



Original Article

Bilateral triceps tendon approach is flexible and efficient in the treatment of type C distal humerus fractures

Jian Ding, Wen-Jing Yin, Bao-Kun Zhang, Xin-Gang Yu, Hong-Jiang Ruan, Wei Zhang*

Department of Orthopedic Surgery, Shanghai Jiao Tong University Affiliated No.6 People's Hospital, Shanghai, 200233, China

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ABSTRACT

Purpose: The purpose of this study was to assess and compare elbow range of motion, triceps extension strength and functional results of type C (AO/OTA) distal humerus fractures treated with bilateral triceps tendon (BTT) approach and olecranon osteotomy (OO). At the same time, we are also trying to know whether BTT approach can provide sufficient vision for comminuted intra-articular fractures of the distal humerus, and whether it is convenient to convert to the treatment to total elbow arthroplasty (TEA) or OO.

Methods: Patients treated with OO and BTT approaches for type C distal humerus fractures between July 2014 and December 2017 were retrospectively reviewed. Inclusion criteria include: (1) patients' age were more than 18 years old, (2) follow-up was no less than 6 months, and (3) patients were diagnosed with type C fractures (based on the AO/OTA classification). Exclusion criteria include: (1) open fractures (Gustillo type 2 or type 3), (2) treated by other approaches, and (3) presented with combined injuries of ipsilateral upper extremities, such as ulnar nerve. Elbow range of motion and triceps extension strength testing were completely valuated, when the fractures had healed. Assessment of functional results using the Mayo elbow performance score and complications were conducted in final follow-up. The data were compared using the two tailed Student's *t*-test. All data were presented as mean \pm standard deviation.

Results: Eighty-six patients of type C distal humerus fractures, treated by OO and BTT approach were retrospectively reviewed between July 2014 and December 2017. Fifty-five distal humerus fractures (23 males and 32 females, mean age 52.7 years) treated by BTT approach or OO were included in this study. There were 10 fractures of type C1, 16 type C2 and 29 type C3 according to the AO/OTA classification. Patients were divided into two surgical approach groups chosen by the operators: BTT group (28 patients) and OO group (27 patients). And the mean follow-up time of all patients was 15.6 months (range, 6–36 months). Three cases in BTT group were converted to TEA, and one converted to OO. Only one case in BTT group presented poor articular reduction with a step more than 2 mm. There were not significantly different in functional outcomes according to the Mayo elbow performance score, operation time and extension flexion motion are values between BTT group and OO group ($p > 0.05$). Complications and reoperation rate were also similar in the two groups. Triceps manual muscle testing were no significant difference in the two groups, even subdivided in elder patients (aged >60 years old).

Conclusion: BTT is a safe approach to achieve similar functional result comparing with OO. BTT were not suitable for every case with severe comminuted pattern, but it avoids the potential complications related to OO, and has no complications concerning with triceps tendon. It is convenient for open reduction internal fixation and flexible to be converted to OO, as well as available to be converted to TEA in elder patients.

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* Corresponding author.

E-mail address: orthozhang_wei@163.com (W. Zhang).

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Introduction

Various approaches for distal humerus fractures have been described in recent decades. Most common surgical approaches used in treating comminuted distal humerus fractures were olecranon osteotomy (OO) and triceps sparing. Both approaches can achieve reduction in distal fragments for different feature types.¹ OO was commonly selected for the treatment of intraarticular comminuted cases, especially for type C3 fractures. Its exposure areas was more extensive than other intact olecranon approaches including triceps sparing, triceps reflecting, triceps fascial tongue and triceps splitting.^{2,3} Good surgical field of view was convenient to operations of reduction and fixation. However related complications of osteotomy such as delayed union, nonunion and prominent hardware were not uncommon.^{4–6} While triceps splitting or para-triceps approaches can preserve the normal joint structure of elbow extension mechanism and avoid the potential complications associated with OO. Due to limited exposure of the intraarticular fragments of the comminuted fractures, those approaches with OO were recommended to treat the type C3 fractures.^{7,8} Even in the recent reports of modified approach, lateral para-olecranon triceps-splitting approach was also suggested to treat type C1 and C2 fractures.⁹ As we all knew, the treatment of type C3 fractures were more frequently to transfer to total elbow arthroplasty (TEA), when it was too difficult to restore the bony structures in old people. It would be not conducive to complete arthroplasty procedures after completing OO, which is also not conducive to postoperative rehabilitation training.^{10,11} Therefore, the ideal approach for internal fixation should provide sufficient visualization, promote recovery, and be easily altered to TEA. Bilateral triceps tendon (BTT) is designed as splitting triceps tendon via both sides of olecranon, but preserving central band of the triceps tendon insertion. Therefore, we hypothesis it can provide a better exposure than other non-osteotomy approaches, avoid OO complications and easily switch to TEA when necessary.

The purpose of this study was to present and evaluate the results of type C of distal humerus fractures treated by BTT approach. We also compared the functional results, triceps extension strength and complications with OO, and evaluated practicability of alteration to TEA by this approach.

Methods

Patients

Eighty-six patients of type C distal humerus fractures, treated by OO and BTT approach were retrospectively reviewed between July 2014 and December 2017. Fifty-five cases of distal humerus fractures treated by BTT approach or OO were reviewed in this study, including 23 males and 32 females, with an average age of 52.7 years. The inclusion criteria were: (1) patients' age were more than 18 years, (2) the follow-up was no less than 6 months, and (3) patients were diagnosed with type C fractures. The exclusion criteria were: (1) diagnosed with open fractures (Gustillo type 2, or type 3), (2) treated by other approaches, and (3) presenting with combined injuries of ipsilateral upper extremities, such as ulnar nerve. Radiographs and CT scan were reviewed to determine the classification of fractures and reduction quality. Operative records data, complications and reoperation rate were also evaluated.

Surgical technique

Patients treated by BTT approach were placed on either a prone or a lateral position. A midline posterior incision with a curve around olecranon was performed, and subcutaneous flaps were

released both laterally and medially. After the ulnar nerve is identified and freed, the incision from distal coronoid level on both sides of the proximal ulna were started. Medial incision was extended by splitting the triceps tendon just proximal to olecranon fossa when fragments needed to be exposed, and lateral incision of proximal ulna was extended more proximally in the same method when fixation was needed. Central band of triceps tendon should be kept intact during the operation. The lateral part of the triceps along with the anconeus should be released laterally from distal humerus and proximal ulna as a single unit (Fig. 1). Both the medial and lateral triceps flaps retain at least 0.5 cm width of tendon tissue to facilitate easy suture back to central band of the triceps tendon. Then medial and central parts of triceps were elevated and released from dorsal humerus, and medial part could be pulled medially or laterally in order to expose olecranon fossa or medial column. Distal aponeurosis of anconeus and triceps were released at the level of coronoid. Therefore, surgical field of view could be from lateral, medial and middle windows.

Medial triceps flap could also be completely released from medial proximal ulna and proximally reflected in order to enlarge surgical field of view, then the medial and middle window were connected to one larger medial window. In each case, the medial and lateral collateral ligament should be kept intact. For patients receiving OO, the standard V-shaped or transverse osteotomy was performed to expose the distal humerus. Tension bands or screws were used for olecranon fixation in the study. All patients underwent fracture fixation using the techniques described by O'driscoll after exposure of the fragments in operative area.¹² The comminuted fragments were first reduced and temporarily fixed using Kirschner wires to reconstruct distal humeral articular surface. Then, the proximal fracture fragments were reduced and fixed with parallel or perpendicular double-locking plate systems with pre-contoured or anatomical plates placed laterally and medially. Internal fixation were achieved and checked by fluoroscopy, the bilateral split triceps tendon and anconeus fascia was sutured using a 1.0 absorbable suture (Figs. 2 and 3). Subcutaneous or sub-muscular anterior transposition of the ulnar nerve was not regularly completed.

When BTT approach cannot ideally restore and fix the fractures, especially type C3 fractures, medial part of triceps was sutured back to central band, and OO should be performed according to the standard method. Proximal olecranon along with medial part triceps and lateral split triceps were then reflected proximally for more exposure. When the fracture is difficult to achieve fixation due to osteoporosis or comminuted status, TEA can be used instead.

Postoperative care

Patients with stable fixation were allowed to start rehabilitation of the elbow immediately after operation. For severe osteoporosis, the elbow was immobilized with an adjustable orthosis for two weeks, and the elbow was locked in flexion or extension alternately at the maximum angle for one or two times if the patient tolerates it. The orthosis was locked in 90° flexion, when patients were rest. Due to poor bone quality, it is difficult to achieve sufficient stability, and the full range of elbow activities should be postponed for two weeks. Indomethacin was given 25 mg three times a day for six weeks postoperatively, to prevent formation of heterotopic ossification.

Clinical evaluation

Patients were routinely evaluated at 2nd week, 1st, 3rd, 6th and 12th months after surgery. Elbow joints were regularly evaluated with anteroposterior and lateral radiographs until bone

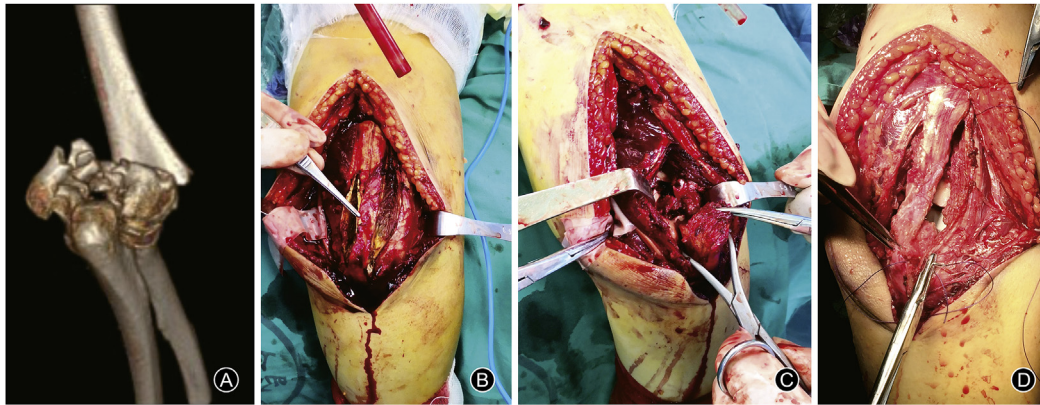


Fig. 1. One case of comminuted distal humeral fracture treated with total elbow arthroplasty. (A) A type C3 distal humerus fracture; (B) Medial short para-olecranon and triceps tendon incision and lateral long incision; (C) Fragments are too comminuted to be fixed; (D) Conversion to total elbow arthroplasty is then completed.

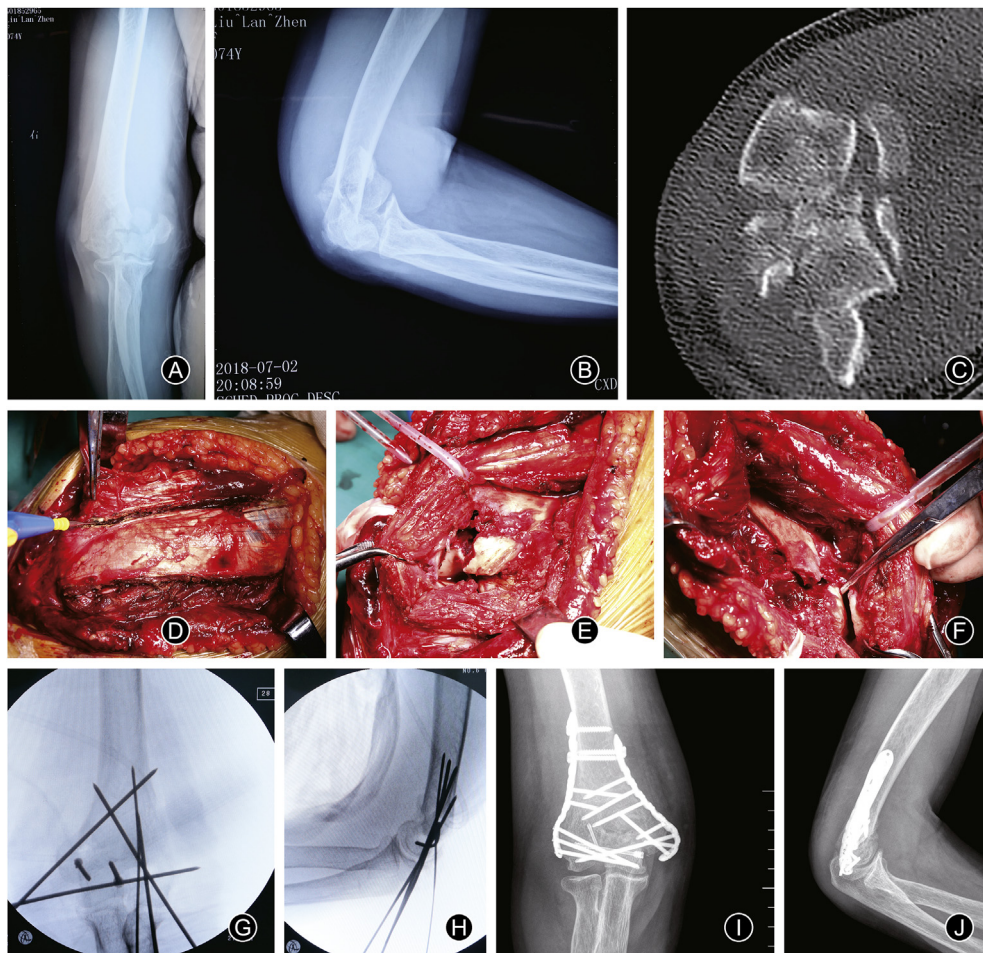


Fig. 2. Imaging and intraoperative findings of one 62-year-old female with type C3 distal humerus fracture. (A, B and C) Radiograph and CT scan displayed a comminuted distal humeral fracture; (D) Medial aponeurosis can be stripped from olecranon to become a larger medial window; (E) Surgical field of view from lateral window of BTT approach; (F) Surgical field of view from medial window of BTT approach; (G and H) distal humeral fracture was temporarily fixed with Kirschner wires and identified by AP and lateral view by fluoroscopy; (I and J) Postoperative radiography showed good reduction and rigid fixation.

union was observed. Then strength of the elbow extension was evaluated via manual muscle testing (MMT), which was graded 0 to 5 by performing the resisted extension in a 90° position flexion with the forearm in a neutral position.¹³ Function evaluation at the final follow-up was completed by measuring the

elbow joint range of motion. The functional evaluation was used the Mayo elbow function score (MEPS), which was usually obtained at the 6th and 12th month or at the last follow-up. Operation time, complications and particularly infections were recorded from the medical data.



Fig. 3. Fifteen months after the operation, patient is satisfied with her elbow function.

Statistical analysis

Medical records, elbow range of motion, triceps extension strength and MEPS scores between the two groups were compared using the two tailed Student's *t*-test. All data were presented as mean ± standard deviation. Normality tests were performed to conform the approximate normal distribution of the data. The categorical outcomes of the two groups were checked by the Chi-square test. A *p* value < 0.05 was considered statistically significant (SPSS statistics 20.0, USA).

Results

During the study period, 28 patients were treated with BTT approach and 27 with OO operated by 3 senior surgeons (1 professor and 2 associated professors) at Shanghai 6th People's Hospital (Level I trauma center), altogether 55 participants, met the criteria, with the average age of 52.7 years (range 26–81 years). The average age in BTT group was (54.1 ± 14.1) years and in OO group was (51.4 ± 14.4) years. In BTT group, there were 6 cases with type C1 (21.4%), 8 with type C2 (28.6%) and 14 with type C3 (50.0%). In OO group, there were 4 cases with type C1 (14.8%), 8 with type C2 (9.6%), and 15 with type C3 (55.5%). The average duration between initial injury and surgical treatment was 3.0 days (range 2–9 days) in BTT group and 2.9 days (range 2–7 days) in OO group. Patients

Table 1 Patient demographics in OO group and BTT group.

Demographics	OO group	BTT group	<i>p</i> value
Age (years)	51.4 ± 14.4	54.1 ± 14.1	0.481
Gender (male/female)	11/16	11/17	0.912
Duration (days)	2.9 (range, 2–7)	3.0 (range, 2–9)	0.212
Fracture type (C1/C2/C3)	4/8/15	6/8/14	0.812
Follow-up (months)	15.6 (range, 10–24)	15.9 (range, 6–30)	0.859
Operation time (mins)	139.8 ± 37.3	123.2 ± 39.1	0.113
Parallel/perpendicular (<i>n</i>)	12/15	14/11	0.405

OO: olecranon osteotomy; BTT: bilateral triceps tendon.

had been followed up for a mean of 15.9 months (range 6–36 months) in BTT group and 15.6 months (range 6–30 months) in OO group. Two open fracture classified Gustilo I was present one case in each group (Table 1).¹⁴ Fracture union was conformed in all cases by radiograph evidence, with an average time of 12.2 weeks (range 6–16 weeks) in both groups. Operation time was averaged 123.2 min and 139.8 min, respectively in BTT group and OO group. The average arc of elbow motion (flexion/extension) at the most recent postoperative evaluation was 104.8° (range 30°–145°) in BTT group and 109.6° (range 45°–145°) in OO group. There was no significant difference in arc of elbow motion, flexion, extension, pronation and supination. Most of patients achieved an excellent or

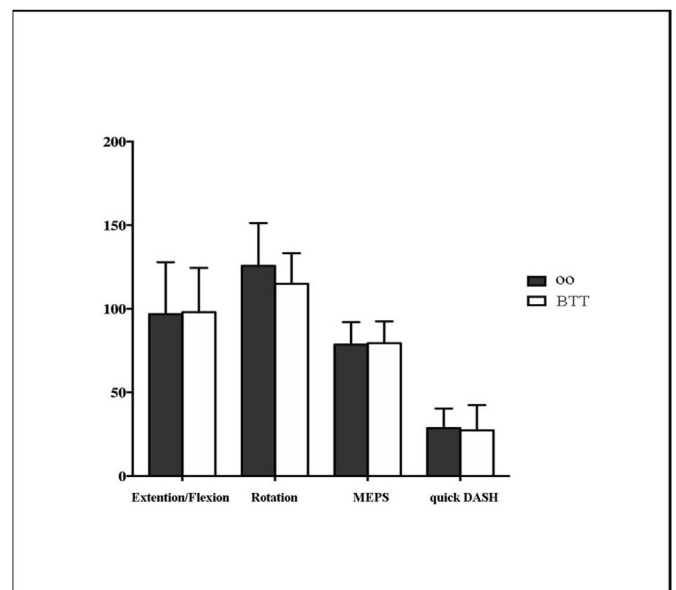


Fig. 4. Result of sub-group of olecranon osteotomy and bilateral triceps tendon with patients' age >60 years.

Table 2
Results of patient treated by OO and BTT approach.

Results	OO	BTT approach	<i>p</i> value
Range of motion (°)	109.6 ± 26.6	104.8 ± 27.0	0.509
Flexion (°)	125.4 ± 14.9	122.4 ± 14.1	0.450
Extension (°)	15.0 ± 16.9	17.6 ± 16.3	0.568
Rotation (°)	131.7 ± 24.0	136.3 ± 28.4	0.522
Pronation (°)	66.5 ± 12.1	68.9 ± 14.2	0.494
Supination (°)	65.2 ± 12.4	67.3 ± 14.5	0.560
MEPS	85.2 ± 13.3	83.2 ± 11.5	0.558
QuickDash	19.6 ± 15.1	22.5 ± 12.9	0.454
MMT	5 (range, 4–5)	5 (range, 4–5)	0.763
Severe complications (<i>n</i>)	5	6	0.787
Reoperation (<i>n</i>)	2	2	0.999

OO: olecranon osteotomy; BTT: bilateral triceps tendon; MEPS: Mayo elbow performance score; MMT: manual muscle testing.

good result of MEPS in both groups without statistical difference. Triceps MMT had no significant difference in two groups (Fig. 4 and Table 2), and similar results were also observed in sub-groups (age >60 years).

Three cases with type C3 fractures were converted to treat with TEA during the operation due to comminuted fragments and severe osteoporosis, which were impossible to acquire ideal fixation and not due to the poor surgical field of view. Only 1 case in BTT group was converted to using OO for increasing the articular surface exposure.

No infection was found in this case series. Fixation failure was not observed in any case in OO group. In BTT group, 1 case of the elbow joint internal fixation gradually protruded, with moderate pain and limited range of motion. The plate screw needed to be removed. One patient in each group had symptom of postoperative arthritis. Two patients in BTT group and 1 in OO group showed ulnar nerve paresthesia, which was recovered spontaneously within 12 weeks postoperation. One patient in BTT and OO groups, respectively suffered severe elbow stiffness and the flexion-extension arc was no more than 50°, which could not be resolved with physical therapy, so release operation was performed. One patient in OO group complained of persistent skin irritation due to the prominent part of Kirschner wires at the end of tension band. One patient in each group had heterotopic ossification around the elbow (Table 2).

Discussion

Stable fixation of comminuted articular fractures is essential for early unrestricted range of motion of the elbow joint.¹⁵ Recent data suggested that TEA may be an effective alteration method and result in acceptable outcome for complex distal humeral fracture in old patients.^{16,17} TEA for the treatment of comminuted intra-articular fractures resulted in more predictable and improved 2-year functional outcomes compared with open reduction and internal fixation (ORIF).¹⁸ Therefore, we should pay attention to the choice of surgical method during surgery for the patient with severe comminuted fractures or osteoporosis. We still look forward to a suitable approach, which can not only provide a good surgical field of view to repair complex distal humeral fractures, but also can be easily converted to TEA or OO approaches to obtain a full vision.

Our results showed that BTT approach is not only suitable for ORIF of type C1 and C2 fractures, but most type C3 fractures can also be reliably reduced and fixed. To eliminate triceps tension and expose more articular surface, only 1 case converted to choose OO. The cases converted to TEA presented with rapid rehabilitation and good function without any complications. In this study, BTT approach can provide a larger area of surgical view compared with

triceps spare and triceps splitting approaches, but a smaller area of surgical view than with OO. Although BTT approach cannot provide the largest articular visualization among those approaches, it has several advantages. First, the triceps remain intact, which allows the active and passive range of motion. Second, BTT approach adds a middle surgical window that can also be integrated into a larger medial window with the distal stripping aponeurosis of the medial olecranon. Third, BTT approach decreases triceps tension as compared with the triceps sparing approach by the reflection of the medial part of the triceps, which is beneficial for reduction and fixation. Fourth, BTT approach prevents the potential complications of OO. Fifth, if we need more sufficient exposure of intraarticular areas, BTT approach can be converted to OO after re-suturing the medial split triceps tendon. Finally, this approach can safely be converted to TEA, if distal humerus fractures are too comminuted or the patient has severe osteoporosis.

Comparing with triceps sparing or triceps reflecting approaches, OO could provide more articular surface exposure that was 57% in cadaver model.^{3,4} Even some authors think that OO can produce better functional outcomes than triceps lifting approach, because it provides more control over the elbow joint and had a better vision.¹⁹ However, young patients were very satisfied with these results. Age may also play an important role in decision to choose the optimal approach, though there are still controversial on this point. In report of Zhang et al.,²⁰ triceps sparing approach instead of OO would lead to restore better functional outcomes of elbow.²¹ Furthermore, the retrospective study comparing triceps splitting approach and OO has not shown any significant difference in terms of functional outcomes.²² Olecranon fixation with a plate after OO is one significant risk factor for major wound complications.²³ One of more important factors, as we think, the triceps sparing approach can avoid drawbacks related to OO. Hardware prominence and delayed union or nonunion are the major complications of OO.^{24,25} Such disadvantages will be significantly magnified in elderly patients. Postoperative recovery will be affected by such factors. The Bryan-Morrey approach or the triceps reflecting anconeus pedicle approach described by O'Driscoll can also provide a good exposure of the joint surface for reduction and ORIF even for comminuted fractures.²⁶ It has the same advantages as the BTT approach, including the surgical field of view. The triceps reflecting approach is a safe and valuable option for TEA and ORIF of distal intraarticular humerus fractures.^{27,28} But triceps tendon was stripped from dorsal olecranon and should be reattached on, of which the procedures will influence the rehabilitation. Patient's rehabilitation procedure may be similar to who have had an OO, in which active extension against gravity or resistance is avoided for approximately 3–6 weeks after fixation.^{28–30} Furthermore, both Bryan-Morrey approach or triceps-reflecting anconeus pedicle approach are not conveniently converted to OO.²⁴ Like triceps splitting or sparing approach, BTT maintains the triceps extension mechanism, which can not only reduce the risk of triceps dysfunction, but also allow early active range of motion exercises.⁹

One study showed that triceps dividing approach should not cause obvious muscle dysfunction, but the number of cases (9 cases) is too limited to strengthen the evidence that splitting triceps rather than OO for children should be recommended.³¹ MMT in cases with more than 60 years old had also similar results in our study.

Although blood perfusion to the central bend of triceps tendon may decrease, hemorrhage will be observed in the area after termination of inflatable tourniquet. Methylene blue injections confirmed that blood supply of the triceps tendon was through triceps muscle and not through lateral arm fascia.³² This is the reason to keep muscular and tendon together. The complications about the wounds were not presented in any cases between both

groups. Reduction and fixation by BTT approach of fractures in elderly patients with myasthenia is relatively easy. And male patient with bulky triceps or high muscular tension may influence exposure and may be more likely to be converted to OO group.

This study still has several limitations. First, this is a retrospective study without another triceps reflecting or sparing approach as the control group, and the number of cases is also limited. Further study is needed to design to evaluate the possible advantages of BTT over triceps spare or OO. Second, this article does not evaluate the soft tissue damage, nor analyze how it may affect the blood supply of the triceps tendon. Third, extension strength of the elbow was evaluated only by a rough method of qualitative MMT. More accurate measurement should be performed by quantitative methods, such as Cybex test.

Based on this case series, we found that BTT, especially for elderly patients, can be treated for C1, C2, and some C3 types of intra-articular fractures of the distal humerus. This approach can avoid the potential complications of OO, and can be safely and flexibly converted to OO. It can also be converted to TEA, if necessary.

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Nil.

Ethical statement

The above experiments were conducted in accordance with the regulations of the Ethics Committee of the Sixth People's Hospital Affiliated to Shanghai Jiao Tong University.

Declaration of competing interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Author contributions

Jian Ding: Conceptualization, methodology, writing-original draft. Wen-Jing Yin: Writing-review & editing, validation. Bao-Kun Zhang: Investigation, visualization. Xin-Gang Yu: Resources. Hong-Jiang Ruan: Data curation, formal analysis. Wei Zhang: Supervision, project administration and funding acquisition.

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