Case report

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THE ROLE OF UNILATERAL EXTERNAL FIXATION IN THE TREATMENT OF CLOSED HUMERAL SHAFT FRACTURES EXTENDED PROXIMALLY OR DISTALLY

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Closed fractures of the humeral shaft gain their specific characteristics when extending into the proximal or distal region of the bone. The aim of this work was to analyze the current role of external fixation in the treatment of these fractures, and to present corresponding cases. In this study, there was performed an analysis of the treatment using Mitkovic type external fixator in patients with a humeral shaft fracture extending into the region of greater and lesser tubercle or into the supracondylar region. The range of motion in the shoulder or elbow joint (depending on the direction of the fracture extension from the shaft) was measured in the first week after surgery, on the day of pins removal, and 3 years after external fixation. A comparative analysis with data from the literature, regarding both internal and external fixation of the humerus, was also performed. In the period next after surgery, all patients had used the operated arm for independent light daily activities. One patient had pin tract infection, what was successfully treated by more frequent pin dressing and by oral antibiotic therapy. There were no mechanical or neurovascular complications or problems with fracture healing. All patients returned to

their full daily activities, with full range of motion. Unilateral external fixation still has its significance in the treatment of closed humeral shaft fractures with proximal or distal extension, taking into account advantages such as: rotator cuff preserving, small surgical incisions, sufficient stability, outpatient controlled dynamization, and absence of the need for implant removal surgery.

Keywords: external fixation, humerus, dynamization, stability

Prikaz slučaja

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ULOGA UNILATERALNE SPOLJNE FIKSACIJE U LEČENJU ZATVORENIH PRELOMA DIJAFIZE HUMERUSA SA PROKSIMALNIM ILI DISTALNIM ŠIRENJEM

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Zatvoreni prelomi dijafize humerusa koji se šire u proksimalni ili distalni deo kosti su praćeni odredjenim specifičnostima. Uz prikaz slučajeva, cilj ovog rada je bilo sagledavanje trenutne uloge spoljne fiksacije u lečenju navedenih preloma. U ovoj studiji je analizirano lečenje pacijenata sa prelomom dijafize humerusa koji se širi u regiju velikog i malog tuberkuluma ili u suprakondilarnu regiju humerusa, primenom spoljnog fiksatora po Mitkoviću. Opseg pokreta u ramenom ili lakatnom zglobu (u zavisnosti od pravca širenja preloma iz dijafize) meren je u prvoj nedelji nakon operacije, na dan uklanjanja klinova i 3 godine nakon spoljne fiksacije. Izvršena je i komparativna analiza sa podacima iz literature, koji se odnose kako na unutrašnju, tako i na spoljnu fiksaciju preloma humerusa. U neposrednom postoperativnom periodu, svi pacijenti su se služili operisanom rukom za samostalno obavljanje lakših svakodnevnih aktivnosti. Kod jednog pacijenta je došlo infekcije oko klina, koja je uspešno lečena češćim previjanjem i oralnom antibiotskom terapijom. Nije bilo mehaničkih, niti neurovaskularnih komplikacija, kao ni problema sa zarastanjem preloma. Svi pacijenti su se vratili

svakodnevnim aktivnostima u punom obimu, sa potpunim opsegom pokreta. Unilateralna spoljna fiksacija i dalje ima značajno mesto u lečenju zatvorenih preloma dijafize humerusa sa proksimalnim ili distalnim širenjem, uzimajući u obzir prednosti, kao što su: očuvanje rotatorne manžetne, mali hirurški rezovi, stabilnost fiksacije, ambulantno kontrolisana dinamizacija i odsustvo potrebe za hirurškim uklanjanjem fiksacionog materijala.

Ključne reči: spoljna fiksacija, humerus, dinamizacija, stabilnost

Introduction

Surgical treatment of humeral shaft fractures is being mostly performed by internal fixation today, whereas open reduction and internal fixation (ORIF) by plates is considered as the gold standard (1-5). Intramedullary (IM) fixation, also often used in the treatment of these fractures, is followed by lower risk of iatrogenic neurovascular injury, but some studies had confirmed generally lower functional results in relation to ORIF (2, 4). Such a widespread statement can lead to the question – where is the role of external fixation in humeral shaft fractures treatment today? In addition to its use for primary fixation of an open fracture, or as a damage control in polytrauma, indications for external fixation (EF) of humeral shaft fractures include: delayed union or nonunion (the possibility of controlled dynamization to achieve the compression between bone fragments, thus to stimulate the bone healing), bilateral fracture (function of the arm during the period next after surgery could be expected as higher in EF than in internal fixation, due to the shorter surgical incisions and rotator-cuff preserving), and fractures with insufficient bone mass for stable internal fixation (6-8).

Internal fixation of an oblique and/or comminuted humeral shaft fracture with the extension proximally or distally could be more difficult. Performing ORIF in these fractures includes larger surgical approach, followed by increased risk of n. radialis lesion (2, 4, 9, 10). Intramedullary fixation of the fractures where the fracture line extends to the place of the proximal or distal locking screws, or close to its location, could result in insufficient stability of the fixation (11-14). Regarding these reasons, EF could also be considered as a method of choice in the fixation of these fractures. External fixation provides open reduction by less surgical incision, or even closed reduction of these fractures, decreasing the risk of iatrogenic n. radialis lesion. Also, EF of such fractures does not require incision through the rotator-cuff (being necessary in intramedullary fixation), preserving the shoulder function (6, 15, 16).

The aim of this paper was to analyze results and technique of unilateral external fixation in the treatment of humeral shaft fractures that extend proximally (into the region of humeral tuberosities) or distally (into supracondylar region). The purpose was also to present an original feature of Mitkovic type external fixator used – simultaneous providing of: freedom of orientation for each pin, using just one rod in the frame, freedom of orientation for the rod, and the dynamization feature.

Cases presentation

Three consecutive patients with a closed humeral shaft fracture extending next proximally (one patient) or next distally (two patients), treated by Mitkovic type unilateral external fixator, are being presented.

Surgical technique

All pins are set at beginning of the surgery, by free technique, without the need for any guidance. Four pins are most often being used – two in each of the most peripheral bone fragments. Although, more pins can be used if necessary. The frame of Mitkovic type external fixator is being attached after all pins setting. This frame contains of just 3 components: clamps, claps carriers, and the rod (Fig. 1). This high adjustable assembly provides using just one rod in the frame, with the freedom of the rod direction regardless of the pins position. The direction of the rod determines the direction of dynamization that can be subsequently performed by a temporarily unlocking of some clamp carriers. The purpose of the dynamization is to allow compression between fracture fragments, promoting bone healing. For these reasons, just the group of clamp carriers that belong to one of the bone fragments (it is mostly two clamp carriers) is being temporarily unlocked. It is recommended to be performed on the group of clamp carriers with the larger distance between. While these clamp carriers are being unlocked, the dynamization can be performed both by natural strength of the muscles and tendons, and by the pressure performing on the shoulder in direction to the elbow, while the elbow rests on the support. For the reasons of dynamization, it is suggested the rod to be in a convergency to the fracture line. If the rod were parallel to the fracture line, temporarily clamp carriers unlocking described above would lead to more shear and less compression in the fracture.

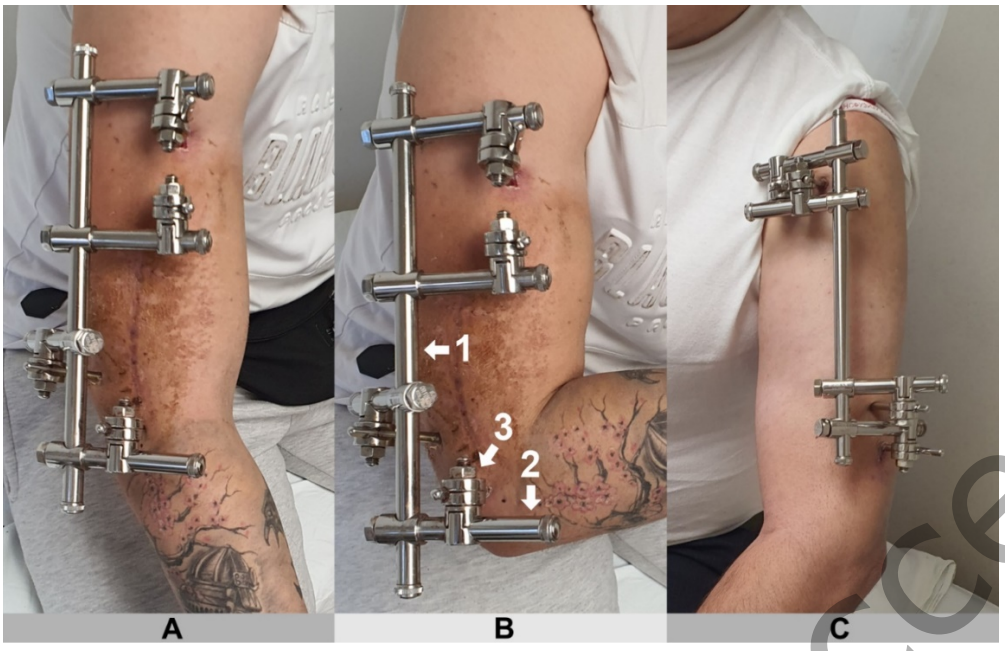

Figure 1. Clinical presence of pins configuration in the treatment of a humeral shaft fracture with distal extension (A – elbow extended; B – elbow flexed; Patient 2) and with proximal extension (C; Patient 3). Mitkovic type external fixator frame components: the rod (1), clamp carrier (2), and clamp (3).

Safe zones for pins insertion are different, depending on the upper arm level. For humeral shaft fractures, at least two pins are being screwed in the shaft from the lateral direction.

If the fracture extends proximally, then another at least two pins are being placed in the proximal humerus. Here should be paid attention to n. axillaris, located in the region between 5 cm and 7 cm distal to the acromion. Also, since the cortex is thinner and the bone is generally softer in the proximal humerus, it is recommended to check with intraoperative fluoroscopy whether these pins pass through the both cortices (except when the pin is directed towards the cartilage – then the tip of the pin should be at least 5 mm subchondrally). Sometimes, while screwing the pin into the proximal part of the humerus, a partially loose contact of the pin to the bone can be observed until the pin is being screwed into the other cortex.

If the humeral shaft fracture extends into the supracondylar region, a suitable place for the distal pins are the trochlea and the supracondylar region, avoiding the olecranon fossa. The bony mass in these areas provides a solid support for the pins. Lateral supracondylar ridge (crista supracondylaris lateralis) is considered a factor that can cause the local pin placement difficult. The edge of this narrow

ridge can easily cause slipping of the drill, thus the procedure must be repeated until enough opening is made in the bone. It is recommended to use a sleeve when drilling on or close posteriorly the lateral supracondylar ridge of the humerus, both to protect the local soft tissues and to have better control of the drill. When placing the pin in humeral trochlea, lateral and medial epicondyle of the humerus are used as the palpatory reference points, keeping in mind that the pin passes 5-10 mm anterior and distal to both epicondyles, to provide as more central position of the pin (Fig. 2).

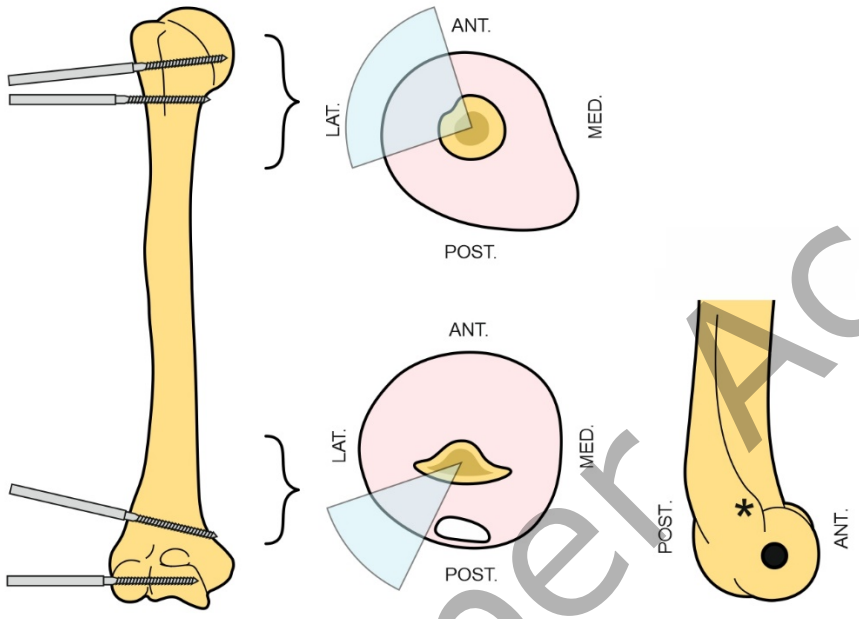

Figure 2. Schematic presentation of safe zones (blue circle slices in transverse views) for external fixator pins placement in proximal and distal humerus. The pin in the trochlea (black small circle) should be placed as centrally as possible, 5-10 mm anterior and inferior to both epicondyles (asterisk).

Case 1:

Male, 22 years old patient suffered a bilateral closed humeral shaft fracture extending distally into the supracondylar region, sustained in the car accident. Both fractures had a clinically acceptable initial position for non-operative treatment. Due to the bilateral presence, at least one fracture was desirable to be treated surgically, so the patient could use that arm more than the other arm non-surgically treated by a plaster splint. The right side fracture contained one free fragment, while the left

side fracture was without a comminution. To provide as less pain in operated arm during the period next after surgery, the left arm (without the comminution) was decided to be treated surgically, by closed reduction (to avoid surgical incisions as more as possible).

Intraoperative reduction of the left side humeral fracture was achieved using a traction performed by the assistant. There was no angulation. The contact surface between fracture fragments was 3/4 of the fracture line. A shortening of about 1 cm seemed acceptable. Due to the initial shortening, the dynamization was not performed in this patient after surgery. External fixator's frame was removed in 8 weeks after surgery, when the plaster splint on the right arm was removed too. Pins were removed in 9 weeks after surgery. Physical therapy started 3 weeks after pins removal.

This patient used his left arm for some light everyday activities (eating, personal hygiene, moving light objects) since the first day after surgery. There was some secretion around the most distal pin on 3 weeks after surgery (pin tract infection), and that was successfully treated by pin dressing twice a week for next 2 weeks and by 7 days of oral antibiotics (Ciprofloxacin). On the 6th day after surgery, active flexion in the left elbow was feasible in the range of 50-100°. On the day of pins removal, the range of elbow flexion was 25-120° on the left side and 25-110° on the right side. Three years after external fixation, the range of elbow flexion was 0-140° on the left side and 15-140° on the right side. This patient was fully back to the work, as a construction worker (Fig. 3).

Case 2:

Male, 23 years old patient suffered a closed right humeral fracture, by the fall at the same level while holding a load in the hands. It was a 2-parts spiral fracture in the humeral shaft extending into the supracondylar area. As in the Patient 1, intramedullary fixation was not considered here either, due to the too low position of the fracture. Performing ORIF would require longer surgical incision, increasing the risk of n. radialis lesion. The patient was muscular, thus the fixation with one plate would be considered insufficiently stable, and two plates would be desirable. For these reasons, it was decided to perform EF.

Intraoperative traction didn't give an acceptable fracture reduction, due to the muscle interposition in the fracture area. Therefore, an open reduction was performed throw the lateral incision of 8 cm length. At outpatient exams, once a week between 5 and 8 weeks after surgery, temporary

unlocking of two proximal clamp carriers was performed to stimulate the dynamization, i.e. fracture compression. External fixator's frame was removed 10 weeks after surgery. Pins were removed 11 weeks after surgery. On the patient's decision, physical therapy was not performed.

This patient independently used his right arm for light everyday activities already from the first day after surgery. On the 4th day after surgery, active flexion in the right elbow was feasible in the range of 30-110°. At the time of pins removal, the right elbow flexion was 10-125°. The patient's occupation was pizza-maker and waiter, and he fully returned to the work 1 month after pins removal, when he could perform full extension in the right elbow. Three weeks after external fixation, the range of flexion in the right elbow was 0-140°. There was no infection around the pins during the fixation in this patient (Figure 3).

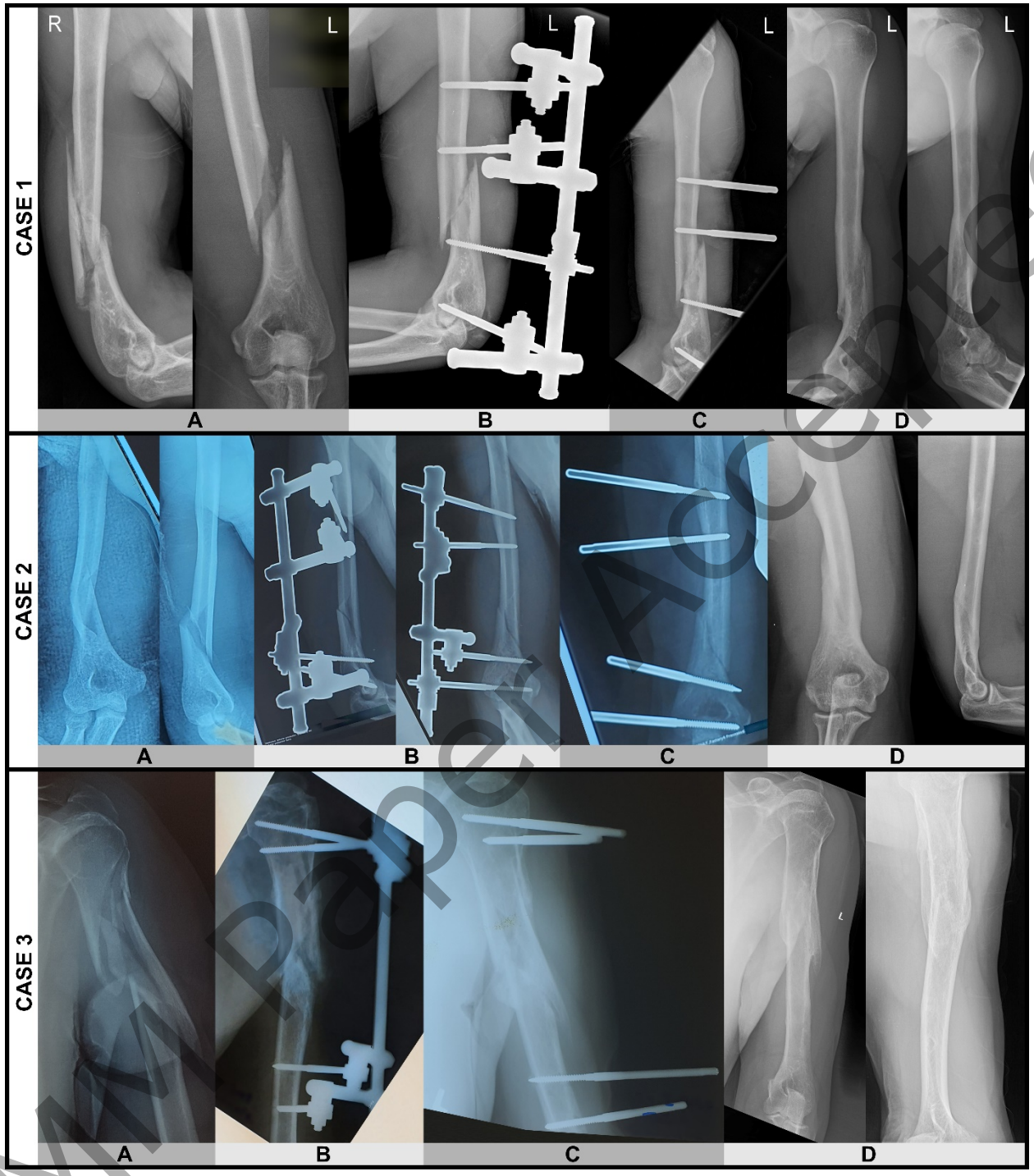

Figure 3. X-rays of the cases on the day of injury (A), about one week after surgery (B), on the day of pins removal (C), and three years after external fixation (D).

Case 3:

Male, 65 years old patient suffered the closed left humeral fracture by the fall at the same level. It was an oblique and comminuted fracture in the proximal humeral shaft, extending into the region of tubercles. Using ORIF in this patient would require long plate, followed by the need for longer incision and by higher risk of n. radialis lesion. Due to the fracture comminution extending into the tubercular region, the stability of proximal locking screws in intramedullary fixation was considered uncertain. For these reasons, it was decided to perform EF.

Intraoperative traction, performed by the assistant, provided clinically correct closed fracture reduction. At outpatient exams, once a week between 6 and 9 weeks after surgery, temporary unlocking of two distal clamp carriers was performed to stimulate the fracture dynamization. External fixator's frame was removed 11 weeks after surgery. Pins were removed 12 weeks after surgery. This patient decided on his own not to have physical therapy.

The patient successfully used his left arm for light everyday activities on the first day after surgery, without significant pains in the shoulder. On the 5th day after surgery, active flexion and abduction were feasible up to 90°. At the time of pins removal, the maximal active left shoulder flexion and abduction were feasible up to 110°. He was satisfied to return in hunting as a hobby at 2 months after pins removal. In this patient, there was not observed a pin tract infection during the fixation (Fig. 3).

Analyzing all three patients, the pins unscrewing was followed by a greater mechanical resistance for pins in the distal part of the humerus and in the shaft area, compared to the pins in the proximal part of the humerus. There were no neurovascular complications in any patient.

The study was performed in line with the Declaration of Helsinki and approved by the Ethics Board of the University Clinical Center Nis (Decision No. 29879).

Discussion

Closed humeral shaft fractures that are not part of polytrauma are today mostly treated by internal fixation. Unconformity for the patient and the risk for pin tract infection are considered the main

reason to avoid external fixation. However, some risks are specific for internal fixation of those fractures. Some studies comparing ORIF and IM fixation of humeral shaft fractures reported that ORIF was followed by a longer incision, higher risk of iatrogenic injury (especially n. radialis injury), more common infection, and more common reoperation, while IM fixation was followed by reduced shoulder range of motion, higher postoperative pain (especially in the shoulder), and higher risk of rotational malalignment (2, 4, 9, 17). In EF, length of the incision at the fracture site (if desired) is determined only by the need to perform open reduction. It can be considered that a shorter incision is required in EF comparing to ORIF, reducing the risk of open reduction associated complications (iatrogenic injuries, infection). The importance of the surgical incision length on n. radialis symptoms has been confirmed by lower prevalence of these symptoms in minimally invasive plate fixation (MIPO technique) compared to the more extensive surgical approach (18).

Min et al. have reported that the risk of n. radialis injury in humeral fracture EF is reduced if the distal pins are placed in the distal 15% of the humerus length (19). The technique described in our study provides the possibility the pins to be positioned in this part of the humerus.

Since EF of a humeral shaft fracture does not require an incision through the rotator cuff, higher function of the shoulder could be expected with EF, compared to IM fixation, even the pins are screwed in the proximal part of the humerus. This was confirmed by the shoulder functionality in the Patient 3.

In addition to rotator cuff damage, proximal nail protrusion and screw pullout could also be considered the causes of pain and shoulder ROM reduction in IM fixation of humeral shaft fractures (10, 14, 20). Sobel et al. reported the screw pullout in plate fixation of humerus was more common for non-locking screws, especially in the proximal humerus (21). Since the proximal screws in IM fixation do not have a locking contact with the nail stem, here could be considered the screw pullout in proximal humerus can be expected in IM fixation too. The pullout risk is avoided in EF, since there is a rigid contact of pins with the frame. Despite the cortex of the proximal humerus is thinner compared to the shaft, making the strength of the screw-bone contact weaker, some studies have confirmed that EF can provide sufficient stability in fractures involving the proximal part of the humerus (15, 16, 22).

Vishwanathan reported about higher risk of fixation failure in distal shaft and supracondylar humeral fractures using just one plate, and therefore suggested using two fixation plates (23). This confirms that high biomechanical forces exist in this region of the humerus (11). Since the frame of an unilateral external fixator is more massive than the plate, there can be considered the unilateral EF is

mechanically stronger than one plate. Here could also be mentioned that a smaller number of pins are used in EF compared to the number of screws used in ORIF by two-plates, thus the bone mass is being more preserved. Moreover, less periosteal damage is expected in EF in comparison to two-plates fixation. External fixator according to Mitkovic provides the possibility of both parallel and convergent pins orientation. Convergent orientation of the pins/screws provides a more balanced 3D stability of the fixation, corresponding more to the natural biomechanics of the bone, thus providing a less expected mechanical complications rate (24, 25). Such increased biomechanical stress in the distal part of the humeral diaphysis is a factor increasing the risk for local periprosthetic fracture occurrence after IM humeral fixation (12, 13). Since a unilateral external fixation does not include any IM component concentrating the load to the bone in the small distal contact surface, there can be considered that the fracture around implant-bone contact in the distal humeral shaft is expected to be less common in unilateral EF in relation to IM fixation.

The dynamization was not performed before 5 weeks (Patient 2) and 6 weeks (Patient 3) after surgery due to the time for soft callus mineralization (the mineralization starts at 2-4 weeks after fracture) (26). The intention was to start the dynamization only if the callus has a partially higher strength than at the very beginning of the fracture healing process, thus to reduce the risk of the fracture dislocation during the temporary unlocking of the clamp carriers. Taking into account that the humerus is not a load-bearing bone, dynamic fixation gains more significance in the fixation of humeral shaft fractures (7, 8, 27). Unlike plates, that do not provide the dynamization, and conventional IM nails, where the transition from initially rigid to postponed dynamic fixation can be achieved only by additional surgical intervention (interlocking screw removal), external fixation enables a delayed dynamization in a simple way, in outpatient conditions (7).

According to the literature, a gentle early rehabilitation can be performed in external fixation of the humerus, with recommendation for fractures extending into the proximal part of the humerus to be more gently. Since Daoub et al. reported that 14 weeks after the fracture are being considered the average healing time for humeral shaft fractures in external fixation. Therefore, even the physical therapy started in the third month after surgery in the Patient 1, a caution with the arm loading could be recommended during the first 3 months after surgery in a humeral shaft fracture external fixation. Our study confirmed that the position of unilateral external fixation pins in the humerus near the elbow or the shoulder joint do not compromise performing many light daily activities (hygiene, nutrition, etc.)

in the period next after surgery. Here was also confirmed that, although the pins pass through the region of the muscles acting in elbow or shoulder motions, the range of movements in these joints gradually increases during the period of external fixation.

Conclusion

Although ORIF and intramedullary fixation are being mostly used today, external fixation of closed humeral shaft fractures with proximal or distal extension still has its place in the treatment of these injuries. In addition to its disadvantages (discomfort for the patient during the fixation, the need for regular dressings for at least 2 months, the risk of infection around the pins), external fixation of such fractures has also its advantages, such as the possibility of closed or minimally opened reduction, a low risk of n. radialis lesion, preservation of the rotator cuff, no implant protrusion requiring surgical reintervention, and sufficient stability in humeral shaft fractures extending distally. The application of Mitkovic type unilateral external fixator has been confirmed as a simple surgical technique, with full freedom of orientation of just one rod used, regardless of pins orientation. Using this device provides a simply performable delayed dynamization in these fractures. Injured arm can be gently used next after surgery, with the start of more intensive physical therapy in the 3rd month postoperatively.

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