doi: 10.21823/2311-2905-2020-26-1-76-84

Minimally Invasive Plate Osteosynthesis for Distal Radius Fractures: Are There Any Advantages Against Conventional Technique?

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Abstract

Purpose of the study — to illustrate the potential and to evaluate the late term results of minimally invasive plate fixation for distal radius fractures (DRF) and compare it to the treatment outcomes for patients with similar injuries where internal fixation was performed through conventional volar surgical approach. ***Material and Methods.*** 96 patients with DRF fractures were included into the study who underwent volar plate fixation by with angular stability. The main group included 42 patients (29 women and 13 men) with DRF where minimally invasive volar approach was used. Mean age of patients was 38 years (from 21 to 57 years). Control group consisted of 54 patients (33 women and 21 men) with mean age of 43 years (from 26 to 64 years) who underwent fracture stabilization via conventional volar approach. Minimal follow up after surgery and discharge was 3 months. In the late period roentgenological, functional and cosmetic outcomes were evaluated as well as patients' satisfaction by QuickDASH-9 survey. ***Results.*** 95 patients (98.9%) demonstrated fracture consolidation in terms up to 6 weeks irrespective of surgical technique which was confirmed by X-rays during control examination. In one female patient (1.1%) consolidation following minimally invasive plating was not achieved even in one year after surgery which was considered as distal radius pseudarthrosis but featuring excellent functional outcome. Surgery time for minimally invasive fixation was 47 (41;53) minutes and for conventional surgical approach – 43 (37;46) minutes (p = 0.731). Mean time of image intensifier use during internal fixation averaged 54 (47;63) seconds during minimally invasive technique and 33 (29;37) seconds for conventional open technique (p = 0.046). Statistically significant larger flexion and extension ranges, pronation and supination angles as well as higher grip force were observed in the group of minimally invasive internal fixation in 1, 2 and 3 months after the surgery (p<0.001). Statistically lower scores for QuickDASH-9 survey were reported for the main group in 2 and 3 months postoperatively (p<0.001). Cosmetic results were better in patients after minimally invasive approach. ***Conclusion.*** Minimally invasive plating fixation of DRF is the efficient and relatively safe surgical option for such injuries. The key arguments for such approach: preservation of bone vascularization which minimally slows down fracture healing, reduced risk of infectious complications, fast functional wrist recovery already in early postoperative period as well as satisfaction of patients with cosmetic effects.

Keywords: minimally invasive approach, internal fixation, distal radius, volar plate, quadrate pronator muscle.

Cite as: Maximov B.I. [Minimally Invasive Plate Osteosynthesis for Distal Radius Fractures: Are There Any Advantages Against Conventional Technique?]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2020;26(1):76-84. doi: 10.21823/2311-2905-2020-26-1-76-84. (In Russian).

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Received: 02.08.2019. Accepted for publication: 22.01.2020.

Introduction

Fractures of на distal radius fractures (DRF) pose a serious medical and social challenge being the most frequent fractures of the upper extremity and one of the most frequent injuries of the locomotor system [1]. In particular over 600 000 new clinical cases are registered annually in the USA [2]. Besides, trauma and orthopaedic surgeons often face complex unstable fractures that require open reduction of bone fragments and internal fixation by various implants [3].

Today the most common option for surgical treatment of DRF fractures is fixation by angular stability plates [4]. Such procedures are performed through a 8–10 cm surgical incision along the volar aspect of the lower third of forearm. We can hardly dispute potential damage of the skin incision itself, excluding cosmetics, but the subsequent manipulations of the surgeon on adjacent soft tissues, muscles primarily, can significantly impact the outcome.

More and more publications has been available in the scientific literature in recent years reporting successful application of minimally invasive surgical approaches for internal fixation of DRF fractures by plates with angular stability placed upon the volar aspect of the forearm [5, 6]. Historically, the minimally invasive plating fixation was first described and introduced into clinical practice for treatment of comminuted fractures of the lower limb complicated by damage of adjacent soft tissues. The essence of the suggested method was the maximally delicate treatment of damaged skin and muscles as well as minimal degloving of bone fragments to preserve blood supply which is of critical importance for further fracture consolidation. The fractures were fixed by plates inserted through submuscular tunnels without soft tissue dissection.

In the early XXI century the minimally invasive internal fixation was started to be applied for treatment of DRF fractures [7]. Recently there are more and more scientific publications reporting successful use of the minimally invasive surgical procedures for treatment of not only simple, but also complex comminuted fractures of the distal forearm [8, 9, 10]. The key arguments supporting this surgical technique are as follows: preserved blood supply minimizing the risk of delayed fracture union, reduced risk of infectious complications, as well as patients' satisfaction with treatment outcome [11, 12]. Besides, it should be noted that classical volar approach requires dissection of quadrate pronator from its attachment on the lateral border of ulna. Some authors suppose that this may result in 20% loss of forearm pronation force [13] despite subsequent re-fixation of pronator during the surgery.

The purpose of the study — to illustrate the potential, evaluate the late term efficiency of minimally invasive plate fixation for fractures of на distal radius fractures (DRF) and compare it to the outcomes of treatment for patients with similar injuries by internal fixation through a conventional volar surgical approach.

Material and Methods

From November 2015 till December 2018 214 patients with DRF fractures underwent surgery using volar plates with angular stability. The following inclusion criteria for study groups were defined to ensure a more precise statistical retrospective analysis of obtained data:

– Age of patients over 21 and below 65 years;
– Isolated fracture of distal forearm;
– Closed fracture;
– I, II, III type fractures by classification of D.L. Fernandez [14];
– Time from injury not exceeding 7 days;
– Consent of the patient.

Exclusion criteria:

– Dorsal Barton fractures (subgroup of type II by D.L. Fernandez classification) while those require dorsal surgical approaches;
– Open fracture;

– Time from fracture over 7 days;
– Supplementary fracture fixation by K-wires;
– Combination of DRF fracture with distal ulna fracture (excluding fractures of the styloid process).

Thus, the study included 96 patients with DRF fractures who underwent surgical fixation of fractures by volar plates with angular stability.

Depending on the surgical approach used, the patients were divided into two groups comparable in terms of all inclusion criteria.

The main group included 42 patients (29 women and 13 men) who underwent internal fixation through the minimally invasive volar approach [11]. The method consists of two small skin incisions (Fig. 1) preserving integrity of quadrate pronator of the forearm and demarcating the tendons of anterior forearm surface. Degloving of bone fragments was minimal (preserving blood supply), tendons of anterior forearm surface and inserted plate were demarcated, and active stabilization of distal radioulnar joint was preserved. Mean age of patients was 38 years old (standard deviation (SD) 8.7 years; minimal 21 and maximal 57 years). Fracture distribution per D.L. Fernandez classification was as follows: type I — 24 cases (57%), type II — 7 (17%), type III — 11 (26%).

Control group included 54 patients (33 women, 21 men) who underwent DRF fracture fixation was performed by conventional volar surgical approach popularized by J. Orbay and D.L. Fernandez [15] (Fig. 2).

Fig. 1. Skin incisions for minimally invasive approach

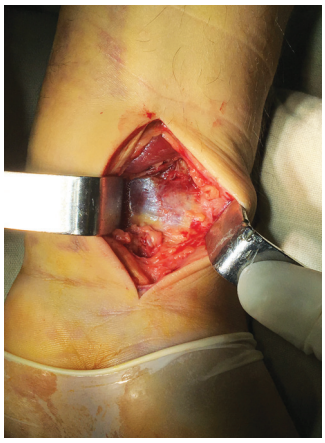

Fig. 2. Standard volar incision

Mean age of patients in this group was 43 years old (SD — 2.1 years), range from 26 to 64 years. Fracture distribution per D.L. Fernandez classification in this group was as follows: type I — 21 (39%) cases, type II — 14 (26%), type III — 19 (35%). Both groups were comparable in gender (two-tailed Fischer exact test) p = 0.519), age (Student *t*-test, $p = 0.674$), fracture type by D.L. Fernandez (χ^2, $p = 0.233$).

It should be noted that all procedures were performed by the same surgical team who fixed acute isolated trauma by volar plates with angular stability of the screws. In 23 cases (10 cases in the main group and 13 — in control group) the authors reported concomitant fracture of the styloid process without or with a minor displacement which did not require active surgical manipulations. During surgeries in both groups the authors evaluated such parameters as the overall time of procedure and application time of image intensifier which determines radiation exposure for the patient and the surgical team.

There were no differences in terms of patients follow up in postoperative period. After surgery and discharge from hospital the minimal follow up term was 3 months, regular clinical examinations were completed in 2, 4, 8 and 12 weeks. In the late follow up period the authors evaluated roentgenological (fracture healing, palmar inclination of articular facet of the radius, height of the radius, radial inclination, joint congruity as well as

congruity of the radioulnar joint), functional (wrist flexion-extension, forearm pronation-supination, grip force of the wrist) and cosmetic outcomes as well as satisfaction of patients by QuickDASH-9 questionnaire.

Statistical analysis

Критический уровень значимости при проверке статистических гипотез принимали равным 0.05. Statistical processing was done using Statistica 10.0 (StatSoft Inc., США) software. To demonstrate quantitative continuous characters (abnormal distribution) and qualitative ordinal characters the results were presented in form of a median, upper and lower quartile (interquartile range); to demonstrate quantitative character with normal distribution — as a mean value and SD. Mann Whitney U-test was used to evaluate group differences by qualitative ordinal and quantitative continuous characters. Wilcoxon test was used to calculate statistical significance of dynamic changes in the characters. The critical level of significance was taken equal to 0.05 in testing statistical hypotheses.

Results

Comparative evaluation of time for surgery by described methods demonstrated the following: in the main group of minimally invasive plating fixation the minimal and maximal surgery time was 39 and 57 minutes, median of 47 (41;53) min while values distribution in case of conventional surgical technique was from 27 to 58 minutes, median of 43 (37;46) min. No statistically significant variances were observed (p = 0.731). Total time of image intensifier exposure in the OR varied from 43 to 71 sec with median of 54 (47;63) sec during DRF fractures fixation by minimally invasive technique, and from 26 to 39 sec with median of 33 (29;37) sec during conventional open procedure. The authors reported statistically significant variances (p = 0.046).

Outcomes of surgical treatment for patients with DRF fractures were followed up and evaluated in all patients of the main (n = 42) and control groups (n = 54), and the mean follow up term was 6,2 months (from 3 to 14 months). In 41 patients (97.6%) of the main group fracture consolidation was achieved in terms up to 6 weeks after surgery which was confirmed roentgenologically during control examination. One female patient (2.4%) did not demonstrate fracture healing in one year postoperatively which was considered as DRF pseudarthrosis, however, with excellent functional outcome.

3 patients (7%) of the main group observed lack of skin sensitivity in the thenar area postoperatively due to iatrogenic injury of palmar branch of median nerve during surgery. None the less, all three patients recovered sensitivity within 6 months after surgery. Excellent cosmetic result was reported in all patients.

Fracture healing in the control group occurred in all patients in terms up to 6 weeks postoperatively which was confirmed roentgenologically. No complications were reported in control group. Accuracy of healing in both groups was evaluated based on normal values of roentgen-anatomical parameters such as palmar inclination of articular facet of the radius, radius height and radial inclination. It should be noted that recovery of above parameters did not depend on the approach used but was the primary goal of the internal fixation, so no comparison with statistical methods was made.

Key roentgenological treatment outcomes of patients in both groups are given in Table 1.

Evaluation of dynamics of postoperative recovery for wrist flexion-extension, forearm rotation and grip force of the wrist was performed in 1, 2 and 3 months after fixation. Results are given in Table 2.

Table 1

Roentgenological outcomes of internal fixation in patients of both groups with various DRF fractures

Roentgenological parameters	Patient groups					
	Main (minimally invasive volar approach), *n* = 42			Control (standard volar approach), *n* = 54		
	Fernandez type I (*n* = 24)	Fernandez type II (*n* = 7)	Fernandez type III (*n* = 11)	Fernandez type I (*n* = 21)	Fernandez type II (*n* = 14)	Fernandez type III (*n* = 19)
Volar inclination, degree	11 (CO 0,7)	11 (CO 3,11)	10 (CO 2,83)	11 (CO 3,3)	10 (CO 1,3)	11 (CO 1,21)
Radius height, mm	10 (CO 1,3)	11 (CO 1,9)	11 (CO 0,7)	11 (CO 0,7)	11 (CO 0,9)	11 (CO 1,3)
Inclination of radius, degree	22 (CO 0,94)	21 (CO 3,88)	21 (CO 4,6)	23 (CO 1,54)	21 (CO 2,66)	21 (CO 4,43)

Table 2

Dynamics of functional wrist and hand recovery after internal fixation in patients of two clinical groups

Parameter	Functional parameters (mean values)								
	1 month after fixation		*p*	2 months after fixation		*p*	3 months after fixation		*p*
	Main group	Control group		Main group	Control group		Main group	Control group	
Flexion, degree	68 (68;70)	60 (59;62)	<0.001	72 (71;72)	68 (68;69)	<0.001	74 (73;74)	72 (72;73)	<0.001
Extension, degree	61 (59;62)	56 (55;57)	<0.001	69 (68;69)	64 (64;66)	<0.001	69 (68;70)	67 (67;68)	<0.001
Supination, degree	81 (79;82)	74 (73;76)	<0.001	83 (82;84)	79 (78;79)	<0.001	84 (84;85)	83 (82;84)	<0.001
Pronation, degree	68 (67;68)	60 (58;63)	<0.001	69 (68;70)	62 (62;63)	<0.001	70 (69;70)	65 (64;65)	<0.001
Grip force, % against contralateral hand	78 (76;79)	60 (59;64)	<0.001	85 (84;86)	77 (74;78)	<0.001	93 (92;94)	86 (84;86)	<0.001

The authors demonstrated that in 1 month postoperatively in the patients who underwent minimally invasive surgery wrist flexion constituted 93% of normal values, while after conventional surgery — 83,2%. At the same time extension was 85,6% and 78,4%, respectively. The authors explain such values by preservation of quadrate pronator muscle which demarcated tendons of anterior forearm surface and implants and minimized their contact with tendons. This allowed the patients to do pain free and active rehabilitation. Functional parameters of forearm rotation and wrist grip force were also higher in the main group: supination — 92,7% against 84,9% in control group, pronation — 97,4%

against 86.6% in control group, wrist grip force 78% (76;79) against 60% (59;64) in control group. Statistically significant greater values of all measured parameters were observed in 1, 2 and 3 months postoperatively (p<0.001) in the group of minimally invasive fixation.

Patients' satisfaction with treatment outcomes in 1, 2 and 3 months based on QuickDASH-9 questionnaire is given on chart (Fig. 3).

Comparable outcomes in both groups in 1 month after surgery were reported (p = 0.653). However, QuickDASH-9 scores in 2 and 3 months after surgery were lower in the main group of patients which corresponds to a higher satisfaction with surgery due to better functional wrist recovery as compared to control group. Statistically significant variance was observed between the groups (p<0.001 in 2 and in 3 months).

Discussion

Internal fixation of DRF fractures with volar plates with angular stability is the golden standard currently. This technique provides precise reduction and stable fixation and demonstrates significantly less complications and unsatisfactory later outcomes as compared to extrafocal fixation, dorsal implants or conservative plaster cast treatment [16].

Surgical approach is the key stage of the procedure accuracy of which impacts not only other manipulations of the surgeon for reduction and final fixation of bone fragments by an implant but, possibly, bone perfusion. Currently such procedures are mainly performed using standard volar approach popularized by J. Orbay et al [15]. However, volar approach in its classical version is rather aggressive stipulating dissection of functionally important anatomical structures and the need for their further restoration. In particular, dissection of quadrate pronator muscle. Blood vessels that perfuse distal radius are also damaged and this might affect fracture healing and viability of small bone fragments [5, 8].

Refixation of quadrate pronator is a key stage of surgery while apart from supply function this muscle provides demarcation of implant (volar plate) from tendons on the anterior surface of forearm and is the active stabilizer for distal radioulnar joint [17]. However, the full-fledged refixation of pronator (in terms of muscle stability and complete coverage of implant) is not always tech-

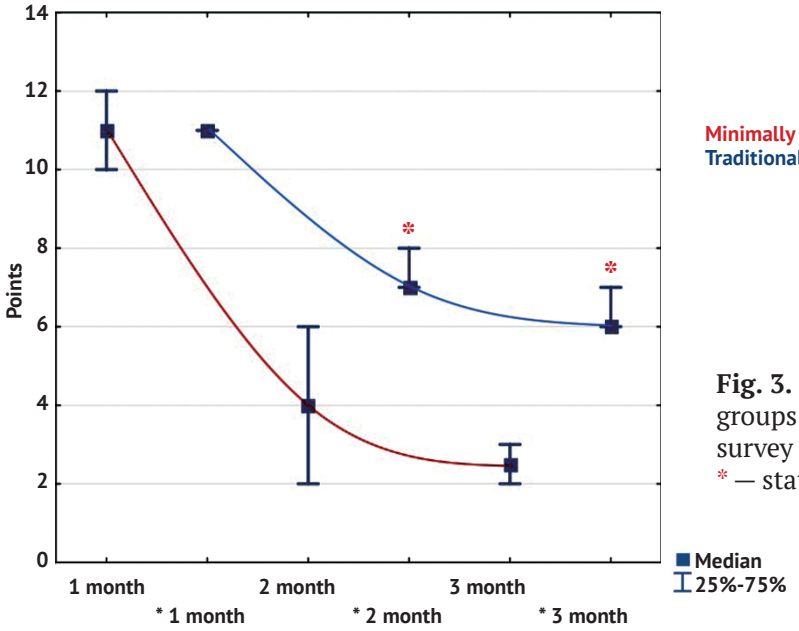

Fig. 3. Satisfaction of patients in two clinical groups with surgery outcomes by QuickDASH-9 survey
* — statistically significant variances

nically feasible [18]. This might be caused by substantial muscle damage during injury and failure of muscular sutures due to cut out that result to implant under-coverage and its direct contact to superior tendons of anterior surface of the forearm [18, 19]. Besides, some authors report that postoperative scarring at the area of surgical wound and in pronator may result in chronic pain and functional limitations of the forearm, primarily — rotation [5]. M. Armangil et al reported some interesting facts: detachment of quadrate pronator from its ulna attachment site during conventional volar approach results in loss up to 20% of forearm pronation force [13].

What was the evolution of trauma and orthopaedic surgeons' views on the surgical approach to DRF fractures? Minimally invasive internal fixation was introduced into practical trauma surgery in order to preserve bone perfusion improving healing process, to reduce risk of infectious complications after open reduction, as well as patients' satisfaction with aesthetic results of surgery. Over time, the favorable outcomes of such approach for treatment of various locomotor fractures [20, 21] contributed to spreading the minimally invasive philosophy towards treatment of DRF fractures [7].

J. Imatani et al were the first to publish in 2005 their treatment results of comminuted DRF fractures using minimally invasive technique [5]. Present literature describes several options of minimally invasive volar approaches which differ only in geometry of placing the skin incisions [11, 12]. The most important and fundamentally common between them — preserving the integrity of quadrate pronator muscle. Today this approach is being widely applied in practical trauma and wrist surgeons [18, 22, 23] demonstrating excellent functional and esthetic results. So, X.M. Wei et al reported safe and efficient minimally invasive internal fixation by volar plates with angular stability noting comparable X-ray treatment results in comparison to conventional fixation through standard volar approaches and better outcomes in terms of early functional and esthetic results [12]. Similar data was presented by Y. Zenke et al [8].

However, there were no publications on this method in Russia which encouraged the authors to study such surgery option and introduce it into regular practice [11]. Early and late outcomes obtained during accumulation of experience with minimally invasive volar approach demonstrate the efficiency of this method for patients with extra-articular and simple intra-articular DRF fractures. This technique allows stable fixation of radius fragments in correct positioning for the whole period of bone healing, ensuring early rehabilitation without additional external immobilization.

The key advantages of minimally invasive internal fixation allowing to reduce surgical aggression is the preservation of quadrate pronator and periosteum supplying bone fragments at the area of fracture and favorably influencing healing process. Besides, such pronator-preserving approach provides for active stabilization of distal radioulnar joint and reduces the postoperative risk for conflict of tendons of anterior forearm and plate by muscle interposition.

Without diminishing the stated advantages of minimally invasive osteosynthesis of DRF fractures, it is worth noting its disadvantages. The approach limits visualization and requires high skills from surgeon in terms of indirect bone reduction and intraoperative roentgenography. Otherwise, general time of surgery and the number of intraoperative X-ray scans increases, and the possibility of precise reduction for complex intraarticular comminuted fractures is limited which primarily is the more important aim of surgery rather than esthetic outcome and preservation of quadrate pronator. Besides, transverse skin incision in the area of proximal palmar ligament bears a risk of iatrogenic injury to palmar branch of median nerve

originating from main nerve trunk in this area. So, S. McKay et al report that frequency of such complication can reach 17% [24]. In own practice the authors observed such complication in 3 cases (7%). Non the less sensitivity in all three patients recovered within half a year from surgery. Use of transverse surgical approach aimed to follow cleavage lines to establish maximally favorable conditions for skin healing and reducing the risk of coarse scarring. To prevent intraoperative injury to the branch of median nerve during surgical approach, scalpel should be used only within skin layer and further dissections to be made by mosquito clips. Following this rule allowed preventing such complication in other patients.

Another drawback of the minimally invasive approach is lack of full visualization of tendons on anterior forearm surface. During plate fixation this might result in compression of a tendon towards bone (most often flexor pollicis longus tendon) with subsequent functional deficit. Finally, in case of intraoperative difficulties this approach has no option for extension which it should be taken into account at the stage of preoperative planning when assessing the injury and possible complexities during reduction and fixation.

The experience of the authors in use of minimally invasive internal fixation for DRF fractures confirms the promising nature of this method and its efficiency. In particular, the patients who underwent minimally invasive procedure demonstrate faster recovery of wrist range of motion and sooner return of pain free function and active work which is critical in today's reality. Besides, preserving the quadrate pronator of the forearm and good cosmetic effect of minimally invasive approach make this procedure attractive and promising for wide practical application.

The authors would like to note that exactly the possibility of early functional recovery and esthetic outcome are the main arguments in favor of the minimally invasive internal fixation of DRF fractures. However, despite the advantages described above and obtained results we would like to caution surgeons (especially, beginners) in respect of wide application of this method for all DRF fracture types. Minimally invasive internal fixation for DRF fractures is indicated and efficient only for stabilization of extra-articular and simple intra-articular DRF fractures subject to easy manual closed reduction.

Competing interests: the authors declare that there are no competing interests.

Funding: state budgetary funding.

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