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Principles of surgical treatment of delayed carpal tunnel syndrome in malunion of the distal metaepiphysis of the radius

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Abstract

Introduction Delayed carpal tunnel syndrome (DCTS) in patients with malunited fracture of the distal metaepiphysis of the radius (DMR) develops from several weeks to months after the injury. The main treatment method for these patients is corrective osteotomy and fixation of the radius bone. However, the necessity and methods of median nerve decompression still remain controversial.

Purpose To evaluate long-term results of surgical treatment of patients with a malunited distal radius fractures and concurrent delayed carpal tunnel syndrome, depending on the method of median nerve decompression, and to develop a treatment concept.

Methods The results of treatment were studied in 33 patients (30 women and three men, average age 54.6 years) with malunited DMR fracture complicated by DCTS. All patients underwent corrective osteotomy of the distal radius and osteosynthesis with a volar locking plate. Open carpal tunnel release (OCTR) was performed in the first group of patients through a separate limited surgical approach (n = 19), while decompression of the median nerve was carried out through an extended flexor carpi radialis (EFCR) approach in the second group (n = 14). Patients were evaluated clinically (wrist range of motion, hand strength, VAS pain level, DASH score), radiographically, and electromyographically before surgery and one year after it. DCTS severity and DR deformity were compared.

Results After the operation, patients in both groups showed improvement in clinical, radiographic and ENMG parameters. The average union time was 12 weeks. Better results were achieved in the first group: the hand grip strength increased significantly, as did daily activity and the amplitude of the M-response of the short muscle abducting the thumb. The most significant changes were observed in moderate and severe DCTS cases, as well as in the intermediate and predominantly dorsal DR deformity.

Discussion The questions about the advisability of simultaneous decompression of the median nerve in patients with OCTR and the nature of the corresponding approaches do not have a clear answer. Most authors believe that it is sufficient to perform only corrective osteotomy and osteosynthesis. Our study showed the importance of a differentiated approach to solving this problem.

Conclusions Corrective osteotomy and volar locking plate osteosynthesis in carpal tunnel release are reliable and effective treatments for malunited DMR fractures with concurrent delayed carpal tunnel syndrome. The best results were obtained after open carpal tunnel release from a separate limited approach in patients with moderate and severe deformity of the distal metaepiphysis of the radius, combined with “intermediate” and “predominantly dorsal deformity. In mild DCTS cases, as well as in cases of predominantly palmar DMR deformity, decompression of the median nerve can be performed from the main EFCR approach.

Keywords: distal radius fracture, malunion, osteotomy, delayed carpal tunnel syndrome, carpal tunnel release, limited open approach, extended flexor carpi radialis approach, median nerve

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INTRODUCTION

Malunion of fractures of the distal metaepiphysis of the radius (DMR) may involve soft tissue structures passing through the carpal tunnel in the regeneration process [1]. In this case, the median nerve, which is subject to compression, suffers particularly, what predisposes to the formation of carpal tunnel syndrome (CTS). Based on the time of its development, CTS is divided into acute, appearing within a few hours and days after the fracture (5.4–8.6 %), subacute or transient (4 % of cases), and delayed or chronic that occurs several weeks or months after the injury (0.5–22 %) [2, 3].

Delayed CTS (DCTS) develops during consolidation of the radius fragments and, in most cases, in their malunion [4–10]. According to Stewart et al., at 3 months after the fracture, the incidence of DCTS reaches 17 %, and 6 months later, 12 % [11]. The immediate causes of DCTS are a decrease in the volume of the carpal tunnel space, residual dorsal or palmar displacement of the distal fragment, edema, tenosynovitis, prolonged immobilization of the hand in the Cotton-Loder position, and excessive bone callus size [12–17].

Questions about the indications for decompression of the median nerve in case of DMR malunion and the preferred methods of its implementation remain open [18, 19]. Considering these questions from a systemic perspective, it is possible to conditionally distinguish two types of surgical approaches used for the purpose of prompt elimination of the DCTS.

The first type of approach is through a longitudinal incision in the lower third of the forearm along its anterior surface, which is 3 cm long, with an angular deviation to the radial side in the projection of the palmar folds of the wrist, through the tendon of the radial flexor of the hand, cutting off the external leaves of the retinaculum flexorum. This type of approach was first described by Weber et al. [20] and was used by the authors only for decompression of the median nerve. This approach was later adapted by Gwathmay et al. [21] for prophylactic decompression of the median nerve with simultaneous osteosynthesis of the DMR by prolongation of the skin incision to 7–8 cm. A similar approach, distinguished by a length of 8–10 cm, but used only for operations on the DMR, was also used by Orbay et al. [22]. To generally designate approaches of this type that are performed only for the purpose of decompression of the median nerve, we, with some conventionality, used the term EFCR approach (Extended Flexor Carpi Radialis Approach) [23], which is well known among hand surgery specialists. Thus, approaches of the first type involve performing one incision, but to achieve two goals: to release the median nerve and for reconstructive intervention on the DMR.

The second type is combined approaches, which involve two incisions: the first for decompression of the median nerve in the palmar surface of the wrist, which is known among hand surgeons as the OCTR approach (Open Carpal Tunnel Release) [24], and the second for corrective osteotomy and osteosynthesis of the DMR in the lower third of the forearm. Thus, approaches of the second type involve two differently localized incisions, each with its own specific purpose.

In this study, we examined the effectiveness of both types of approaches in order to determine the therapeutic potential of each of them and the possibility of their differentiated use for different DCTS severity and different inclination of the articular surface of the DMR in case of a malunited fracture.

Purpose To evaluate long-term results of surgical treatment of patients with a malunited distal radius fracture and concurrent delayed carpal tunnel syndrome, depending on the method of median nerve decompression, and to develop a treatment concept.

MATERIALS AND METHODS

In the period from 01.01.2006 to 31.12.2022, we followed 33 patients (30 women and three men) aged 36 to 71 years (mean 54.6 years) with malunion of the DMR associated with DCTS. The time from injury to surgery ranged from 3 to 16 months (mean 4.8 months).

Study characteristics: a prospective, randomized, controlled in parallel groups, multicenter study. The subject of the study is DCTS that developed as a result of a malunion of the DMR fracture. The object of the study is patients suffering from DCTS due to malunion of the DMR fracture. Inclusion criterion: malunion of the DMR in the patient with clinical signs of DCTS. Exclusion criteria were concomitant diabetes mellitus, severe osteoporosis, and fixed wrist displacement.

The primary endpoint of the study was to evaluate the effectiveness of surgical treatment of DCTS using a combined surgical approach, including an incision in the lower third of the forearm to correct a malunited fracture and osteosynthesis of the DMR, and a mini-incision on the palmar surface of the wrist for decompression of the median nerve, epineurotomy and neurolysis (OCTR approach); the development of recommendations for differentiated surgical treatment based on DCTS severity and the magnitude of the palmar tilt of the articular surface of the radius.

Secondary endpoints of the study were clinical parameters (pain intensity during exercise, total range of active wrist movements, hand grip strength, daily activities), radiographic parameters (radio-ulnar angle, palmar tilt of the articular surface of the radius, radio-ulnar index), and ENMG parameters (amplitude of the M-response of the abductor pollicis brevis muscle, distal latency of the motor fibers of the median nerve, motor conduction velocity along the motor fibers of the median nerve, conduction velocity along the sensory fibers of the median nerve).

All patients were divided into two clinical groups randomly. Group 1included 19 patients who were treated with a combined approach: from the first mini-incision on the palmar surface of the wrist, decompression of the median nerve was performed by dissecting the transverse carpal ligament, epineurotomy and neurolysis (OCTR approach), and from the second incision in the lower third of the forearm, corrective osteotomy and osteosynthesis of the DMR were performed. Group 2 included 14 patients who were treated with an approach from only one incision in the lower third of the forearm, through which corrective osteotomy, osteosynthesis of the DMR and decompression of the median nerve were performed (EFCR approach) without epineurotomy and neurolysis.

The clinical groups were comparable in terms of age, type of DMR fracture, DCTS severity, the magnitude of the palmar tilt of the articular surface of the radius, and the timing of reconstructive surgery (Table 1).

Table 1

Characteristics of patients in the study groups

Parameters		Clinical groups				p
		1 (n = 19)		2 (n = 14)		
		n	%	n	%	
Age (years)	Up to 50	5	26.3	4	28.6	> 0.05
	51–60	11	57.9	6	42.8	> 0.05
	Over 60	3	15.8	4	28.6	> 0.05
Fracture type	Type A	10	52.6	7	50.0	> 0.05
	Type B	3	15.8	2	14.3	> 0.05
	Type C	6	31.6	5	35.7	> 0.05
Terms of reconstructive surgery after trauma	< 6 months	14	73.6	9	64.3	> 0.05
	6 < 12 months	4	21.0	5	35.7	> 0.05
	⩾ 12 months	1	5.4	–		> 0.05
DCTS severity	Mild	12	63.2	5	35.7	> 0.05
	Moderate	2	10.5	4	28.6	> 0.05
	Severe	5	26.3	5	35.7	> 0.05
Palmar tilt of the articular surface of the radius (PT)	PT ⩾ (+)11°	1	5.3	4	28.6	> 0.05
	PT = from (+)10° to (–)10°	7	36.8	4	28.6	> 0.05
	PT ⩽ (–)11°	11	57.9	6	42.8	> 0.05

The indications for surgery were complaints of pain in the hand, mainly at night, a feeling of numbness in the first, second and third fingers of the hand, deformity and pain in the wrist under load, decreased hand strength, and limited mobility in the wrist joint. Moreover, we studied the changes in radiographic parameters: a deficit in the palmar tilt of the articular surface of the radius of more than 20°, radial inclination of less than 10°, an increase in the ulnar variance of more than 2 mm, and an intra-articular displacement of more than 2 mm. Contraindications to corrective osteotomy were uncompensated diabetes mellitus, severe osteoporosis, and fixed displacements in the wrist.

Preoperative planning was based on radiographs of the wrist joints in standard views, anteroposterior and sagittal. Computed tomography was performed on CT systems Toshiba Aquillion 32 and Philips Brilliance 190 P (Netherlands) in the spiral scanning mode with a reconstructed slice thickness of 0.5 mm and a reconstruction step of 0.3 mm. The magnitude of the displacement of DMR fragments in millimeters and degrees was measured, the level of osteotomy, shape and size of the bone defect were determined.

The effectiveness of surgical treatment was assessed according to the following criteria:

— clinical findings

- Pain intensity under load in VAS;
- Total range of active motion (TRAM) in the wrist;
- Grip strength (GS);
- Daily activity in DASH score;

— radiographic findings:

- Radial inclination (RI) angle;
- Palmar tilt (PT) of the radius articular surface;
- Shortening of the radius relative the ulna;
- Ulnar variance (UV);

— ENMG findings:

- compound muscle action potential (CMAP, mV);
- Distal motor latency (DML, ms);
- Motor conduction velocity (MCV, m/s) and sensory conduction velocity (SCV, m/s) in the median nerve fibers

All the parameters were studied before the intervention and one year after it.

The OCTS severity was determined according to Żyluk et al. [25]. Based on the magnitude of the M-response amplitude of the abductor pollicis brevis muscle (CMAP), patients with mild (> 4 mV), moderate (4–2 mV), and severe (< 2 mV) OCTS were identified.

Based on the PT value, all patients were conditionally divided into those with predominantly palmar deformity (PT ⩾ (+) 11°), intermediate (PT (+)10° — (–)10°), and predominantly dorsal (PT ⩽ (–)11°) DMR deformity.

The IBM SPSS Statistics package (USA license No. 5725-A54) was used for statistical analysis. Descriptive statistics are presented as mean and standard deviation (M ± SD). The Kruskal – Wallis analysis of variance, Mann – Whitney criteria, and Wilcoxon paired test were used in the work.

Surgical technique

The intervention was performed under general anesthesia and regional tourniquet, placing the upper limb in the supination position on a radiolucent side table. In the patients of the first group, open decompression of the median nerve was performed using a limited open approach (OCTR approach). For this purpose, a Z-shaped incision 3.5–4 cm long was made on the palmar surface of the wrist.

The skin and tissue were dissected at the level of the ulnar part of the carpal tunnel, and the palmar aponeurosis was dissected on its radial side. The incision line of the transverse palmar ligament was drawn obliquely from the dorsoradial to the palmar-ulnar side of the tunnel. The median nerve and its motor branch were mobilized, epineurotomy and neurolysis were performed. The palmar aponeurosis and skin were sutured. Next, through the incision in the lower third of the forearm along its palmar-radial surface, corrective osteotomy and DMR osteosynthesis were performedaccording to Orbay et al. [22] (Fig. 1).

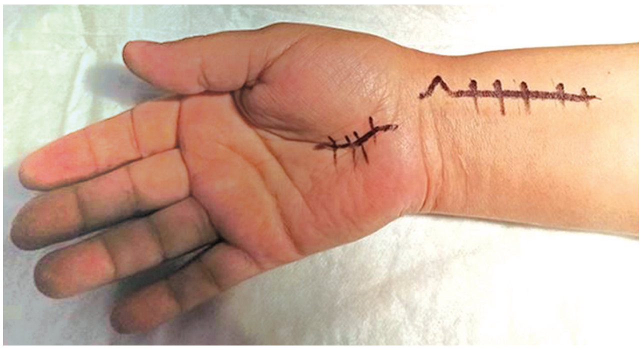


Fig. 1 Planning of incisions for open decompression of the median nerve in the wrist, corrective osteotomy and DMR osteosynthesis

In the patients of the second group, decompression of the median nerve was performed using an approach to the forearm, simultaneously performing corrective osteotomy and osteosynthesis according to Gwathmay et al. [21]. For this purpose, a 7–8 cm long linear incision was made on its palmar-radial surface in the lower third in the projection of the tendon of the radial flexor carpi radialis and extended distally like a Z-shaped curve by 7–10 mm (EFCR approach) (Fig. 2 a). Then, along the tendon of the radial flexor carpi radialis, the superficial flexor retinaculum was mobilized and dissected. The palmar branch of the radial artery was ligated and transected, or retracted to the side. The tendon of the radial flexor carpi radialis was retracted radially, and the deep ligament was dissected. After the ulnar abduction of the tendon of the long flexor of the thumb, the superficial and deep sheets of the transverse carpal ligament were finally dissected from the tubercle of the scaphoid bone and from the trapezium bone (Fig. 2 b). To approach the radius, the quadratus pronator muscle was cut off from the bone in the lateral and distal parts and abducted to the ulnar side. The tendon of the brachioradialis muscle was dissected in a Z-shape. This made the deformed surface of the radius accessible.

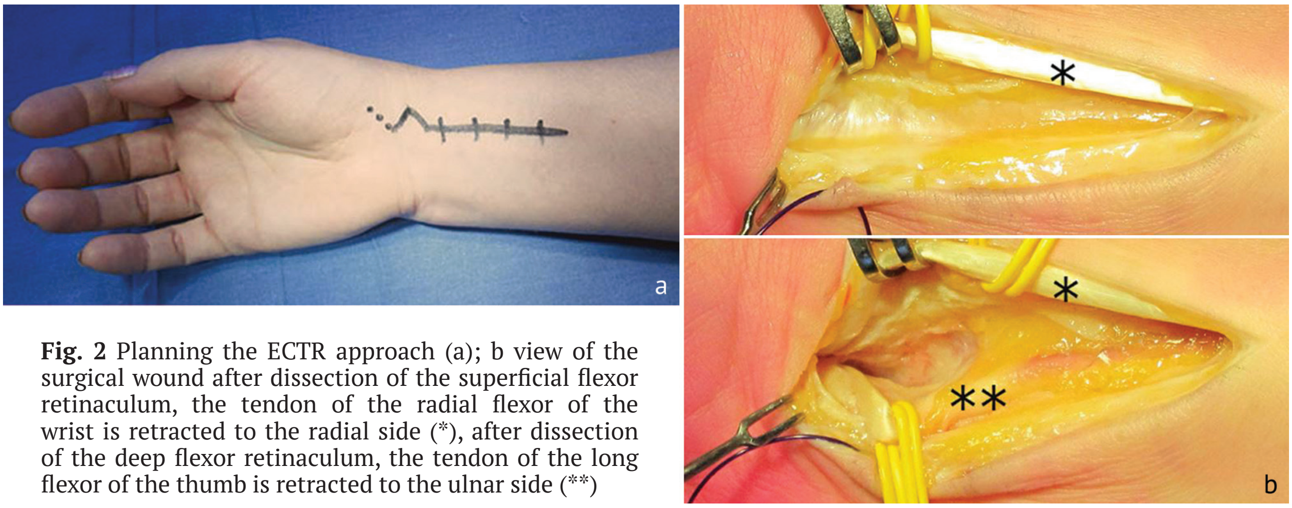


Fig. 2 Planning the ECTR approach (a); b view of the surgical wound after dissection of the superficial flexor retinaculum, the tendon of the radial flexor of the wrist is retracted to the radial side (*), after dissection of the deep flexor retinaculum, the tendon of the long flexor of the thumb is retracted to the ulnar side (**)

In the patients with predominantly dorsal deviation of the distal fragment of the radius ($n = 17$), an additional dorsal mini-incision up to 4 cm in size was made for complete mobilization and retention of the distal fragment of the radius [26]. The proximal part of the extensor retinaculum was dissected in a Z-shape, and the flaps were moved apart. Using precision surgical technique, the fibrous bone canals of the extensors were identified in the periosteal bone callus. The first, second, third, and fourth canals were dissected; and the extensor tendons were moved apart. Particular attention was paid to preserving the tendon of the long extensor of the thumb.

In accordance with the preoperative planning, osteotomy of the radius was performed under the control of an operating stenoscope, alternately using both the palmar and dorsal incisions. Direct reduction of bone fragments was performed, restoring normal anatomical DMR relationship. The bone defect was filled with autogenous bone or synthetic osteoplastic material based on β-3 calcium phosphate. A plate of a personalized size was placed on the volar surface of the radius so that it did not protrude beyond the distal and volar edges of the DMR "watershed line". Locking and cortical screws were installed under the control of an operating stenoscope (Fig. 3). Continuity of the brachioradialis tendon, the integrity of the pronator quadratus and the extensor retinaculum were restored. The tendon of the extensor pollicis longus was left in the subcutaneous tissue. The wounds were sutured layer by layer, active drainage was placed.

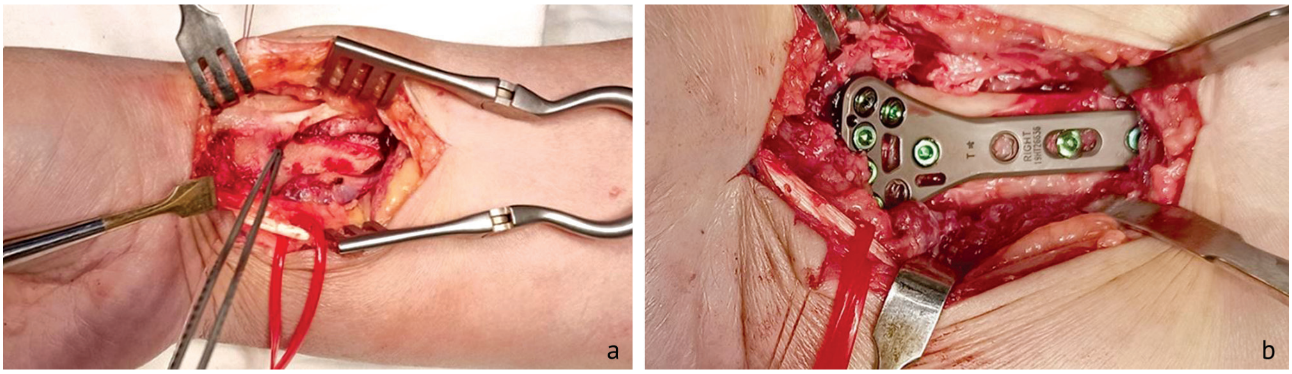


Fig. 3 View of the surgical wound: a before corrective osteotomy; b after osteotomy with a palmar plate placed

Immobilization was performed with a removable palmar plaster splint in the functional position of the wrist for 2–3 weeks. A removable orthosis was used in the following four weeks. Therapeutic exercises for the fingers of the hand began on the second postoperative day. Active rehabilitation treatment was initiated at 5–6 weeks after the operation. Full loading was allowed after consolidation of bone fragments, but not earlier than 12 weeks after the operation.

All patients signed informed consent; the study was approved by the Bioethics Committee at Samara State Medical University (protocol dated 03.05.2024 No. 285).

RESULTS

Due to the treatment provided, all patients had their DMR deformity completely corrected or significantly reduced. Bone fragment healing was observed on average at 12 weeks.

Moreover, clinical parameters significantly improved. Thus, the intensity of pain under load (VAS) decreased by 66 %, the total range of active motion in the wrist joint (TRAM) increased by an average of 43 %, the hand grip strength (GS) increased by 82 %, and daily activity (DASH-score) improved by 58 % (Table 2).

The radiographic changes were positive. The radial inclination (RI) angle increased by 75 %, palmar tilt (PT) improved by 144 %, and the ulnar variance (UV) decreased by 73 % (Table 2).

The changes in ENMG parameters were also characterized by positive dynamics. The increase in the amplitude of the M-response (CMAP) reached 78 %, the decrease in distal motor latency (DML) was 27 %, the velocity of the motor response (MCV) increased by 19 %, and the velocity of the sensory response (SCV) increased by 47 % (Table 2).

Thus, all 11 parameters significantly improved in all patients one year after the operation.

The values of the parameters in the clinical groups studied before the operation were similar. However, after one year all the parameters in the first group changed more significantly than in the second group. Thus, the hand grip strength (GS) in patients of the first group increased to (74.37 ± 13.52) %, and in the second only to (60.43 ± 16.15) %. Daily activity (DASH-score) in the first group reached (15.06 ± 6.38) points, and in the second (20.82 ± 7.17) points. The amplitude of the M-response of the short muscle abducting the pollicis (CMAP) in the first group increased to (7.53 ± 2.08) mV, and in the second only to (5.48 ± 2.58) mV (Table 3). The changes in these criteria were reliable.

Table 2

Clinical, radiographic and ENMG characteristics of patients in both groups, M ± m

Parameter	Before surgery (*n* = 33)	One year after surgery (*n* = 33)	*P*
VAS, points	4.97 ± 1.66	1.68 ± 0.80	< 0.001
TRAM, %	57.05 ± 12.15	81.76 ± 7.46	< 0.001
GS, %	37.58 ± 16.52	68.45 ± 16.05	< 0.001
DASH-score, points	41.83 ± 8.74	17.50 ± 7.22	< 0.001
RI, °	12.26 ± 5.15	21.50 ± 4.36	< 0.001
PT, °	−9.49 ± 18.58	4.19 ± 5.06	< 0.001
UV, mm	4.38 ± 2.34	1.20 ± 1.98	< 0.001
CMAP, mV	3.75 ± 2.37	6.66 ± 2.49	< 0.001
DML, m/sec	5.66 ± 1.86	4.10 ± 0.73	< 0.001
MCV, m/sec	45.53 ± 10.08	54.28 ± 6.76	< 0.001
SCV, m/sec	30.19 ± 15.01	44.29 ± 10.83	< 0.001

Table 3

Clinical, radiographic and ENMG characteristics of patients one year after surgery, M ± m

Parameter	Group 1 (*n* = 19)	Group 2 (*n* = 14)	*p*
VAS, points	1.62 ± 0.76	1.77 ± 0.86	0.883
TRAM, %	82.11 ± 6.92	81.29 ± 8.38	0.798
GS, %	74.37 ± 13.52	60.43 ± 16.15	0.010
DASH-score, points	15.06 ± 6.38	20.82 ± 7.17	0.038
RI, °	21.45 ± 4.66	21.57 ± 4.07	0.715
PT, °	4.59 ± 4.91	3.64 ± 5.39	0.826
UV, mm	1.21 ± 2.39	1.18 ± 1.34	0.698
CMAP, mV	7.53 ± 2.08	5.48 ± 2.58	0.023
DML, m/sec	3.91 ± 0.74	4.36 ± 0.65	0.065
MCV, m/sec	56.63 ± 3.56	51.11 ± 8.73	0.061
SCV, m/sec	46.98 ± 8.36	40.64 ± 12.93	0.140

The comparing of all 11 indicators based on the severity of DCTS found that one year after the operation, in its mild grade (*n* = 17), there were no reliable changes in the groups. On the contrary, in moderate and severe DCTS (*n* = 16), significant changes were revealed in the values of several indicators. Thus, one year after the operation, the power of grip strength (GS) of the hand in patients of the first group increased to (70.29 ± 18.78) %, and in the second only to (51.89 ± 10.86) %. Daily living activities (DASH questionnaire) in the patients of the first group compared to the second improved better, amounting to (15.51 ± 8.45) and (25.00 ± 4.45) points, respectively. The amplitude of the M-response (CMAP) in the first group reached (5.53 ± 1.98) mV, and in the second only (3.86 ± 1.11) mV. The value of sensory conduction velocity (SCV) in the first group also exceeded the similar indicator in the second group, amounting to (43.43 ± 7.39) m/s and (32.89 ± 8.82) m/s, respectively (Table 4). The changes in these parameters were reliable.

Table 4

Clinical, radiographic and ENMG characteristics of patients with moderate and severe OCTS one year after surgery, M ± m

Parameter	Group 1 (*n* = 7)	Group 2 (*n* = 9)	*p*
VAS, points	1.80 ± 1.05	1.98 ± 0.78	0.957
TRAM, %	80.71 ± 8.42	78.89 ± 9.64	0.671
GS, %	70.29 ± 18.78	51.89 ± 10.86	0.026
DASH-score, points	15.51 ± 8.45	25.00 ± 4.45	0.015
RI, °	23.47 ± 4.43	22.56 ± 4.33	0.594
PT, °	5.00 ± 4.62	5.22 ± 5.49	0.789
UV, mm	0.86 ± 1.68	1.50 ± 1.17	0.449
CMAP, mV	5.53 ± 1.98	3.86 ± 1.11	0.034
DML, m/sec	4.24 ± 0.87	4.61 ± 0.57	0.395
MCV, m/sec	55.19 ± 4.65	47.89 ± 9.33	0.095
SCV, m/sec	43.43 ± 7.39	32.89 ± 8.82	0.029

Our findings show that in mild DCTS, decompression of the median nerve with its epineurotomy and neurolysis via the OCTR approach is inappropriate. Such an approach provides tangible results only in moderate and severe DCTS. In mild DCTS, a positive result can be achieved via the EFCR approach.

The comparison of the changes in the parameters between the groups based on the severity of the DMR deformity found that in predominantly palmar deformity (*n* = 5) there were no reliable changes between the groups. However, in intermediate deformity (*n* = 11), significant differences in the magnitude of several parameters was revealed. Thus, the amplitude of the M-response in the first group increased to (8.80 ± 1.17) mV, while in the second only to (4.40 ± 2.13) mV. The distal latency of the motor fibers of the median nerve (DML) in the first group decreased to (3.87 ± 0.39) m/sec, and in the second to (4.53 ± 0.26) m/sec. The velocity of the motor response also improved. In the first group it increased to (57.16 ± 1.68) m/sec, and in the second one to (43.63 ± 9.59) m/sec (Table 5).

Similarly, in predominantly dorsal deformity (n = 17), significant improvement was noted in several parameters. Thus, the total range of active movements (TRAM) in the wrist joint in the first group increased to (29.64 ± 9.74) % while in the second one only to (14.17 ± 5.95) %. The hand grip strength (GS) showed values of (37.60 ± 10.96) % and (18.47 ± 6.91) %, respectively. Daily activities (DASH questionnaire) also improved, (18.27 ± 4.44) points in the first group and (29.67 ± 7.26) points in the second (Table 5).

Table 5

Clinical, radiographic and ENMG characteristics of patients with intermediate and predominantly dorsal DMR deformity" one year after surgery, M ± m

Parameter	Group 1 (*n* = 7)	Group 2 (*n* = 4)	*P*
Intermediate deformity, PT from (+)10° to (–) 10°			
VAS,points	1.50 ± 0.76	1.53 ± 0.68	0.846
TRAM, %	85.57 ± 5.94	84.25 ± 11.44	0.568
GS, %	75.57 ± 10.45	59.50 ± 14.82	0.071
DASH-score, points	12.67 ± 5.06	19.63 ± 7.27	0.131
RI, °	19.91 ± 5.80	20.75 ± 6.75	0.635
PT, °	4.46 ± 3.14	6.25 ± 3.20	0.340
UV, mm	0.36 ± 1.60	1.00 ± 0.82	0.625
CMAP, mV	8.80 ± 1.17	4.40 ± 2.13	0.013
DML, m/sec	3.87 ± 0.39	4.53 ± 0.26	0.007
MCV, m/sec	57.16 ± 1.68	43.63 ± 9.59	0.008
SCV, m/sec	45.97 ± 5.96	37.00 ± 14.54	0.129

Table 5 (continued)

Clinical, radiographic and ENMG characteristics of patients with intermediate and predominantly dorsal DMR deformity" one year after surgery, M ± m

Parameters	Group 1 (*n* = 11)	Group 2 (*n* = 6)	*P*
Predominantly dorsal deformity, PT ⩽ (–)11°			
VAS, points	1.69 ± 0.83	1.95 ± 1.15	0.575
TRAM, %	29.64 ± 9.74	14.17 ± 5.95	0.006
GS, %	37.60 ± 10.96	18.47 ± 6.91	0.004
DASH-score, points	18.27 ± 4.44	29.67 ± 7.26	0.007
RI, °	22.24 ± 4.03	21.00 ± 1.55	0.225
PT, °	4.18 ± 5.86	–0.17 ± 4.62	0.189
UV, mm	1.68 ± 2.81	1.58 ± 0.97	0.612
CMAP, mV	6.59 ± 2.15	5.93 ± 2.91	0.763
DML, m/sec	3.98 ± 0.93	4.40 ± 0.65	0.391
MCV, m/sec	56.71 ± 4.34	52.83 ± 8.40	0.410
SCV, m/sec	46.45 ± 9.30	41.67 ± 16.48	0.650

The above findings indicate that in patients with predominantly palmar DMR deformity, decompression of the median nerve with its epineurotomy and neurolysis through the OCTR approach is inappropriate. It is quite sufficient to perform decompression through the EFCR approach, not performing epineurotomy and neurolysis.

Complications Two patients in the first group developed a dense and painful postoperative scar at 2 and 3 months after the operation, and three patients developed pillar pain. These symptoms disappeared during the postoperative treatment and did not bother them one year later. One patient in the second group developed transient irritation of the superficial branch of the median nerve. Neither surgical wound suppuration nor migration of screws was observed. There were no repeated operations.

Case presentation Female patient H., 58 years old, was admitted two months after the injury with the diagnosis: malunion of the right DMR fracture (according to the AO/ASIF classification, type A 3.2) and DCTS. Upon admission, she complained of wrist deformity, pain and limited mobility in the right wrist, decreased sensitivity in fingers I–II–III, and decreased hand strength. Objective findings were: the total range of active movements in the right wrist joint compared to the contralateral limb was 64 %, and the strength of the rough grip of the hand was 35 %. The pain intensity (VAS) under load reached 4.7 points. Radiographs showed angular volar displacement of the cortical plate of the distal fragment of the radial bone, a decrease in the radioulnar angle (UV) to 12.3°, an increase in the dorsal tilt of the articular surface of the radius in the sagittal plane to –4°, and 4-mm shortening of the radius (Fig. 4). ENMG of the upper limbs revealed a decrease in the M-response of the median nerve at the right wrist (APB-CMAP), as well as a decrease in the conduction velocity along the sensory fibers of the median nerve (SCV) (Fig. 5). According to the classification

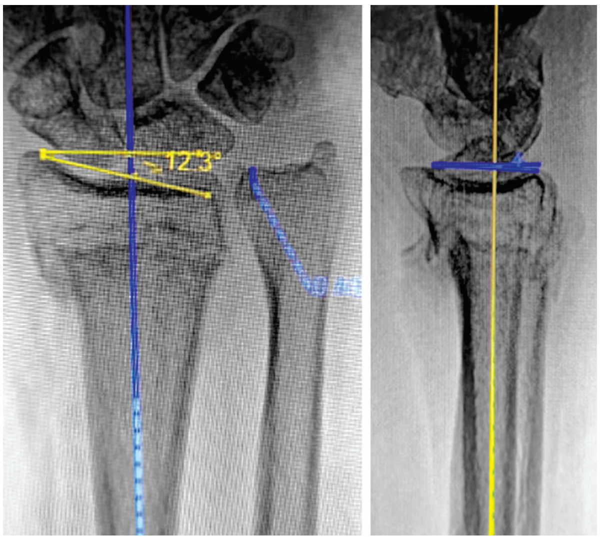
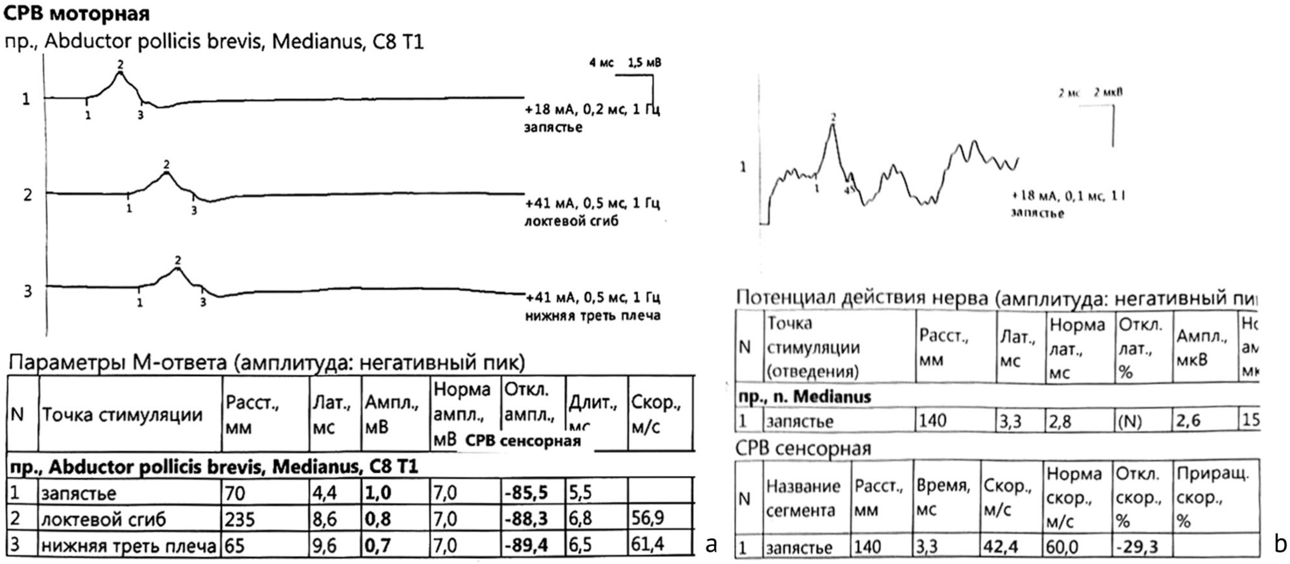


Fig. 4 Radiographs of the right wrist before surgery: decrease in the radioulnar angle (PI), palmar tilt and increase in the radioulnar index (UV)

of Żyluk et al. [25], a pronounced DCTS severity was diagnosed. The function of the right upper limb according to the DASH-score was 45.8 points (poor).



Параметры М-ответа (амплитуда: негативный пик)

N	Точка стимуляции	Расст., мм	Лат., мс	Ампл., мВ	Норма ампл., мВ	Откл. ампл.,	Длит., мс	Скор., м/с
пр., Abductor pollicis brevis, Medianus, C8 T1								
1	запястье	70	4,4	**1,0**	7,0	**-85,5**	5,5	
2	локтевой сгиб	235	8,6	**0,8**	7,0	**-88,3**	6,8	56,9
3	нижняя треть плеча	65	9,6	**0,7**	7,0	**-89,4**	6,5	61,4

Потенциал действия нерва (амплитуда: негативный пи

N	Точка стимуляции (отведения)	Расст., мм	Лат., мс	Норма лат., мс	Откл. лат., %	Ампл., мкВ	Н ам мк
пр., n. Medianus							
1	запястье	140	3,3	2,8	(N)	2,6	15

СРВ сенсорная

N	Название сегмента	Расст., мм	Время, мс	Скор., м/с	Норма скор., м/с	Откл. скор., %	Приращ. скор., %
1	запястье	140	3,3	42,4	60,0	-29,3	

Fig. 5 ENMG parameters before surgery: a decreased M-response of the median nerve on the right wrist (APB-CMAP); b decreased conduction velocity along the sensory fibers of the median nerve on the right wrist (SCV)

In a planned manner, open decompression of the median nerve with epineurotomy and lateral neurolysis was performed from a separate limited approach on the palmar surface of the right wrist (Fig. 6 a). Next, extra-articular open-angle corrective osteotomy and DMR osteosynthesis were performed from the palmar approach on the forearm (Fig. 6 b). Results of osteotomy and DMR osteosynthesis were: the deformity was corrected, the bone fragments were fixed in a satisfactory position (Fig. 7).

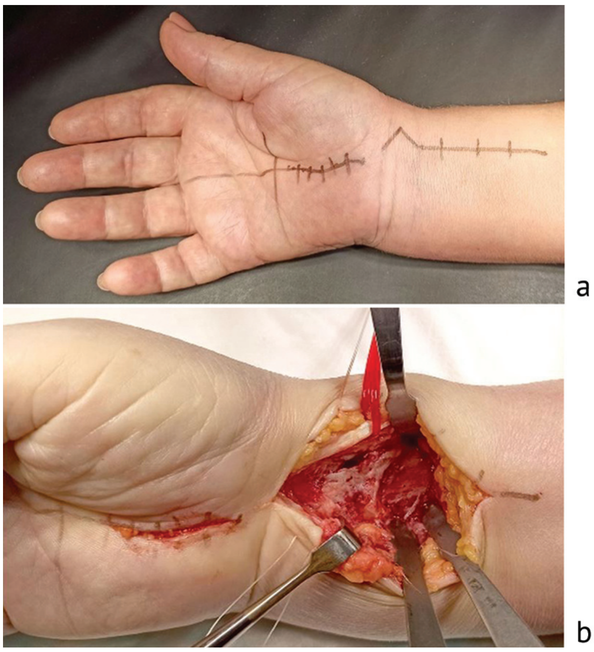


Fig. 6 View of the right forearm and hand on the operating table: a surgical approach marks; b view of the wound on the palmar surface of the wrist after open decompression of the median nerve and access to the distal radius for osteotomy and osteosynthesis

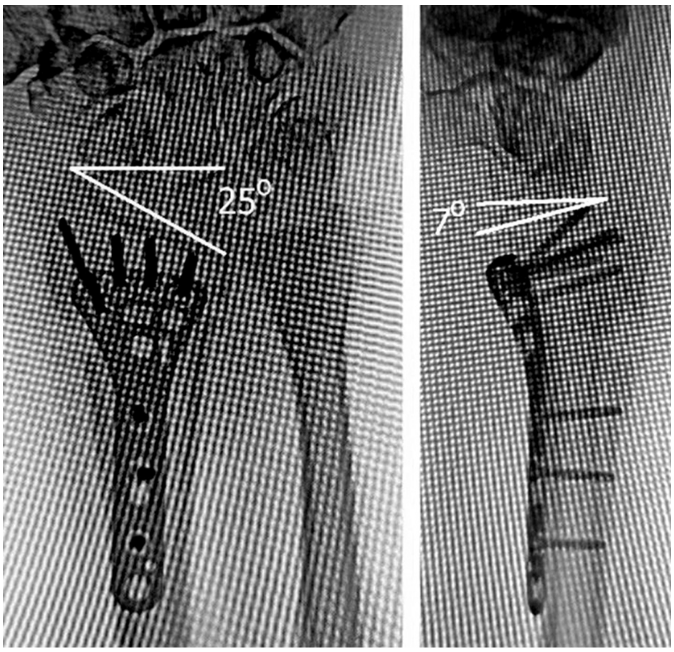


Fig. 7 Radiographs of the right wrist joint after surgery: correct relationships of the articular surfaces and the length of the forearm bones have been restored

The patient was examined one year later. She was satisfied with the result of the operation, complaining of periodic aching pain in the wrist joint only after heavy load (VAS, 2.8 points). The DMR is not deformed (Fig. 8), the total range of active movements in the right wrist joint compared to the contralateral limb is 91 % (Fig. 9), the strength of rough grip of the hand is 84 % (Fig. 10). ENMG showed restoration of the M-response, conduction velocity along motor and sensory fibers, distal motor latency normalization (Fig. 11). The indicators of daily activities (DASH-score) were 7.5 points, which corresponded to an excellent result.

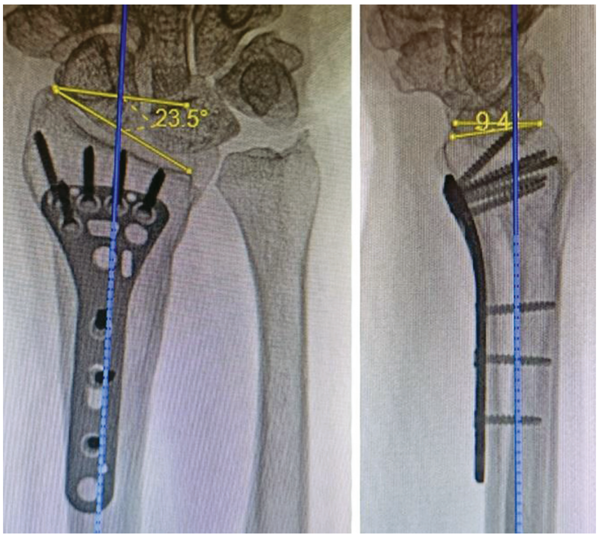
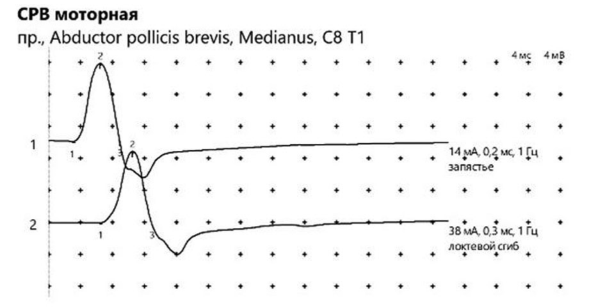


Fig. 8 DMR radiographs one year after the intervention

Fig. 9 Range of active movements in the wrist joint one year after surgery: *a* ulnar and radial abduction of the wrist; *b* flexion and extension of the wrist

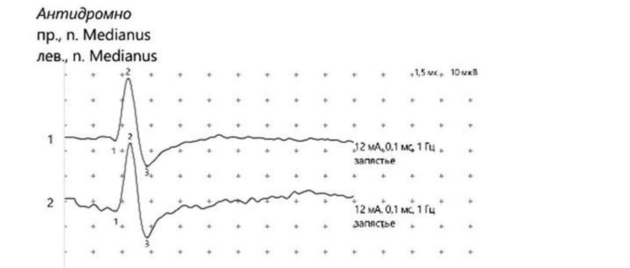
Fig. 10 Range of active movements in the wrist joint one year after surgery: *a* pronation and supination of the forearms; *b* measurement of the rough grip strength of the hands



Параметры М-ответа (амплитуда: негативный пик)

N	Точка стимуляции	Расст., мм	Лат., мс	Ампл., мВ	Норма ампл., мВ	Откл. ампл., %	Длит., мс	Скор., м/с
пр., Abductor pollicis brevis, Medianus, C8 T1								
1	запястье	55	3,0	9,7	7,0 (3,5-12,0)	(N)	5,9	
2	локтевой сгиб	210	6,5	8,9	7,0 (3,5-12,0)	(N)	6,4	60,3

a



Потенциал действия нерва (амплитуда: негативный пик, площадь: расчетный пик)

N	Точка стимуляции (отведения)	Расст., мм	Лат., мс	Норма лат., мс	Откл. лат., %	Ампл., мкВ	Норма ампл., мкВ	Откл. ампл., %	Скор., м/с
пр., n. Medianus									
1	запястье	130	2,6	2,8 (2,3-3,3)	(N)	24,5	15,0 (5,0-30,0)	(N)	50,8
лев., n. Medianus									
2	запястье	140	2,6	2,8 (2,3-3,3)	(N)	26,9	15,0 (5,0-30,0)	(N)	53,0

b

Fig. 11 ENMG parameters one year after surgery: a normalization of the M-response and conduction velocity along the motor fibers of the median nerve on the right wrist; b improvement of conduction velocity along the sensory fibers of the median nerve

DISCUSSION

The assertion of most hand surgeons that malunion of DMR fractures contributes to the development of DCTS and that the only way to eliminate or reduce the manifestations of this complication is surgical is beyond doubt. However, the question of the preferred approaches for corrective osteotomy and decompression of the median nerve does not have a clear answer.

Thus, Watanabe et al. convincingly proved that in DMR fractures, the displacement of the distal fragment together with the wrist significantly changes the anatomical relationships of the structures of the carpal canal, thereby causing morphological and functional disorders in the median nerve. According to the authors, DCTS almost always developed within 6 weeks to 6 months in dorsal displacement of the center of the head of the capitate bone by 1 cm or more from the palmar cortical plate of the radius. Therefore, the authors recommended paying special attention to these patients even in the acute period of injury and take adequate measures to prevent it [16].

Kim et al. examined 216 elderly patients with malunion of the DMR fracture and diagnosed DCTS in only 12 % of patients at least 6 weeks after the fracture. Independent predictors of this complication were radiographic criteria of the volar tilt (VT) and tear drop angle (TDA). Their multivariate logistic regression analysis found that for each degree of decrease in the volar tilt angle and tear drop angle, the probability of developing DCTS increased by 12 and 24 %, respectively [27]. In our patients, the volar tilt angle ranged from (+)28° to (–)45°. Moreover, all of them had both clinical and ENMG signs of DCTS.

Bourque et al. found that the removal of the plaster cast 6–8 weeks after injury caused paresthesia in the area innervated by the median nerve in 20 %, and after another week in 26 % of patients. However, ENMG performed at the same time did not detect signs of focal demyelination of the median nerve or “axon loss” in none of them [28].

In our 33 patients, nerve conduction disorders were recorded in all patients with ENMG study performed upon admission for surgical treatment. In 10 patients (30.3 %), ENMG changes corresponded to a severe grade, in 6 patients (18.2 %) to a moderate grade, and in the remaining 17 patients (51.5 %) to mild DCTS.

Stewart et al. found that in 235 patients with fractures of the DMF, aged 66 years on average, and treated conservatively, the rate of DCTS at 3 months after injury was 17 %, and 12 % 6 months later. The authors explained the relatively low DCTS rate by avoiding excessive flexion of the wrist when applying an immobilization plaster cast in the acute period of injury. Due to the developed DCTS, 8 patients (3.4 %) required surgical treatment. All of them underwent a standard decompression of the median nerve, with an incision at the level of the carpal tunnel (n = 7) and extended technique with another incision at the level of the fracture (n = 1). The PI of the articular surface of the DMR in them was ⩾ (+)12.6°. At the same time, patients with an inclination angle ⩽ (+)7° did not have DCTS symptoms [11]. This study clearly showed that DCTS does not develop in all patients with malunion of DMR fractures.

According to Kwasny et al., it is sufficient to perform isolated opening wedge osteotomy and osteosynthesis without median nerve release in malunion of DMR fracture complicated by DCTS in order to eliminate tension and compression of the median nerve. After such an operation, night pain stopped in 12 patients within 2 days, and tactile and pain sensitivity in the fingers was restored within 2 months. One patient required an additional operation, open decompression of the median nerve, which was performed 6 months after the first one. It should be noted that all patients were diagnosed with pronounced predominantly dorsal deformity of the articular surface of the radius in the sagittal plane ranging from (–)17° to (–)47°. The authors noted a direct proportional relationship between the duration of the clinical DCTS picture from the moment of its onset to surgery and the fair clinical results of restoration of the function of the median nerve [18].

Megerle et al. performed only corrective osteotomy with DMR osteosynthesis without additional intervention for decompression of the median nerve in 30 patients with malunion of the DMLC fracture accompanied by DCTS. Of these, clinical manifestations of DCTS before surgery were present in 7 patients (23.3 %), and ENMG disorders were present in 19 (63.3 %). In the late period, pain relief and improved sensitivity in the fingers were recorded in 10 patients (33.3 %). ENMG signs of improvement were revealed in 6 patients (20.0 %), and ENMG signs of normalization of nerve conduction were found in 4 patients (13.3 %). The authors concluded that corrective osteotomy is a self-sufficient treatment measure that effectively relieves the DCTS signs, and decompression of the median nerve in the carpal tunnel is indicated only in cases of DCTS that occurs before the injury and is associated with other causes, but not with a DMR fracture [19]. In our study, there were no patients with DCTS that occurred before the DMR fracture. In all of them, this complication developed in the late period, and reconstructive surgeries were performed within 3–13 months after the injury.

We believe that in the presence of clinical findings of DCTS, decompression of the median nerve, along with corrective osteotomy of the radius, is an indicated and even mandatory surgical intervention, regardless of DCTS severity. Moreover, chronic compression of the median nerve, in our opinion, requires not only the elimination of the DMR deformity and decompression of the nerve, but also its mobilization, and in moderate and severe DCTS - epineurotomy and neurolysis. In the present study, we noted a significant improvement in clinical, radiographic and ENMG characteristics in patients of both clinical groups, but to a greater extent in patients of the first group, who additionally underwent epineurotomy and neurolysis from a separate limited approach on the palmar surface of the wrist (OCTR approach).

Odumala et al. surgically treated 69 patients with DMR fractures without concomitant clinical DCTS and found that with simultaneous prophylactic decompression of the median nerve, complications such as its dysfunction developed in 38 % of patients. At the same time, in patients who did not undergo prophylactic decompression, the frequency of such complications was almost two times lower, amounting to 18 %. Thus, the authors stated that preventive decompression of the median nerve is inappropriate [29].

Niver et al. also believe that preventive release of the carpal tunnel during fracture fixation is inappropriate. The exception is patients who already had signs of CTS unrelated to trauma before the fracture. If decompression of the median nerve is still necessary, it should be performed through an incision along the tendon of the radial flexor carpi radialis or through a separate incision [30].

In our study, we used a separate Z-shaped incision with a total length of up to 4 cm for decompression of the median nerve in patients of the first group. We did not find a similar description in the available literature on the problem of DCTS. In its essence, this is a variant of the OCTR approach. What was important for us was that it allowed us to effectively perform not only decompression, but also epineurotomy and neurolysis, virtually eliminating the conflict with the motor and palmar sensory branches of the median nerve.

Weber et al. used an approach through the tendon of the radial flexor carpi radialis (a variant of the EFCR approach) to decompress the median nerve, which allowed them to sufficiently visualize the carpal tunnel without an auxiliary incision, significantly reduce the intensity of postoperative pain, and almost eliminate the incidence of postoperative complications. The authors claim that their method was effective in 91 % of clinical cases in terms of relieving DCTS symptoms [20].

Nevertheless, critics of this approach believe that its most frequent complication is damage to the motor branch of the median nerve. Therefore, Pensy et al. conducted a cadaveric study and found that the reverse motor branch of the median nerve most often passes 11 mm below the distal edge of the transverse ligament of the wrist. According to the authors, this parameter should be considered and will ensure safe dissection of the ligament, minimizing the likelihood of iatrogenic damage to the motor branch of the median nerve [31].

Gwathmey et al. performed DMR osteosynthesis in the acute period of injury and simultaneously performed preventive decompression of the median nerve in 65 patients (mean age, 48 years). To do this, the authors used an approach that allowed them to perform both osteosynthesis and dissection of the transverse carpal ligament along the radial side from a single skin incision, i.e. prophylactic decompression (a variant of the EFCR approach). According to them, this approach did not involve skin incision extension and its transition to the wrist. At the same time, it allowed avoiding direct contact with the median nerve. All patients had no signs of CTS before the operation. In the postoperative period, two developed late neuropathy of the median nerve, which did not require surgical correction. However, no one experienced complications associated with damage to the sensory or motor branches of the median nerve, or damage to the tendons [21].

Tannan et al. performed osteosynthesis with palmar plates in 27 patients with acute DMR fractures that did not have signs of acute CTS in a prospective study. For this purpose, the EFCR approach was used in 15 patients (the first group), with simultaneous preventive decompression of the median nerve, and the traditional Henry (VH) approach along the anterior surface of the forearm, which involves only DMR osteosynthesis was used in 12 patients (the second group). In both groups, a significant improvement in the function of the upper limb and an increase in the grip strength of the hand were noted. However, in the first group, statistically significant improvement was achieved after 1.5 months, and in the second after 3 months after surgery. The authors concluded that it is advisable to simultaneously perform osteosynthesis and prophylactic release of the median nerve with the preferred use of the EFCR approach [23].

The results of our study indicate that the EFCR approach should be recommended for patients with mild DCTS and predominantly palmar DMR deformity, when there is no need for nerve mobilization, epineurotomy, and neurolysis. In patients with moderate and severe DCTS, as well as with intermediate and predominantly dorsal DMR deformity, the OCTR approach is most appropriate. An appropriate limited incision on the palmar surface of the wrist allows for minimally traumatic and at the same time maximally effective decompression, epineurotomy, and neurolysis, prevents the formation of a linear constricting scar in the area of the palmar crease of the wrist, and minimizes the risk of damage to the superficial palmar branch of the median nerve.

CONCLUSION

Corrective osteotomy and simultaneous decompression of the median nerve in patients with malunited DMR fractures and developed DCTS is an effective and reliable method of surgical correction of the resulting complication.

In mild DCTS, as well as in cases of predominantly palmar DMR deformity, it is advisable to perform decompression of the median nerve through the EFCR approach, which involves an incision in the lower third of the forearm.

In moderate and severe DCTS, as well as in intermediate and predominantly dorsal DMR deformity, decompression of the median nerve should be performed through the OCTR approach, which involves a separate limited incision on the palmar surface of the wrist.

In most patients, regardless of the DCTS severity, corrective osteotomy and osteosynthesis of the distal metaepiphysis of the radius are best performed through an incision in the lower third of the forearm along its anterior surface. However, in patients with predominantly dorsal deformity, it is advisable to use an additional mini-incision on the dorsal surface of the forearm, which enables o reduce and ensure strong fixation of bone fragments as correctly as possible.

Conflict of interests *The authors confirm that they have no conflict of interest. .*
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