Comminuted Fracture of Elbow – Ostheosynthesis vs. Total Joint Replacement

Tříštivá zlomenina lokte – osteosyntéza vs. totální náhrada kloubu

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SUMMARY

Comminuted fractures of the elbow are very rare and in most cases very complex and the successful treatment can be a challenge for the treating surgeon. Due to the elbow joint's complex functional anatomy, the multi-fragmentary nature of many fractures and concomitant destabilizing associated injuries, comminuted fractures of the elbow still present a serious challenge for the orthopedic surgeon. Especially in more severe communicated injuries an osteosynthesis or endoprosthesis must be discussed with the patient. There is a lack of clear treatment recommendations based on solid evidence.

An overview of the literature including a treatment algorithm to guide decision making for the distal humeral fracture in the adults is presented and own results are analyzed.

Key words: comminuted fracture of elbow, total joint replacement of the elbow, elbow prosthesis, elbow arthroplasty, distal humeral fracture.

INTRODUCTION

The incidence of distal humeral fractures in adults is 5.7 per 100,000 per year (43). The bimodal distribution of these fractures has been clearly documented. One peak of these fractures is in young patients is during the second decade of life and they often involve high-energy trauma, such as motor vehicle accident, gunshot wound, or fall from height. The second group of distal humeral fractures peak in elderly women aged greater than 60 years and typically occur from a low-energy fall. The needs and expectations of these 2 different groups are quite dissimilar and must be considered in the treatment plan.

Comminuted fractures of the elbow are very rare and in most cases very complex and the successful treatment can be a challenge for the treating surgeon.

Due to the elbow joint's complex functional anatomy, the multi-fragmentary nature of many fractures and concomitant destabilizing associated injuries, comminuted fractures of the elbow still present a serious challenge for the orthopedic surgeon. Thorough knowledge of the elbow's anatomy and biomechanics is essential to analyze and understand the injury and plan its treatment. The aim of a differentiated therapy approach is to restore the joint's anatomy and kinetics, stable and painless joint function, and to avoid or at least delay posttraumatic joint changes. The degree of dislocation, stability of fragments, size and number of fractured joint surfaces and associated bony and ligamentous injuries (and the instability they incur) must be addressed in the therapy regimen. Especially in more severe communicated injuries an osteosynthesis or endoprosthesis must be discussed with the patient. There is a lack of clear treatment recommendations based on solid evidence.

Intra-articular fractures of the distal humerus and comminuted fractures of the elbow especially in the elderly pose a challenging therapeutic problem. The osteoporotic nature of the bone cannot always guarantee anatomic reduction and stable fixation of the fracture. As a result, prolonged immobilization is often applied leading to subsequent joint stiffness and impaired elbow function. Moreover the corresponding incidence of non-union, malunion, hardware failure, repeated surgical intervention, posttraumatic osteoarthritis and unsatisfactory outcome may raise up to 20% of cases (24).

Since Cobb and Morrey (17) published their landmark paper on the use of total arthroplasty for distal humeral fractures, it has become accepted that this technique is a treatment option for these injuries. Their paper advised that in elderly patients who had sustained comminuted distal humeral fractures, total elbow arthroplasty could be expected to give good clinical results. However, their study population included 48% of patients with rheumatoid arthritis, and, as such, this group might be expected to benefit from this procedure.

Elbow arthroplasties recently have undergone an evolution in the last years because of better anatomical and biomechanical understanding, continuous development of biomaterials, continuous improvement of operative techniques and better definition of the surgical indications. More extensive knowledge of anatomy and biomechanics

has enabled improvement of the prosthetic design and more adherent reproduction of the elbow kinematic. There has been an increase in the survival of the implants as a result of the use of more biocompatible and wear-resistant materials, and the improvement of cementing techniques. The advent of surgical approaches that are less harmful for the extensor apparatus, the availability of better instrumentation and the more accurate definition of the indications and contraindications for surgery are among the factors that have considerably contributed to increase the quality of the clinical results and reduce the complications (14, 21). With the expected rise in the elderly population, it is estimated that there will be a significant increase in the number of distal humeral fractures by 2030. There was a 2-fold increase in Finish women aged greater than 60 years from 1979 to 1995 in distal humeral fractures and a 9-fold increase in distal humeral fractures for woman aged greater than 80 years (22). The frequency of patients with comminuted type C distal humeral fractures will increase in the future. If these patients are to be well managed, early operative treatment is essential, thus allowing rapid rehabilitation and a return of functional elbow movement.

ORIF

Decision regarding ORIF of the distal humeral fracture will be dictated by the fracture pattern and comminution. ORIF should be considered in all patients who are candidate for surgery and in whom stable fixation of the bone can be obtained. Small articular fragments of the distal humerus are often salvageable and have a surprisingly low incidence of avascular necrosis after stable fixation (16).

Bi-columnar stabilization of the distal humerus should be achieved, either 90°–90° orthogonal plate configuration or the parallel plate technique. The addition of a third plate to the ORIF may even be considered for comminution of the posterior and lateral column or for fixation of fragments in the coronal plane for highly unstable fractures (9). If adequate stability cannot be obtained with fixation, application of an external fixator to the elbow can unload and protect questionable fixation, and upgrade the fixation to allow for postoperative range of motion (42). Elderly patients with distal humerus fractures have also been treated with a ring fixator with satisfactory results (32). The best plate construct, whether orthogonal plates (90°–90°) or parallel plates (medial and lateral) is discussed controversy in the literature (7, 13, 23).

Stoffel et al. (23) performed a biomechanical study comparing the stability of pre-contoured perpendicular and parallel plating systems with locking screws. Elderly female cadaveric humeral specimens were confirmed to have osteoporosis and then divided into perpendicular plating and parallel plating groups. A 10mm comminuted zone was simulated above the olecranon fossa before plating. Biomechanical testing showed that the parallel plating construct proved stiffer in compression and external rotation and showed significantly better resistance to plastic deformation with cyclic axial loading. Park et al. (31) studied the 3D osseous micro-architecture of the distal humerus, finding the weakest trabecular bone in the posterolateral distal condyle. They concluded that parallel plate fixation along the ridges may have an advantage over perpendicular plating because of better cortical and trabecular bone than for the posterolateral surface of the humerus. These recent biomechanical and micro-architecture studies suggest parallel plating superior to perpendicular plating.

Sanchez-Sotelo et al. (41) showed that stabile fixation and high rate of union can be achieved with parallel plating in challenging AO type C3 distal humeral fractures using a principle-based technique that maximizes fixation of screws into the distal fragments through the parallel plates. O Driscoll (30) enumerated the "rules" for bi-columnar fixation of the distal humerus when using parallel plates. This principled application of internal fixation maximizes the "arch" configuration of the distal humerus, often likened to a spool held by 2 fingers. According to his principles:

1 – every screw in a distal fragment should pass through a plate,
2 – every screw should engage a fragment on the opposite side that is also fixed to a plate,
3 – as many screws as possible should be placed into the distal fragment,
4 – each screw should be as long as possible,
5 – each screw should engage as many articular fragments as possible,
6 – the screws in the distal fragment should lock together by interdigitation creating a fixed angle structure,
7 – the plates should be applied such that compression is achieved at the supracondylar level for both columns,
8 – the plates must be strong enough and stiff enough to resist breaking or bending before union occurs at the supracondylar level.

Applying these principles, Sanchez-Sotelo et al. reported no hardware failures or fracture displacement in a series of 34 elbows. Union was achieved in all but one elbow. Five elbows required further surgery for stiffness.

In non-unions of distal humerus in younger patients after ORIF, repeat ORIF, bone grafting, and aggressive contracture release have been shown to be successful (15, 37).

Contracture in a healed distal humeral facture can be addressed with joint release. Late ulnar nerve symptoms can be addresses with neurolysis and anterior transposition of the ulnar nerve (24).

Total elbow arthroplasty

Total elbow arthroplasty (TEA) includes ''linked'' (e.g. Coonrad-Morrey-Zimmer; GSB III-Zimmer; Discovery-Biomet) and ''unlinked'' (e.g. Capitellocondylar-Johnson & Johnson Orthopaedics Inc; Souter-Strathclyde-Stryker; Howmedica Osteonics; iBP-Biomet, Kudo-Biomet) implants. The main difference is the presence (linked) or absence (unlinked) of a hinge between the humeral and ulnar components. Recently, ''linkable'' (also called ''convertible'' or ''combined'') implants (e.g. Latitude-Tornier, Acclaim-DePuy Ortho-

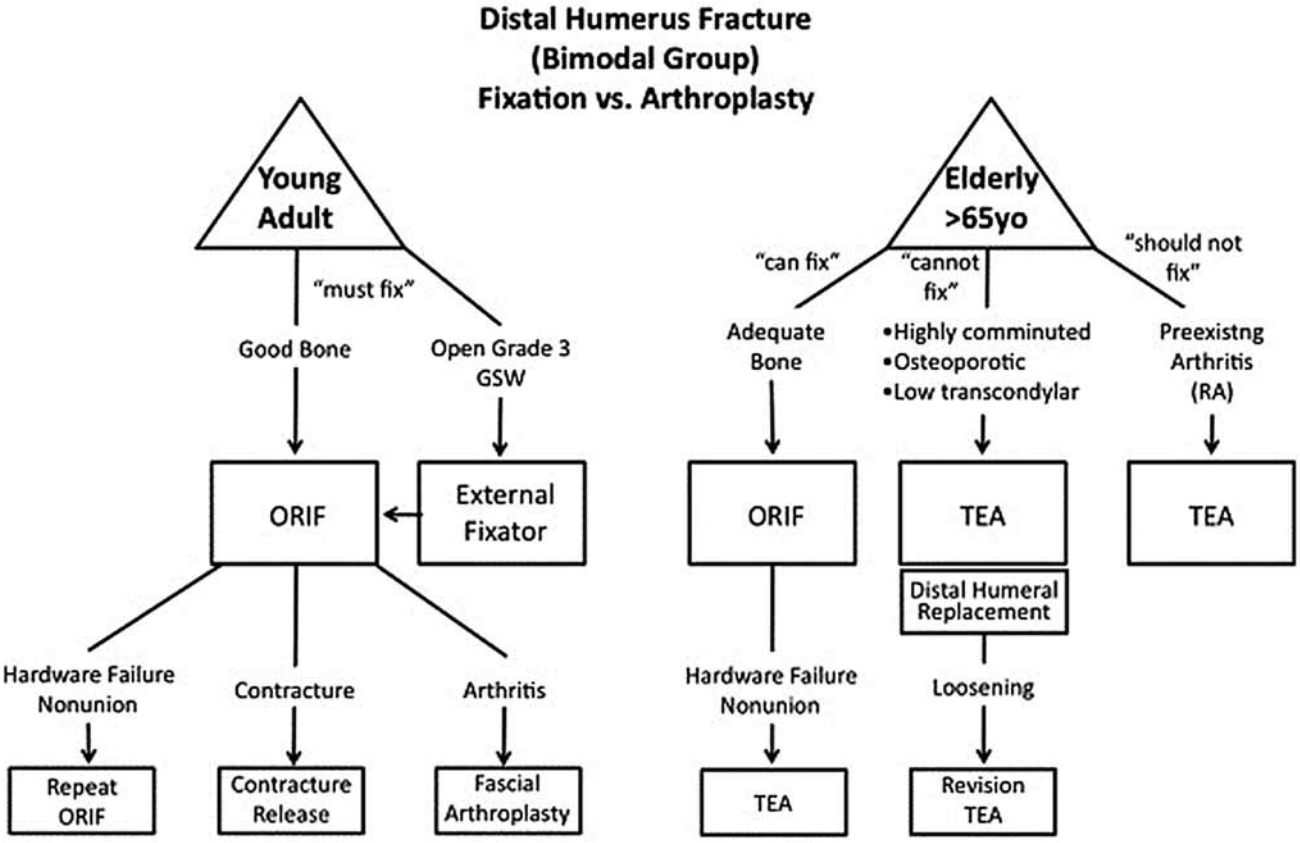

Fig. 1. Treatment algorithm to guide decision making for the distal humeral fracture in the adult (28).

paedics Inc.) have been introduced. These are modular prostheses that can be converted from unlinked to linked in the presence of intraoperative or postoperative instability. This conversion can be carried out by replacing the hinge only, thus leaving the ulnar and humeral components in place. Furthermore, the Latitude convertible implant enables a humeral endoprosthesis to be transformed into a TEA without the need to revise the previously implanted humeral component. In North America and Europe the use of linked prostheses greatly increased, to the detriment of unlinked implants, because of the lack of a clear-cut evidence on the ability of unlinked implants to save bone stock and increase the survival of the prosthesis (5, 40)

The presence or absence of the hinge should be completely differentiated from the degree of ''constraint'', which is a biomechanical feature of the implant. The constraint is the ability of the articular bone components to resist the forces of dislocation and is strictly dependent on both the geometry of the prosthetic components and their interaction with the elbow dynamic and static stabilizers. The degree of constraint (minimally constrained, semi-constrained, and constrained) varies in different prosthetic implants and is unrelated to the type of hinge (unlinked or linked) or their ''anatomical conformity'', which is the morphologic resemblance of the prosthesis to the normal joint anatomy. By contrast, the ''constraint'' degree can be determined only by complex bio-mechanical studies; in fact some unlinked implants were found to have a higher constraint degree than linked implants (19).

All commercially-available linked TEA prostheses are semi-constrained, i.e., they have a sloppy hinge that allows slight rotational (about 5°–7°) and valgus-varus movements (about 5°–10°) between the humeral and ulnar components. The introduction of the sloppy hinge greatly modified TEA survival because it reduces the stresses at the implant-bone-cement interface. This decreases the rate of aseptic mobilizations/movements and periprosthetic fractures occurring with the fixed-hinge implants (8).

Another variation in the prosthetic design that contributed to the increase in implant survival was the introduction of the anterior flange that allowed torsional and posteriorly-directed stresses to be contrasted, with resultant decrease in the risk of aseptic mobilizations/movements (34).

Absolute or relative contraindications include active or recent infections, open fractures, non-painful elbow ankylosis in patients with low functional demand, paralysis of arm muscles (flexors in particular), severe functional impairment of the hand, working activities entailing lifting or carrying heavy weights, previous arthrodesis, poor quality of elbow skin and last, but not least, poor patient compliance and neuropsychiatric disorders.

The results of linked TEA for distal humeral fractures are very encouraging (1, 2, 10-12, 17, 18, 24, 27, 33, 35). Treatment using total elbow arthroplasty for com-

minuted distal humeral fractures in the elderly was first proposed by Cobb and Morey 1997 (4). At mean follow-up of 3.3 years, a mixed population of rheumatoid and non-rheumatoid patients achieved excellent and good Mayo elbow performance scores.

The 186 patients with a mean age of 76 years (69–85 years) who are included in the 11 reports had an average MEPS of 92 points (85–95) at 18 months to 7 years follow-up. The range of motion (ROM) in extension–flexion was 24–127°, and the range of pronation–supination, in the studies in which it is reported, was 61–90° for pronation and 60–90° for supination. A total of 10 implant revisions (5%) were conducted in the 11 studies because of traumatic periprosthetic fractures (three cases), prosthetic stem fractures (two cases), aseptic loosening (three cases) or septic loosening (two cases). The most common complication was heterotopic ossification (7%), which led to severe stiffness that required surgical release in only one case. Additional complications were ulnar nerve neuropathy (6%), which required neurolysis and nerve transposition in one patient, wound dehiscence (4%), superficial infection (3%) and algodystrophy (2%). The rate of reoperations excluding TEA revision was 17%. In 22 cases (12%), non-progressive periprosthetic radiolucencies were detected, most of which were already present on the first postoperative radiographs. Eight (4%) progressive radiolucencies were also noted that did not require revision. The clinical relevance of radiolucencies is unclear because not all authors indicated their location, classification and possible association with pain. A prospective randomized, multicenter study (Level-II) compared the results obtained with ORIF or Coonrad-Morrey linked TEA in 40 patients older than 65 years who had intra-articular comminuted fracture of the distal humerus (27).

At 2-year follow-up, the authors found better results (MEPS and DASH) in the group treated with TEA. In this study, an intraoperative conversion from osteosynthesis to arthroplasty was performed in 25% of cases because it was technically impossible to perform the synthesis. Prasad et al. compared primary TEA with TEA implanted after failure of osteosynthesis or conservative management (33): they reported excellent or good results in 85% of patients in the former group and 79% in the latter group, the difference being not significant. There was a higher rate of complications (infections, ulnar nerve lesions and early implant failures) and greater difficulties in carrying out TEA in the group with TEA implanted after failure of osteosynthesis or conservative management compared with the primary TEA group.

Fig. 2. Distal humerus fracture AO Type 13-C3.1 (a, b) treated with a Coonrad-Morrey prosthesis (c, d).

Fig. 3. Non-union after ORIF of a pathological distal humerus fracture (a, b) sustained in 5/2012 was treated in 2/2015 with a Coonrad-Morrey prosthesis.

Two prospective randomized trials have recently analyzed superior results for replacement over open reduction and internal fixation (ORIF) for unstable complex fractures (3, 39), with several studies finding ORIF to be associatedwith increased of early failure and non--union and one study determining three fracture fragments as the cutoff point for progressing to replacement (6, 20, 25, 38).

Most of the complications which are associated with TEA are not specific to the arthoplasty and can occur with other elbow procedures, including ORIF. Perioperative medical complications include myocardial infarction, stroke, and pulmonary embolus (4, 12). Complications related to the procedure include wound problem, superficial and deep infection, ulnar nerve symptoms, reflex sympathetic dystrophy, stiffness, and heterotopic ossification (4, 18, 27). Complications related to the implant include component fracture or uncoupling, periprosthetic fracture, bushing wear, and aseptic or septic loosening (10, 18). Comlications more specific to hemiarthroplasty include instability either from an improperly balanced prosthesis or an unrecognized injury, symptomatic hardware – particulary from the olecranon osteotomy, non-union of the olecranon osteotomy, and arthrosis of the sigmoid notch.

Mehlhoff et al. (28) suggested the treatment algorithm to guide decision making for the distal humeral fracture in the adult. The bimodal groups are separated by age and expected bone quality (Fig. 1).

Retrospective analysis

A retrospective, radiographic and clinical review of the available data of implanted elbow prothesis in our clinic revealed 11 patients from 4/2003 to 2/2016. Follow-up data were available in 9 cases, 7 female and 2 male patients. In 8 cases consequences of a trauma made the implantation necessary and in one case a metastasis of the distal humerus was the indication for total joint replacement. The mean age was 66.3 years (±11.9 years) and clinical investigation was performed on average 34 months (±42 months) after implantation of the prosthesis.

The average movement was the following:

Extension	24° ± 9°
Flexion	122° ± 23°
Range of motion (Extension / Flexion)	98° ± 28°
Pronation	84° ± 5
Supination	76° ± 27
Range of motion (Pro- / Supination)	151° ± 30°

The mean visual analog score (36) was 1.2 ± 2.3 points and presented therefore only mild pain daily life. Five patients did not have any pain in the elbow in daily life.

The functional outcome was graded from excellent to poor according to the Linscheid-Wheeler score (26). 4 patients had an excellent score, 2 patients a good and 2 patients a fair outcome by using the score.

Moreover the score of Morrey (29) was used in the clinical investigation. 5 patients had a good and 4 patients had a fair outcome.

Only one patient showed relevant heterotopic ossification. Clinical evaluation were performed in cases:

Case 1

59-year-old female patient fall on the elbow suffering a distal humerus fracture (AO Type 13-C3.1) and was treated in 8/2014 with a Coonrad-Morrey prosthesis.

In the one year clinical follow-up she had no pain and the following range of motion, extension/flexion 0°–30°–135 °, free pro-/ supination (Fig. 2).

Case 2

61-year-old female patients with a nonunion after ORIF of a pathological (breast cancer) distal humerus fracture sustained in 5/2012 was treated in 2/2015 with a Coonrad-Morrey prosthesis.

In the two months clinical follow-up she had the following range of motion: extension/flexion 0°–30°–95°, pro-/ supination 80°–0°–80° (Fig. 3).

CONCLUSION

Treatment decision for AO Type C distal humeral fractures will be affected by the surgeon s training, surgeon s bias, and patient s demand.

The current literature has provided support and indications for primary elbow arthroplasty for acute comminuted and distal humeral fractures. Indications for TEA include patient's age above 65 years, significant underlying arthrosis, such as osteoarthritis or rheumatoid arthritis, inability to obtain rigid internal fixation that would allow early motion, and severely comminuted intra-articular fractures (AO/OTA Type C3). The age cutoff is somewhat subjective and other factors should be considered in addition to other factors such as the patient s physiological age, compliance, activity level, and hand dominance.

The indications for hemiarthroplasty are not clearly defined. Nevertheless, it can be considered as an option in younger more active patients without preexisting arthritis if the distal humeral fracture cannot be adequately treated with ORIF. However-, it is important to remember that the ability to restore a stable, balanced articulation is a prerequisite for this procedure. Therefore, the medial and lateral columns, as well as the medial and lateral ligaments must be intact or reconstructable.

Contraindications for arthroplasty include anything that would compromise wound healing or pose significant risk of infections, such as an open fracture, inadequate soft tissue coverage, local or distant infections, or an immunocompromised patient. Nevertheless, arthroplasty may be still be considered in these situations, perhaps as a delayed procedure, if ORIF is not an option or poses more risk to the patient.

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