware prominence 1, ulnar nerve injury 2, infection 1, heterotrohic ossification 3, stiffnes	χ^2 statistic = 0.36, $P = .54$. This difference was not significant at $P < .05$

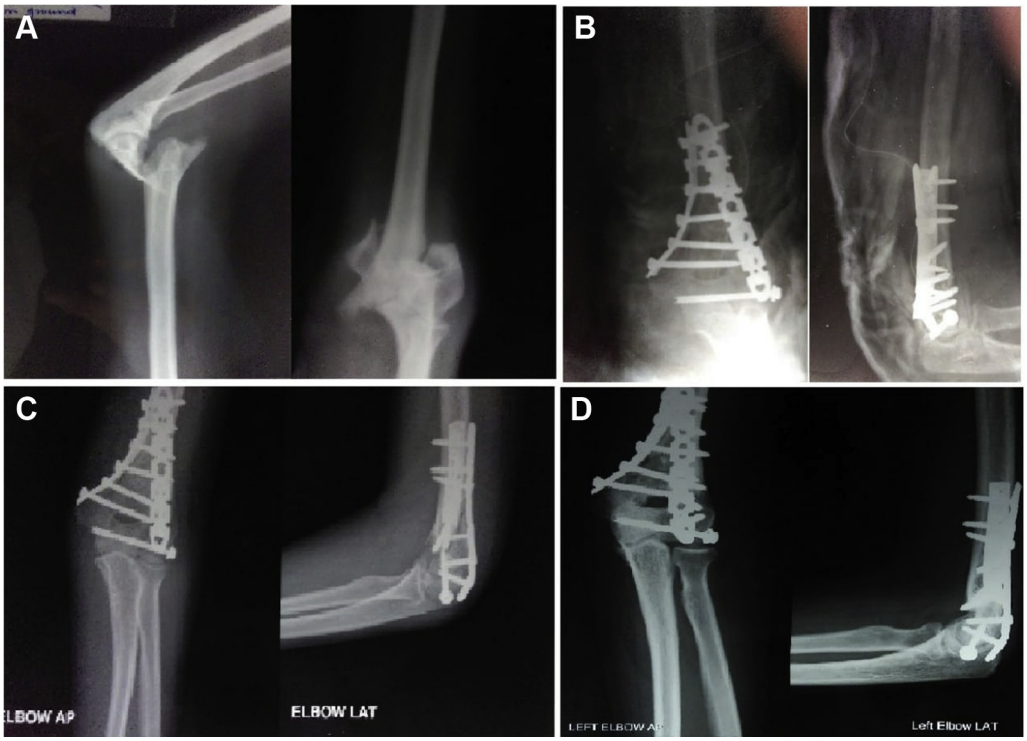


Figure 3 (**A**, **B**) Preoperative and immediate postoperative x-rays of type C1 fracture. (**C**) After 1 month. (**D**) At 3-month follow-up, fracture site was united.

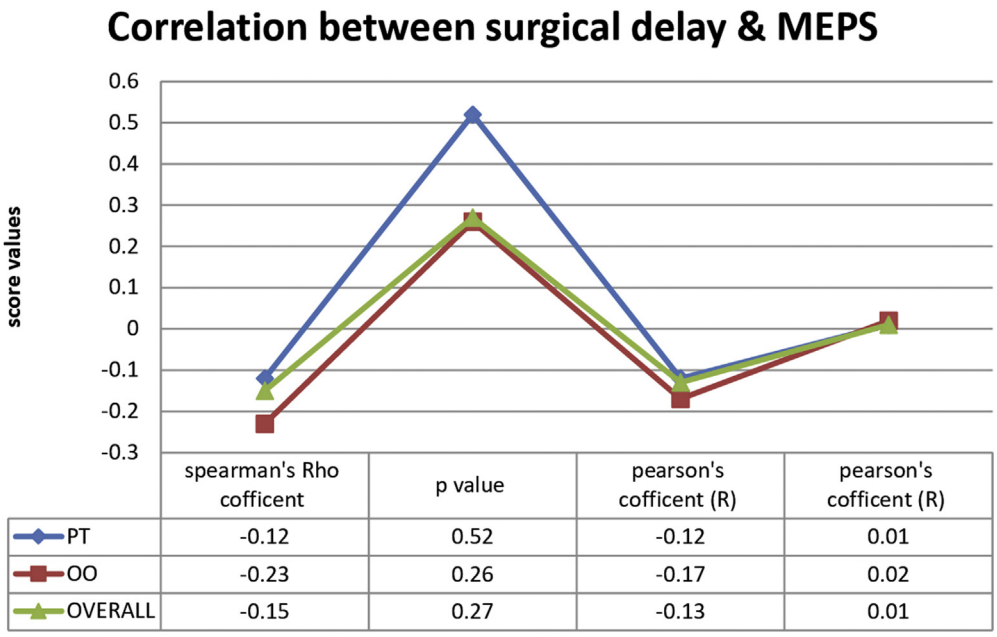
Overall mean flexion achieved, extension lag, and arc of motion were similar in the 2 groups ($P = .382$, .843, .513, respectively). In type C3, the PT approach yields a poor outcome compared with the OO approach. In type C3 fracture, the mean flexion and arc of motion in the PT group were 100° and 78°, respectively, and in the OO group, 118° and 104°, respectively. The difference between these 2 groups was statistically significant in applying a 2-tailed Student's t-test ($P = .004$ and .002) (Table II). The mean MEPS achieved in the PT group was 82 (MEPS was excellent in 5, good in 17, fair in 3, and poor in 2 patients) and in the OO group 87 (MEPS was excellent in 8, good in 14, fair in 1, and poor in1 patient), which was statistically insignificant ($P = .127$). However, in type C3, the PT approach attained a poor score, that is, 65 compared with 83 in the OO group ($P = .019$, statistically significant) (Table II).

Table II Functional outcome and performance score in each subtype of type C intra-articular fracture of distal humerus

Parameter	Fracture type	PT group	OO group	Inference
Flexion (°)	Type C1	126.53 ± 8.98	130 ± 7.07	$t = 0.769$ $P = .453$ NS
	Type C2	126.25 ± 10.60	128.57 ± 6.90	$t = 0.493$ $P = .629$ NS
	Type C3	100 ± 14.14	118.33 ± 9.37	$t = 3.307$ $P = .004$ Significant
	Overall	120.55 ± 15.21	123.75 ± 9.69	$t = 0.881$ $P = .328$ NS
Extension lag (°)	Type C1	6.15 ± 4.6	4.00 ± 5.47	$t = 0.904$ $P = .379$ NS
	Type C2	6.87 ± 3.72	4.28 ± 4.49	$t = 1.220$ $P = .243$ NS
	Type C3	21.66 ± 7.52	14.58 ± 6.55	$t = 2.060$ $P = .055$ NS
	Overall	9.81 ± 8.02	9.37 ± 7.70	$t = 0.199$ $P = .843$ NS
Arc of motion (°)	Type C1	120.38 ± 11.80	126 ± 5.47	$t = 1.008$ $P = .328$ NS
	Type C2	121.25 ± 11.87	124.28 ± 10.17	$t = 0.527$ $P = .606$ NS
	Type C3	78.38 ± 20.41	104.58 ± 10.32	$t = 3.680$ $P = .002$ Significant
	Overall	111.29 ± 22.47	114.79 ± 13.86	$t = 0.658$ $P = .513$ NS
Mayo elbow performance score	Type C1	88.46 ± 7.94	94 ± 8.21	$t = 1.222$ $P = .239$ NS
	Type C2	81.87 ± 8.42	87.85 ± 8.59	$t = 1.359$ $P = .179$ NS
	Type C3	65.83 ± 13.57	83.46 ± 13.44	$t = 2.583$ $P = .019$ Significant
	Overall	81.66 ± 12.93	86.8 ± 11.71	$t = 1.550$ $P = .127$ NS

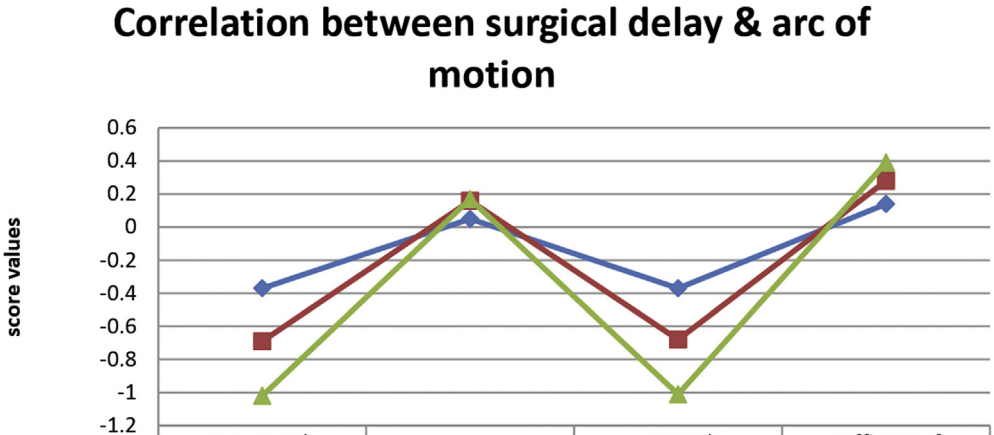
PT, paratricipital approach; *OO*, olecranon osteotomy; *NS*, not significant.

The mean surgical delay (interval between injury and surgery) was 5 days (range, 1-12 days). There was a weak, negative, and nonsignificant correlation between the surgical delay and MEPS (Spearman Rho value = −0.15, 2-tailed $P = .27$, Pearson coefficient = −0.13, coefficient of determination = 0.018) (Fig. 4). Also, the association between surgical delay and arc of motion was weak, negative, but statistically significant (Spearman Rho value = −0.33, 2-tailed $P = .01$, Pearson coefficient = −0.33, coefficient of determination = 0.114) (Fig. 5). The correlation between



	spearman's Rho cofficent	p value	pearson's cofficent (R)	pearson's cofficent (R)
PT	-0.12	0.52	-0.12	0.01
OO	-0.23	0.26	-0.17	0.02
OVERALL	-0.15	0.27	-0.13	0.01

Figure 4 Correlation between variables was weak, negative for both groups overall (Pearson's coefficient value near zero), and association was considered as statistically nonsignificant ($P > .05$). *MEPS*, Mayo elbow performance score; *OO*, olecranon osteotomy; *PT*, paratricipital.

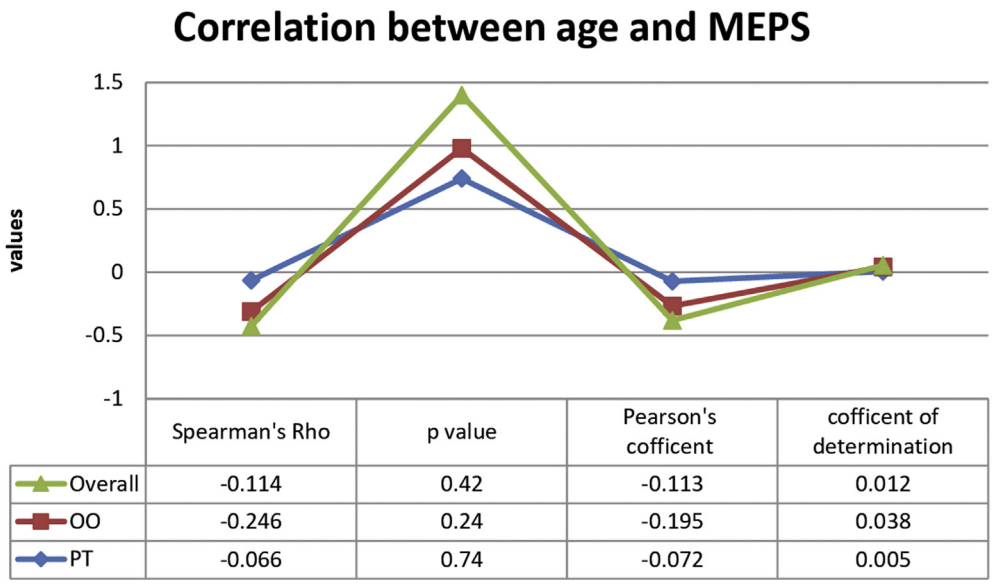


	spearman's cofficent	p value	pearson's cofficent	cofficent of determination
OVERALL	-0.33	0.01	-0.33	0.11
OO	-0.32	0.11	-0.31	0.14
PT	-0.37	0.05	-0.37	0.14

Figure 5 Overall correlation between variables was weak, negative (Pearson's coefficient value near zero), and association was considered as statistically significant ($P < .05$). *OO*, olecranon osteotomy; *PT*, paratricipital.

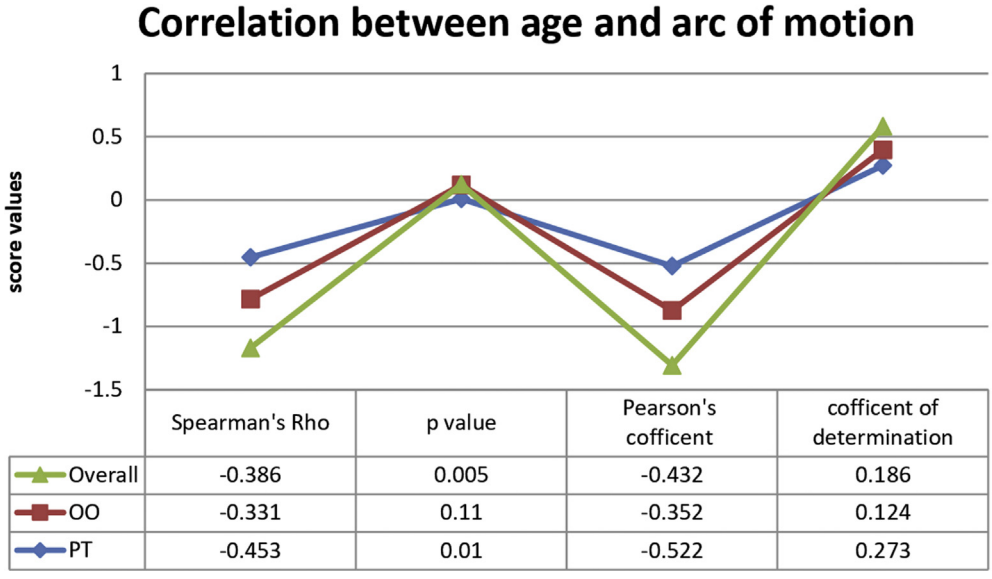
advancing age and MEPS was weak, negative, and not statistically significant (Spearman Rho value = −0.114, 2-tailed $P = .42$, Pearson coefficient = −0.113, coefficient of determination = 0.012) (Fig. 6). The correlation between age and arc of motion was weak, negative, but statistically significant (Spearman Rho value = −0.386, 2-tailed $P = .005$, Pearson coefficient = −0.432, coefficient of determination = 0.186) (Fig. 7).

Major complication in both of our groups was hardware prominence, which was in 5 patients in the OO group(1—over medial epicondyle, 2—over olecranon, and in 2—over both olecranon and medial epicondyle), compared with 2 in the PT group (both over medial epicondyle), and was statistically insignificant. Transient ulnar nerve palsy occurred in 2 cases in the PT group and recovered spontaneously within 3 months. Heterotrophic ossification (HO)



	Spearman's Rho	p value	Pearson's cofficent	cofficent of determination
Overall	-0.114	0.42	-0.113	0.012
OO	-0.246	0.24	-0.195	0.038
PT	-0.066	0.74	-0.072	0.005

Figure 6 Correlation between 2 variables was weak, negative as Pearson's coefficient value was near zero and also statistically nonsignificant as $P > .05$. *MEPS*, Mayo elbow performance score; *OO*, olecranon osteotomy; *PT*, paratricipital.



	Spearman's Rho	p value	Pearson's cofficent	cofficent of determination
Overall	-0.386	0.005	-0.432	0.186
OO	-0.331	0.11	-0.352	0.124
PT	-0.453	0.01	-0.522	0.273

Figure 7 Moderately negative correlation between variables in the paratricipital (PT) group that was statistically significant as the *P* value was .01. Also, for the olecranon osteotomy (OO) group, there was a weak, negative association. Overall, there was a weak, negative correlation between variables and association was considered as significant.

occurred in 1 patient in the OO group. Deep-seated infection occurred in 2 patients in the OO group, which subsided with joint debridement and antibiotics (1 in each type C2 and C3). Stiffness occurred in 3 patients in the OO group and 5 patients in the PT group (Table I).

Discussion

The optimal approach for the distal humerus complex articular fracture should provide adequate fracture fragment assessment with minimal tissue disruption. OO is conventionally well accepted for distal humeral exposure but has concerns with osteotomy and hardware issues. In this research, we analyzed 51 elbows of 51 patients with complex intra-articular (AO 13 type C) fractures. We divided the cohort into 2 groups subjected to the surgical approach used and further subgrouped based on fracture configuration (AO classification) and analyzed the outcome. In types C1 and C2, with comparatively large fracture fragments, indirect reduction with the PT approach can be done without much difficulty and can be checked by visualizing and palpating the joint

surface and also using intraoperative fluoroscopy. The OO approach had a clear advantage over the PT approach in type C3 fractures. Arc of motion as well as functional score was significantly higher in the OO group compared with the PT group. We found that in complex multifragmentary fracture (type C3), utility of the PT approach was limited because of osteochondral fragments, which are difficult to control with limited exposure. Previously Ali et al[1] reported that 86.5% cases achieved good to excellent MEPS in their series of 22 patients with type C fracture distal humerus, managed with the PT approach. In their series, only 1 patient in type C2 had deep infection leading to the poor outcome. Although, they did not report outcome in type C fracture subtypes, but recommended against this approach in type C3, for technical difficulties. Erpelding et al[9] exhibited a median arc of motion of 75° and 29.7% loss of extension strength in type C3 fracture using the PT approach. They also achieved a good to excellent MEPS score in 91.6% cases overall, but the limitation was that they included type A and B fractures also. They concluded the PT approach in a case-to-case basis depending on surgeon expertise in type C3 fracture. Also, in the OO approach, nonunion risk at osteotomy was described in the literature ranging from 0% to 15% cases and as high as 30% with transverse osteotomy; we did not notice any nonunion at the osteotomy site.[10,15,18] We used chevron-type osteotomy in all our cases and fixed that as per the tension band principle. Another technique to fix osteotomy is with plates and screws, but it less favored because of issues such as wide surgical exposure, bulky implant, and wound complications.[13] Ulnar nerve paraxial injuries are common after elbow fracture because of careless handling of the nerve in the perioperative period and also postoperative fibrous scar entrapment.[6] We noted 2 cases in the PT group and 1 case in the OO group with postoperative ulnar nerve palsy. We routinely transferred the ulnar nerve anteriorly as to reduce the impingement between the nerve and hardware during elbow motion in all our cases.

HO is also a well-known sequela of the elbow trauma. We did not use any prophylaxis against HO owing to an increased risk of nonunion at the fracture site and only 1 case with type C3 in the OO group developed HO. The role of the surgical approach in the development of HO is controversial. Chen et al[3] reported 12% cases of HO when the distal humerus fracture was treated with OO compared with negligible HO in the triceps-sparing approach. Also, in a systematic review, Ljungquist et al[14] observed that HO occurred in 4 of total 66 patients with such fractures treated with OO and none in the triceps-sparing group. Hong et al[12] noted that duration of surgery, timing of surgery, and fracture dislocation were independent risk factors for the development of HO, but did not comment on the role of the approach in developing HO. Also, with the PT approach, authors did not report any HO incidence.[1,9] To conclude, the PT approach leads to reduced incidence after elbow trauma, and needs more extensive research.

Surgical delay is also considered an important parameter of a good surgical outcome. Delay in surgical intervention leads to soft tissue contracture and limits functional arc of motion.[1] But there are conflicting reports about surgical delay vs. arc of motion and MEPS. Erpelding et al[9] reported no significant correlation between surgical delay and arc of motion or MEPS. Also, Elmadag et al[8] claimed to obtain a good to excellent functional outcome if operated in less than 3 days. The authors did not comment any further on the statistical correlation between surgical delay and outcome.[8] We noticed that there was a weak negative correlation between surgical delay and age against performance score and functional outcome. However, Chen et al[3] asserted no statically significant correlation between age against MEPS and arc of motion, but they did not mention the *P* value for the same.

Our study had limitations. First, there was lack of proper randomization. Secondly, 2 trauma surgeons had operated the patients. Thirdly, the number of patients was small, mainly in the PT group in type C3. Fourthly, we did not include geriatric population, so drawing an authoritative conclusion on age vs. outcome is not viable. Lastly, we did not objectively note extension strength in fracture types in the 2 groups. Although our main motive was to assess the functional outcome using 2 different approaches, we considered it as a limitation. These flaws may shrink the power of the study on comparative account for these approaches.

Conclusion

These 2 approaches can be used alternatively for intra-articular fracture of distal humerus with relatively large fragments, that is, type C1 and C2. There was a theoretical advantage with the PT approach in these fractures such as intact extensor mechanism and no hardware issues, but outcome and complications were relatively the same. The PT approach in more complex multifragmentary fracture (type C3) yields poor functional outcome compared with the OO approach because it is difficult to control and fix fracture fragments.

Disclaimer

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