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Errors and complications with post-traumatic frontal deformities of the elbow joint corrected with supracondylar osteotomy with the Ilizarov apparatus

Yu.P. Soldatov✉, **A.N. Dyachkov**

Ilizarov National Medical Research Centre for Traumatology and Orthopedics, Kurgan, Russian Federation

Corresponding author: Yuri P. Soldatov, soldatov-up@mail.ru

Abstract

Introduction Transosseous osteosynthesis has the advantages of controllability, mobility and minimal invasiveness and is commonly used by trauma and orthopaedic surgeons for elbow deformity correction. There is a paucity of publications reporting errors and complications with external fixation devices used to restore the biomechanical axis of the upper limb.

The **objective** was to identify errors and complications in patients with post-traumatic coronal deformities of the elbow joint treated with the Ilizarov apparatus and to determine a rational algorithm for the prevention.

Material and methods The study included 68 patients with elbow deformities in the frontal plane. The patients age ranged from 4 to 56 years. The surgeries were performed between 1990 and 2024. Patients were divided into 2 groups: control and treatment. The control group included 41 patients who underwent correction surgery up to 2018. The limb was realigned either acutely or gradually post op through Ilizarov distraction produced on the concave side of the deformity. In order to prevent errors and complications, since 2018, patients with the condition have been treated according to a protocol developed to contain the sequence of intraoperative and postoperative manipulations taking into account time factors. These patients were included in the treatment group (n = 27).

Results Complications were identified in the limb biomechanics (residual deformity, disturbed limb axis); in the joint (contractures); in the bone (comminuted osteotomy, presence of teeth); in the bone regeneration (ischemic regenerate); in the nerves (short-term and long-term neuropathies of the radial and ulnar nerves).

Discussion The number of complications in patients of the treatment group was seven times less compared to literature data, while the total number of complications after supracondylar osteotomy of the humerus and Ilizarov fixation was 1.6 times lower. Review of errors and complications in the treatment of patients with post-traumatic frontal deformities of the elbow joint using supracondylar osteotomy and the Ilizarov fixation facilitated development of a rational algorithm for the correction.

Conclusion The limb axis can be realigned and biomechanics of the elbow joint restored with corrective supracondylar osteotomy of the humerus and manipulations with the Ilizarov apparatus. The algorithm developed for treatment of patients with elbow deformities suggested a strict sequence of actions with time factors, reducing errors and complications in the form of failures in performing osteotomy, residual deformity, poor regeneration, contractures and neuropathies by 6.3 times.

Keywords: elbow joint, deformity, varus, valgus, supracondylar osteotomy, transosseous osteosynthesis, Ilizarov apparatus, errors, complications

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INTRODUCTION

Upper limb injuries can lead to bone deformaties, joint contractures, ankylosis, elbow arthritis and can severely limit the mobility and quality of life [1]. A varus elbow is a common complication following distal humerus fractures in children [2, 3] and can lead to degenerative changes on the inner side of the joint including the medial condyle [4]. The deformity interferes with the limb axis with the direction of the force action of the triceps brachii muscle causing elbow instability, compression of the articular surfaces and osteoarthritis [4]. All this is the cause of chronic pain syndrome of the elbow joint and limitations of the function of the upper limb [5]. The growth zone of the humeral condyle does not remain neutral in transcondylar and supracondylar fractures causing formation of the elbow valgus deformity [6].

A prolonged existence of elbow deformity caused by a supracondylar humerus fracture, due to the disruption of the limb axis and displacement of the humeral condyle in the frontal plane can lead to a bayonet-shaped supracondylar deformity. The deformity is described as "supracondylar syndrome" in the literature [7].

Elimination of the acquired elbow deformities and rehabilitation is a huge problem [8]. Failures can be caused by insufficient rigidity of bone fixation after osteotomy and severely traumatic surgery (opening of the joint cavity, damage to the articular structures) [9].

Frontal deformities can be repaired with intra-articular and extra-articular corrective osteotomies to be used with identified location and degree of humerus deformity [10] including supracondylar [11, 12], transverse, wedge-shaped and dome-shaped types [13].

Bone fixation can be performed with skeletal traction or Kirschner wires ans cause contractures due to joint immobilization. Supracondylar osteotomy can be be fixed with external device using Shantz rods [14] or plating [15, 16].

Transosseous osteosynthesis method has the advantages of controllability, mobility and minimal invasiveness and is commonly used by trauma and orthopaedic surgeons for elbow deformity correction. However, there is a paucity of publications reporting errors and complications with external fixation devices used to restore the biomechanical axis of the upper limb.

The **objective** was to identify errors and complications in patients with post-traumatic coronal deformities of the elbow joint treated with the Ilizarov apparatus and to determine a rational algorithm for the prevention.

MATERIAL AND METHODS

This is a retrospective, cohort, continuous, single-center study. The statistical population is characterized by average values including arithmetic mean and standard deviation (Xi ± SD).

The study was performed in accordance with ethical principles for medical research involving human subjects stated in the Declaration of Helsinki developed by the World Medical Association. Written informed consent was obtained from all patients for publication of the findings without identifying details.

The study included 68 patients with posttraumatic frontal elbow deformities. The patients aged 4 to 56 years were surgically treated at 6 months to 15 years of injury in the years between 1990 and 2024. Elbow fractures had been repaired either conservatively or surgically at a local hospital. Conservative treatment included closed reduction and upper limb fixation with a plaster cast or skeletal traction. Surgical treatment included open reduction, fixation of the humerus with different metal constructs or the Ilizarov frame (Fig. 1).

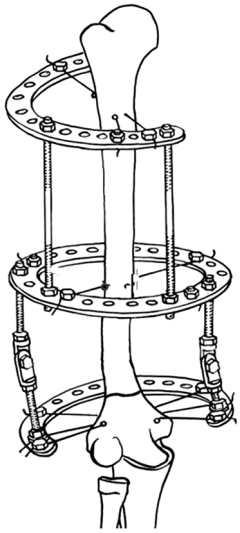

Fig. 1 Anteroposterior view of the Ilizarov frame used to correct elbow deformity in the frontal plane employing supracondylar osteotomy of the humerus (for example, to eliminate elbow varus deformity)

The participants were divided into two groups including controls and treatment cohort. The controls (n = 41) underwent surgical treatment up to 2018) with the limb axis being realigned acutely during the operation or gradually in the postoperative period by Ilizarov distraction on the concave side of the deformity. In order to prevent errors and complications, since 2018, patients with the condition have been treated according to a developed algorithm containing a sequence of manipulations to be performed intraoperatively and postoperatively and considering time factors. These patients were included in the treatment group (n = 27).

Algorithm for Ilizarov correction of post-traumatic elbow deformities

Operational stage

— Placing wires in the humerus:

  ○ proximal olive wires to be inserted bilaterally;

  ○ one or two mid humerus wires to be placed in the oblique sagittal plane;

  ○ distal wires to be placed above the olecranon fossa (three wires including two olive wires to be inserted bilaterally).

— Assembly of the Ilizarov frame:

  ○ a half-ring with curved plates attached bilaterally and placed in the proximal humerus;

  ○ full ring to be attached on the boundary of the middle and distal humerus;

  ○ a half-ring with curved plates attached bilaterally to be placed in the distal humerus considering the deformity and connected with reference rings using hinges; the plane of the hinges is oriented to the plane of the deformity, the axes of the hinges' rotation are located at the level of the proposed osteotomy.

— Corticotomy to be performed in the supracondylar humerus with pre-drilling of six tunnels at the level of the intended corticotomy.

Postoperative stage

— Distraction to be initiated:

  ○ after four postoperative days with compression forces to be transferred to the Ilizarov rods into moderate distraction forces; distraction to be performed evenly at the rate of 1 mm four times/day during the next five days.

— Postoperative control of osteotomy:
  ○ AP and lateral radiographs of the segment after five days of distraction.
— The deformity to be corrected using:
  ○ distraction with the rods of the frame to be produced on the concave side of the deformity at the rate of 1.5 mm per day six times/day.
— Control of the regenerate quality and the limb axis:
  ○ AP and lateral radiographs of the segment every 10 days of distraction.
— Final correction of the limb axis:
  ○ acute translation of the distal bone fragment using the Ilizarov frame (if necessary) for the final correction of the limb axis;
  ○ comparative radiometry (comparison of the radiograph of the operated arm with the radiograph of the contralateral limb).
— Fixation:
  ○ control of regeneration once a month;
  ○ exercising the joint;
  ○ control of distraction forces on the Ilizarov distraction rods and wire tensioning.

General characteristics of patients with frontal elbow deformities are presented in Table 1. The majority of the patients had elbow varus deformity (89.9 %). Pseudarthrosis of the capitate eminence of the humerus was diagnosed in seven patients with elbow valgus deformity.

Table 1

General characteristics of patients with frontal elbow deformities (n = 68)

Description		Control group (n = 41)		Treatment group (n = 27)	
		abs.	%	abs.	%
Gender	male	28	68.3	19	70.4
	female	13	31.7	8	29.6
Age	4–17 years	33	80.5	17	63.0
	18–56 years	8	19.5	10	37.0
Angulation:					
a) varus elbow deformity:	Total	34	82.9	21	77.8
	0°	7	17.1	3	11.1
	5–14°	8	19.5	9	33.3
	15–24°	10	24.4	5	18.5
	25–30°	9	22.0	4	14.8
b) valgus elbow deformity:	Total	7	17.1	6	22.3
	30°	6	14.6	5	18.5
	45°	1	2.4	1	3.7
c) deficient flexion:	10–19°	4	9.8	1	3.7
	20–25°	3	7.3	3	11.1
d) deficient extension:	5–14°	1	2.4	2	7.4
	15–20°	2	4.9	1	3.7
	30°	4	9.8	3	11.1
e) deficient flexion and extension:	5–20°	6	14.6	3	11.1
	25–55°	4	9.8	6	22.3
f) absence of deficiency		17	41.4	8	29.6

Table 1 (continuation)

General characteristics of patients with frontal elbow deformities (n = 68)

Description		Control group (n = 41)		Treatment group (n = 27)	
		abs.	%	abs.	%
Radiography:					
a) deformity of the distal humerus:	varus	34	21	77.8	77,8
	valgus	7	6	22.2	22,2
b) marginal bone growths of articular surfaces		12	5	18.5	18,5
c) deformaity and osteophytes of the olecranon fossa		13	6	22.2	22,2
d) uneven narrowing of the joint space		7	5	18.5	18,5
e) pseudoarthrosis of the capitate eminence of the humerus		6	1	3.7	3,7

Patients performed elbow exercises for flexion and extension three times a day for 60 minutes, actively (using their own muscle strength) and passively (with weights). The deformity correction lasted for 10–36 days. Fixation of the humerus with the Ilizarov frame on lasted for 21–84 days.

A through drilling of the humerus was performed intraoperatively prior to the corticotomy at the level of the proposed osteotomy in the supracondylar zone using a K-wire (six tunnels) in patients of the treatment group (Fig. 2). The maneuver was used to prevent formation of a teeth-like or comminuted bone fragments that would make bone translation difficult. In this case, the bone "tooth" could be located in the soft tissues after deformity correction and lead to pain.

Fig. 3 shows consecutive postoperative radiographs of a 12-year-old patient of the treatment group with post-traumatic varus deformity corrected according to the algorithm.

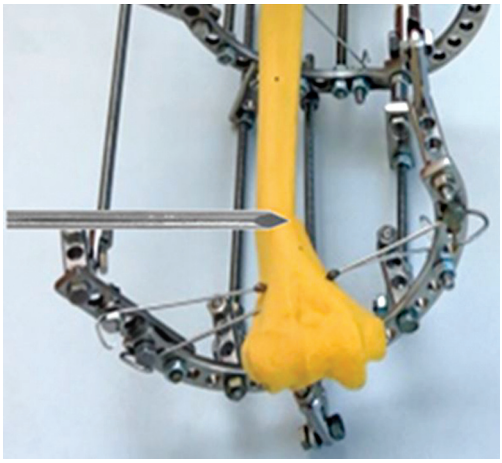

Fig 2 Photo of a humerus model with the Ilizarov apparatus mounted for correction of the frontal elbow deformity with a wire to be used for pre-drilling prior to corticotomy

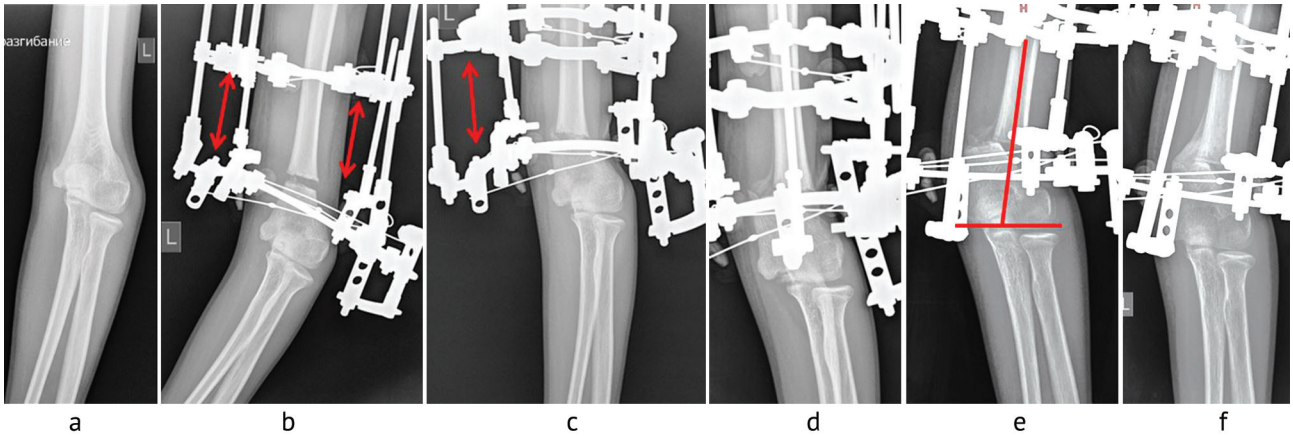

Fig. 3 AP view of the elbow joint of a patient with post-traumatic varus deformity of the elbow joint in the treatment group showing: (a) preoperative view; (b) uniform distraction performed at the rate of 1 mm per day four times/day with the height of the diastasis measuring 5 mm, corresponding to the duration of distraction at five days; (c) ten-day varus correction using distraction performed at the rate of 1.5 mm/day six times/day with two medial rods; (d) twenty-day Ilizarov deformity correction with the distal bone fragment acutely translated by 1.5 cm laterally to restore the limb axis; (e) the last-day deformity correction, the lines of the articular surface of the humeral condyle and the humerus axis are constructed to determine the residual deformity with the correction completed and deformity eliminated; (f) one-month Ilizarov humerus fixation

RESULTS

Four groups of errors were identified in patients of both groups with post-traumatic elbow deformities in the frontal plane that led to a variety of complications during placement of the Ilizarov apparatus in the operating room; performing osteotomy; control of the Ilizarov frame after osteotomy in the operating room; postoperative manipulations with the Ilizarov frame (Table 2).

Table 2

Groups of errors, complications and their prevention during treatment of patients with post-traumatic axial deformities of the elbow joint

Groups of errors	Description	Possible complications	Prophylaxis
Assembly of the Ilizaropv frame	Wires placed distal to the olecranon fossa of the humerus	Elbow contracture	Distal humerus wires to be placed proximal to the olecranon fossa
	Placement of a ring in the distal humerus		A half-ring or open ring must be placed in the distal humerus to allow elbow flexion during treatment.
	Absence of hinges, tilt of correction supports of the device	Incomplete deformity correction	It is recommended to place hinges with the plane of rotation located in the plane of the deformity, and their axes at the level of the proposed corticotomy. The distance between the rings should be maintained considering the correction maneuvers to be performed.
Osteotomy	Osteotomy used in case of altered bone structure	Comminuted osteotomy, presence of „teeth“	Pre-drilling, corticotomy to be performed prior to osteotomy
Intraoperative manipulations with the Ilizarov frame	Diastasis between the osteotomized bone fragments measuring greater than 5 mm	Poor bone regeneration	It is recommended to control the forces on the Ilizarov rods
	Acute correction for severe deformities or multiple scars of the humerus	Neuropathy	Gradual correction of the deformity should be performed in the postoperative period.
Postoperative manipulations with the Ilizarov frame	Inadequate distraction rate	Poor bone regeneration	A rational algorithm for eliminating deformity correction to be followed
	Lack of control over the bone regeneration, the axis of the limb segment	Residual deformity	
		Malaligned bone axis	

As can be seen from Table 3, these errors led to complications in the biomechanics of the limb (residual deformity, malaligned limb axis), the joint (contractures), the bone (comminuted type of osteotomy, presence of teeth), regeneration (ischemic regenerate bone), nerves (short-term and long-term neuropathies of the radial and ulnar nerves).

Table 3

Distribution of patients in the control and treatment groups according to the complications identified

Complications	Control group (n = 41)		Treatment group (n = 27)		Total (n = 68)	
	abs.	%	abs.	%	abs.	%
Comminuted, teeth-like shape of bone fragments at the osteotomy site	3	7.3	–	–	3	4.4
Incomplete deformity correction	6	14.6	2	7.4	8	11.8
"Bayonet-shaped" supracondylar deformity of the humerus	4	9.8	–	–	4	5.9
Ischemic regenerate	6	14.6	–	–	6	8.8
Persistent contractures of the elbow joint, lasting more than 6 months	6	14.6	–	–	6	8.8
Neuropathy of the radial and ulnar nerves	4	9.8	1	3.7	5	7.4
Total	29	70.7	3	11.1	32	47.1

Comminuted, teeth-like shape of bone fragments was observed at the osteotomy site in control patients who had sclerotic bone or with errors occurred with performing the osteotomy (Fig. 4).

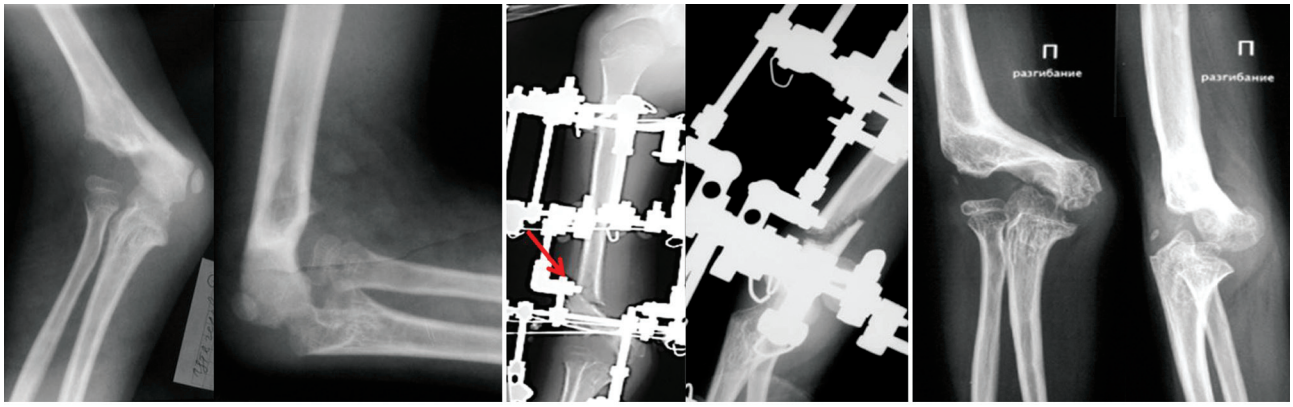

Fig. 4 Photoes from radiographs of an 11-year-old control patient with post-traumatic valgus deformity of the right elbow joint, defect of the lateral humerus condyle showing: (a) preoperative view; (b) supracondylar osteotomy of the humerus performed and valgus deformity of the elbow joint gradually corrected; the distal humerus fragment appears to be teeth-like, being located in the soft tissues (shown by the arrow); (c) a favorable outcome being with the bone fragment being demineralized at one year after removal of the Ilizarov apparatus

Incomplete deformity correction was caused by the lack of comparison of the AP and lateral views of the operated limb with the contralateral limb at the last stage of deformity control with the Ilizarov apparatus. There was no linear correction of the humeral axis in the frontal plane (bone translation for coaxiality) in some cases, which led to a “bayonet-shaped” deformity of the distal humerus. Weak bone regeneration was observed in six control patients after intraoperative acute deformity correction.

Six control patients with valgus elbow deformity and pseudoarthrosis of the capitate eminence of the humerus developed a sharp limitation of movements in the joint after osteosynthesis of the lateral epicondyle of the humerus and capitate eminence (Fig. 5). Neuropathies developed in control patients after acute valgus correction and were observed at a long term (more

than 6 months). A patient with varus elbow deformity of the treatment group demonstrated short-term (1 month) neuropathy caused by compression of the ulnar nerve by a wire that was removed on the first day after surgery.

Fig. 5 Photoes from radiographs of a 13-year-old control patient with post-traumatic valgus deformity of the right elbow joint, pseudoarthrosis of the capitate eminence showing (a) preoperative AP and lateral views with the forearm maximally flexed and extened; (b) AP and lateral views showing the supracondylar osteotomy of the humerus performed, the capitate eminence fixed with the Ilizarov apparatus and cantilever wires with the elbow maximally extended; (c) AP and lateral views showing the joint after removal of the Ilizarov apparatus

DISCUSSION

Trauma and orthopedic surgeons admit that the surgery using supracondylar osteotomy is the optimal method for patients with frontal elbow deformities. According to literature data [16], patients with valgus elbow deformity can benefit from transverse osteotomy for realignment of the limb axis, but a bone defect formed at the site of the osteotomy requires the replacement. An additional operation to repair the defect with biomaterial using autogenous bone filling the would complicate and increase the cost of surgical treatment. There is a similar problem with varus deformities of the elbow joint with the surgical wound to be widened aggravating the trauma. Wedge and dome-shaped osteotomies can shorten the limb and prevent the distal humerus from translation to restore the bone alignment. There is associated risk of progressing osteoarthritis of the elbow and a relapse of the joint deformity as the child grows. The incidence of complications with dome-shaped corrective supracondylar osteotomy of the humerus is 14.5 % [17].

The overall risk of various complications after osteotomies is reported to be 14.5 % [17]. The problems can be resolved with transverse corticotomy using transosseous compression-distraction osteosynthesis and deformity correction with the Ilizarov apparatus. The technique was employed for the 68 patients reviewed.

Cases of insufficient deformity correction and the recurrence are described in the literature. Insufficient bone correction requiring additional surgery is more common in patients treated with plate fixation [12]. Varus deformity caused by a laterally protruding humeral condyle may persist after osteotomy in cases with the distal fragment being insufficiently translated for coaxiality [18, 19, 20]. The complication can be avoided with deformity correction algorithm using the Ilizarov frame and acute bone translation.

Non-union of the bone can develop after osteotomies [12]. Delayed consolidation of the supracondylar osteotomy of the humerus was observed in patients with elbow varus deformity repaired with a Y-shaped plate after osteotomy [20]. According to our data, impaired

regeneration occured after intraoperative acute deformity correction observed in 8.8 % of control patients.

Dissection of the triceps during surgical approaches and osteosynthesis of the humerus condyle in pseudoarthrosis are frequent causes of elbow contractures observed in 4.72 % of patients [21]. Therefore, a sparing approach to the paratriceps is essential [13, 24, 25], and osteosynthesis of the lateral humeral condyle remains a controversial approach in patients with non-union and valgus deformity of the elbow joint after bone osteotomy due to avascular necrosis of the fragment after osteosynthesis [24, 25, 26].

In our opinion, temporary osteosynthesis of the non-union is practical during deformity correction. There is information on intraoperative injuries of the ulnar and radial nerves [24], which are reported in 2.53 % of patients including 78.4 % of cases with temporary injury [17]. Neuropathy of the ulnar nerve can be common with valgus deformity of the elbow joint, when the medial epicondyle of the humerus is displaced relative to the olecranon with the ulnar nerve groove being narrow [26]. Nerve palsies are more common with the posterior surgical approach to the humerus with division of the triceps as compared to the lateral approach with preservation of the triceps [12].

Infectious complications are observed in 9.45 % in patients with elbow deformities post operation [21]. There were no infectious complications of soft tissues and bones in the patients reported in the article.

Data on complications observed in the groups of patients and generalized literature data on the correction of deformities and repair of defects using non-free bone grafting and the Ilizarov frame [27] are presented in Table 4. The number of adverse events in the occurrence of complications in the treatment group was seven times less compared to the literature data. The total number of complications was 1.6 times less after the supracondylar osteotomy of the humerus and Ilizarov fixation as compared to the generalized data.

Table 4

Adverse events and serious adverse events in patients with deformities and defects of long bones treated with the Ilizarov apparatus (literature data [28] and our own data)

Complications	Literary source data (n = 2242)		Own data 68 observations			
			Control group (n = 41)		Treatment group (n = 27)	
	abs.	%	abs.	%	abs.	%
Adverse events	588	26.23	10	24.4	1	3.7
Pin tract infection	258	11.51	–	–	–	–
Contractures	152	6.78	6	14.6	–	–
Neurological disorders	111	4.95	4	9.8	1	3.7
Cutting through soft tissue around the wires	31	1.38	n/a			
Broken wires/rods	18	0.80	–	–	–	–
Dermatitis	11	0.50	–	–	–	–
Injury to blood vessels	7	0.31	–	–	–	–
Severe adverse events	15	0.67	–	–	–	–
Osteomyelitis	14	0.62	–	–	–	–
Fatal outcome	1	0.05	–	–	–	–

With the extensive experience in Ilizarov treatment of the patients the complications appeared to be predictable and could be successfully treated if identified in a timely manner with no affect on the final outcome [28, 29]. There is a tendency in reduced errors and complications with accumulated individual and collective Ilizarov experience [30] and appropriate and promising application of the method.

CONCLUSION

Analysis of errors and complications in the treatment of patients with post-traumatic frontal elbow deformities using supracondylar osteotomy and the Ilizarov fixation facilitated a rational algorithm developed for the deformity correction. Supracondylar osteotomy of the humerus with osteosynthesis and control of the Ilizarov apparatus are practical for the restoration of the anatomical and biomechanical axes of the limb. The algorithm containing a strict sequence of actions with time factors developed for treatment of patients with elbow deformities provided a 6.3 time reduction in errors and complications performing osteotomy, correcting residual deformity, improving bone regeneration and addressing contractures and neuropathies.

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Ethical Standards *The study was carried out in accordance with the Declaration of Helsinki.*

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Information about the authors:

Yuri P. Soldatov — Doctor of Medical Sciences, Professor, Leading Researcher, orthopaedic surgeon, soldatov-up@mail.ru, https://orcid.org/0000-0003-2499-3257;

Alexander N. Diachkov — Doctor of Medical Sciences, Professor, Chief Researcher, naucaalex@mail.ru.