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Long-term outcomes and complications associated with operative and nonoperative treatment of distal radius fractures. Do we need to restore anatomy to have satisfactory clinical outcome?

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Abstract: Aim: The aim of this study was to assess long-term outcomes and complications associated with conservative and operative treatment of distal radius fractures and to determine if restoration of radiographic parameters influences functional outcomes.
Introduction: Distal radius fractures (DRFs) are common injuries associated with many complications. Numerous studies suggest that operative treatment with anatomic reduction and restoration of radiographic parameters leads to better functional outcomes than nonsurgical treatment.
Materials and Methods: We enrolled 207 patients with isolated DRF (mean age 64 ± 17.9 years, women 150 (72.5%)) to our retrospective, single-center study (101 treated operatively, 106 treated nonoperatively). There were no significant differences in sex, age, AO type fracture between study groups. After 3.9 ± 1.6 years (mean ± SD) clinical, functional and radiological assessment was conducted using Disabilities of the Arm, Shoulder and Hand (DASH), Patient Rated Wrist Evaluation (PRWE), 9-Hole Peg Test (9-HPT), grip and pinch strength tools.
Results: We found higher rates of malunion in nonoperative group ($p < 0.0001$) and worse radiologic parameters such as volar tilt ($p < 0.0001$), teardrop angle ($p < 0.0001$) versus operative cohort. Nevertheless radiological parameters were not correlated with DASH and PRWE results. Moreover, patients aged 50 years and above treated operatively had similar functional outcomes (DASH, PRWE) to those treated nonoperatively.
Conclusions: Restoration of anatomic and thus radiologic parameters of radius may not be obligatory to achieve satisfactory functional outcome in patients with DRF aged 50 years or above. Patient is the most important 'factor' in determining appropriate and successful treatment method of distal radius fractures.

Key words: distal radius fracture, nonoperative treatment, surgical treatment, functional outcomes, DASH, PRWE, 9-HPT, grip strength.

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Introduction

Distal radius fractures (DRFs) are the most common orthopedic injuries reported worldwide [1] and can be treated either by operative or nonoperative techniques [2, 3]. The choice of a proper method is extremely important. Appropriate management of DRF is essential due to possible long-term complications including physical activity limitations and chronic pain [4].

Nonoperative treatment involves fracture closed reduction followed by cast immobilization. That type of treatment is recommended for fractures with stable configuration, as well as fractures with unstable configuration in 'low demanding' patients. The area of the distal end of the radial bone is well supplied with blood, which determines high healing potential. However, the main challenge of nonsurgical treatment are more frequently occurring secondary displacements leading to malunions. For this reason, surgical treatment is recommended in certain groups of patients. Currently, volar plating technique increasingly dominates the world trends in surgically reduction of the distal radius fracture [5].

Numerous recent studies suggested that operative treatment with anatomic reduction and restoration of radiographic parameters offers better functional outcomes [5, 6] resulting in increasing rates of performed surgeries. However, it is unclear if operative anatomic restoration translates to improved functionality. Several studies comparing operative and nonoperative treatment of DRFs in selected cohorts reported no significant differences in functional outcomes and complication rates [7, 8]. In consequence correspondence of surgical radiographic measurements and functional outcomes in distal radius fractures is controversial [9]. The long-term results concerning complications and functional outcomes after distal radius fractures are contradictory so the choice of proper treatment method is unclear. No consensus has been reached so far regarding the optimal treatment method.

The primary aim of this study was to assess the long-term outcomes and complications of operative and nonoperative treatment of distal radius fracture among young and elderly adults. The secondary aim was to determine if demographic data, especially age, type of fracture, type of treatment, selected radiologic parameters influenced long-term functional outcomes in distal radius fractures cohort.

Materials and Methods

Participants

We identified all consecutive patients hospitalized between January 1st 2008 and May 30th 2015 with distal radius fracture in 1st level trauma center in Cracow, Poland. The identification process was two-step, based on International Classification of Diseases

10th Revision (ICD10) codes and then radiographic assessment to confirm the diagnosis. We have appointed inclusion criteria as follows: age ≥18 years, isolated distal radius fracture confirmed by x-ray examination. Multitrauma and oncologic patients were excluded from the study. From 1774 identified eligible participants divided into operative and nonoperative groups we have randomly chosen 240 patients: 120 treated surgically and 120 nonsurgically who were contacted via phone or mail. Of approached 240 patients, 29 patients declined to enter the study, 4 were deceased. Observation period was at least 1 year after DRF. All participants gave written informed consent.

Clinical and radiological assessment

Each participant fulfilled questionnaire including data on inter alia: age at the time of trauma, sex, hand side of fracture, hand dominance, education, smoking, work status, time of medical leave. Energy of injury was classified bimodal as low-defined as fractures due to falls from standing height, and high energy as any other fall from greater than standing height i.e. fall downstairs, from ladder or traffic accident. Senior orthopedic hand surgeon specialist and resident assessed dually and simultaneously the prereduction, post reduction and study final radiographs. Assessment of radiographs was conducted as proposed by Medoff [10]. Fractures were classified using i.a. AO classification determining AO type and subtype. During an appointment standard posteroanterior and lateral radiographs of fractured and contralateral side were taken. Radiographic parameters such as radial length, ulnar variance, volar tilt, teardrop angle, anteroposterior distance were assessed. Radiographic outcomes were based on final patient x-ray. Range of motion (ROM) was measured using standard goniometer. All measurements were obtained using the same model goniometer, measurement technique and were performed by the same investigator. To assess the hand sensation and possible neuropathies we used Semmes-Weinstein monofilaments [11]. Additionally, to evaluate long-term functional outcomes we used following tools: Patient Rated Wrist Evaluation (PRWE), Disabilities of the Arm, Shoulder and Hand (DASH), Nine Hole Peg Test (9-HPT). Hand grip and pinch strength data were collected. All surveys and procedures were supervised by an orthopedic surgeon.

PRWE

Patient Rated Wrist Evaluation (PRWE) is a patient reported survey, in which the patient subjectively rates his wrist pain in five groups in scale from 0 to 10 each and assesses his wrist functionality during specific and usual activities. Specific activities are divided into six groups, and usual activities into four groups, each regarding to different physical exercise and rated in scale from 0 to 10 and then divided by two.

The overall results were summed up and formed score ranging from 0 to 100 points. The score of 100 is equivalent to maximum disability and pain and the score of zero is equivalent to no disability and no pain [10].

DASH

The Disabilities of the Arm, Shoulder and Hand (DASH) is a patient reported questionnaire designed to measure physical functions and symptoms in patients with musculoskeletal disabilities of the upper extremity. It is composed of 30 questions scored from 1 to 5 point scale (Likert scale). The overall results from each question were summed up and formed a score ranging from 30 to 150. Then the proper outcome is measured using special formula = ([(sum of n responses)/n] –1) (25) where n represents the number of completed answers. As a result of conversion, scores formed a scale from 0 to 100 points. The lower the score the better the physical functions and the higher the score the worse the physical functions. In this study we have used the translated and validated Polish version of the DASH questionnaire [12].

9-HPT

Nine Hole Peg Test (9-HPT) is a standardized trial used to measure finger dexterity. A small board with 9 holes was positioned in front of the subjects and the pegs container was placed on the side of the dominant hand. Patients were instructed to adjust individually the table height and the chair distance to their preferences. The timer was started when the patient touched the first peg and was stopped when the patient placed the last peg in the board [13]. The shortest time, in seconds, of two independent attempts with each hand was used in the study.

Grip and pinch strength

Grip strength was assessed with a Jamar hand held dynamometer [14], while participants were seated comfortably in a chair, had their elbow flexed with the forearm and wrist in a neutral position, in accordance to guidelines of American Society of Hand Therapists [15]. Participants were requested to complete three trials of hand grip strength for 2 to 3 seconds with each hand with 15 seconds breaks between each measurement to avoid muscle fatigue. The mean of the three trials was calculated. The second handle position was chosen as it is the most effective position for engaging hand muscles [16]. We assessed tip pinch strength with a Jamar hand held dynamometer [14]. The patient was asked to pinch with maximum force, alternating between hands. The mean of three trial was calculated.

Statistical analysis

Sample size was calculated based on previous studies available. Continuous variables are presented as mean ± standard deviation (SD) or median and interquartile range (Q1–Q3), depending on the normality of distribution. The normality of distribution was tested using the Shapiro–Wilk test. Intergroup comparisons were analyzed using t-test for independent samples, or Mann–Whitney U test. The correlation was evaluated by Spearman's correlation test. To assess changes between two categorical variables we used chi-squared test. In the cases of 2 × 2 contingency tables Yates correction was applied. Multivariate regression analysis was used to determine the independent influence of treatment modality on the functional outcomes. All p-values are two-sided, $p < 0.05$ was considered statistically significant. All calculations were performed using Statistica 13 (TIBCO Software Inc. USA).

Ethical approval

The study was approved by the Local Chamber of Physicians and Dentists Bioethics Committee in Cracow, approval no: 141/KBL/OIL/2015. All the procedures complied with the Helsinki Declaration.

Results

We enrolled 207 patients with distal radius fractures: 101 treated operatively, 106 treated nonoperatively. Mean age of entire cohort was 64 ± 17.9 years. Women comprised of 150 (72.5%), men 57 (27.5 %); mean observation time was 3.9 ± 1.6 years; ranged from minimum 1.1 to 8.1 years. There were no statistically significant differences in analyzed operative an nonoperative cohorts in mean age, sex, hand dominancy, trauma energy, smoking, comorbidities and education or AO fracture types distribution. Nonoperative cohort had higher ratios of unemployed and retired patients compared to the operative group. Furthermore, time of leave due to DRF was significantly higher in nonsurgically treated patients. Detailed demographic and fracture characteristics of study subgroups are shown in Table 1.

Distal radius fracture can be treated either operatively or nonoperatively. Recruited patients were treated by reduction of the fracture and stabilization. Operative stabilization was made by volar plating or percutaneus pinning and cast immobilization. Nonoperative cohort was treated by manual reduction and short arm cast as presented in Table 2.

The most common long-term complication was pain syndrome which affected 59.4% of studied population. Loss of motion and arthritis are widespread complications after distal radius fractures, but they were not specifically related to the type of

Table 1. Study group characteristics. SD — standard deviation, DRF — distal radius fracture, AO Foundation fracture classification system.

	Operative n = 101	Nonoperative n = 106	P value
Age mean ± SD (years)	64.5 ± 17.7	65.1 ± 18.5	>0.05
Women, n (%)	71 (70.3)	79 (74.5)	>0.05
Right hand DRF, n (%)	45 (44.6)	46 (43.4)	>0.05
Dominant hand DRF, n (%)	42 (41.6)	41 (38.7)	>0.05
Low energy trauma, n (%)	73 (72.3)	86 (81.1)	>0.05
Smoking, n (%)	30 (29.7)	34 (32.1)	>0.05
Comorbidities, n (%)	48 (47.5)	54 (50.9)	>0.05
Education			
Primary, n (%)	8 (7.9)	8 (7.5)	>0.05
Secondary, n (%)	44 (43.6)	46 (43.4)	
Tertiary, n (%)	49 (48.5)	52 (49.1)	
Working status, n (%)			
employed	51 (50.5)	35 (33.0)	0.01
unemployed	6 (5.9)	17 (16.0)	
retired	44 (43.6)	54 (50.1)	
Leave due to DRF (months)	3 (1.5-6)	4 (2-6)	0.03
AO fracture type, n (%)			
AO type A	22 (21.8)	29 (27.4)	>0.05
AO type B	11 (10.9)	21 (19.8)	
AO type C	68 (67.3)	56 (52.8)	

Table 2. Treatment methods of distal radius fractures in study groups.

Treatment method	Operative n = 101	Nonoperative n = 106
Volar plating	87 (86.1 %)	—
Percutaneus pinning + cast	14 (13.9 %)	—
Cast only	—	106 (100 %)

DRF treatment. Nonoperative cohort has higher rates of malunion compared to operative group, but it was not correlated with higher pain rates (p >0.05). Ulnar nerve neuropathy was observed only in operative group. No significant difference in total number of complications between operative and nonsurgical group was noted. Detailed list and frequency of long-term complications after DRF in our study cohorts were presented in Table 3.

Table 3. Long-term complications after distal radius fractures.

Complication type	No. (%)			P-value
	Total n = 207	Operative n = 101	Nonoperative n = 106	
Arthritis	66 (31.9)	30 (29.7)	36 (34.0)	>0.05
Malunion	98 (47.3)	28 (27.7)	70 (66.0)	<0.0001
Pain syndromes (persistent pain, weather-related pain)	123 (59.4)	58 (57.4)	65 (61.3)	>0.05
Median nerve neuropathy	43 (20.8)	21 (20.8)	22 (20.8)	>0.05
Ulnar nerve neuropathy	5 (2.4)	5 (5.0)	—	0.02
Radial nerve neuropathy	8 (3.9)	3 (3.0)	5 (4.7)	>0.05
Loss of motion (wrist or digit stiffness)	81 (39.1)	37 (36.6)	44 (41.5)	>0.05
Swelling	37 (17.9)	20 (19.8)	17 (16.0)	>0.05
Tendon complications (rupture, trigger, tenosynovitis)	5 (2.4)	2 (2.0)	3 (2.8)	>0.05
Total	466 (25.0)	204 (22.4)	262 (27.4)	>0.05

Nonoperative patients presented unfavorable radiological results compared to patients treated surgically, as shown in Table 4. Similar significant results concerning selected radiological parameters were obtained after subdivision of cohorts into subjects aged below 50 years, and equal or above 50 years.

Table 4. Selected final radiographic outcomes of distal radius fractures in operative and nonoperative cohorts. Data were presented as mean ± standard deviations.

	Operative n = 101	Nonoperative n = 106	P value
Radial length (mm)	9.63 ± 2.90	8.70 ± 2.69	0.024
Ulnar variance (mm)	–0.16 ± 2.30	2.07 ± 2.43	<0.0001
Volar tilt (°)	6.57 ± 4.49	–4.54 ± 14.06	<0.0001
Teardrop angle (°)	54.92 ± 13.77	35.18 ± 12.26	<0.0001
Anteroposterior distance (mm)	21.60 ± 3.02	20.49 ± 3.18	0.029

Assessment of functional outcomes revealed statistically significant differences between operative and nonoperative group in DASH, PRWE, mean grip, pinch strength, wrist flexion and ulnar deviation compared to nonsurgically treated patients as shown in Table 5. Deficits in wrist range of motion after fracture were statistically significant in both groups comparing to the uninjured contralateral side.

Table 5. Long-term clinical and functional outcomes after distal radius fractures. Data were presented as mean ± standard deviations or median (interquartile ranges). P value after comparisons of selected parameters of fractured extremities in operative and nonoperative cohorts. DASH — Disabilities of the Arm, Shoulder and Hand Questionnaire, PRWE — Patient Rated Wrist Evaluation Questionnaire, 9-HPT — Nine Hole Peg Test; * statistically significant compared to uninjured, contralateral side.

	Operative n = 101		Nonoperative n = 106		P value
	Fractured	Contralateral	Fractured	Contralateral	
DASH	7.5 (2.5–24.2)		24.2 (4.2–50.0)		0.012
PRWE	9.4 (2.8–23.3)		17.8 (3.9–49.7)		0.048
Grip strength (kg)	16.7 (10.7–26.0)	20.7 (10.0–36.0)	10.3 (3.0–14.7)	11.5 (4.7–20.0)	<0.0001
Pinch strength (kg)	4.8 (3.3–8.0)	5.4 (3.9–9.7)	2.9 (1.5–5.6)	3.8 (2.4–6.4)	<0.001
9-HPT (s)	16.4 ± 7.8*	15.2 ± 2.5	18.5 ± 8.0	17.1 ± 6.1	>0.05
Extension (°)	59.0 ± 12.2*	66.7 ± 13.5	56.7 ± 14.1*	66.9 ± 5.6	>0.05
Flexion (°)	53.0 ± 12.3*	67.7 ± 11.4	46.8 ± 13.9*	66.8 ± 8.4	0.004
Pronation (°)	79.4 ± 14.4*	87.4 ± 7.4	77.5 ± 14.8*	87.7 ± 6.3	>0.05
Supination (°)	74.1 ± 10.9*	79.0 ± 3.6	75.6 ± 11.7*	80.5 ± 4.8	>0.05
Ulnar deviation (°)	25.8 ± 7.8*	33.3 ± 6.5	20.5 ± 8.6*	28.3 ± 6.9	0.005
Radial deviation (°)	20.9 ± 6.0*	23.5 ± 5.3	19.5 ± 6.6*	22.6 ± 4.9	<0.001

Taking into consideration previous studies and results of multivariate regression [17, 18] we subdivided our cohorts into subgroups aged ≥50 years, and those under 50 years. Abovementioned threshold separates two main demographic groups presenting with a fracture of distal radius. Afterwards, differences in particular functional outcomes comparing age and intervention subgroups were calculated as presented in Fig. 1. Population with DRF aged ≥50 years has similar DASH and PRWE scores independently from type of treatment operative versus nonoperative. In younger population, aged less than 50 years, operative treatment was associated with significantly better functional outcomes according to DASH and PRWE tools.

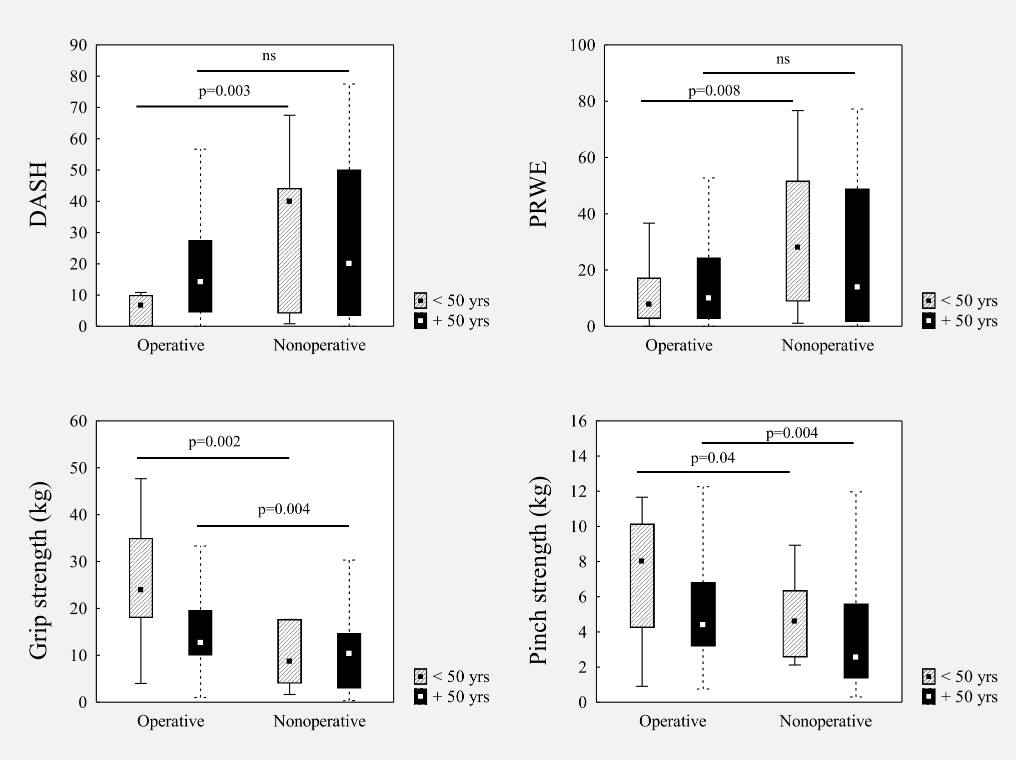

Fig. 1. Selected long-term functional outcomes after distal radius fractures. Study groups were divided into subpopulations of patients aged ≥50 yrs, and <50 yrs. DASH — Disabilities of the Arm, Shoulder and Hand questionnaire, PRWE — Patient Rated Wrist Evaluation questionnaire, ns — non-significant (p value >0.05).

Afterwards we performed multivariate regression analysis. Age was significantly associated with DASH results in operative cohort (RR: 0.24, 95% CI: 0.04–0.43; $p = 0.021$). We found no associations between other demographic data, radiologic parameters versus measured functional outcomes in study groups.

Discussion

We found that patients aged ≥50 years with distal radius fractures did not have statistically significant differences in functional outcomes measured by DASH and PRWE, comparing between operative and nonoperative treatment, meaning that regardless of performed surgery or nonoperative treatment, long-term DASH and PRWE scores were alike. However, taking into account subjects younger than 50 years, we observed differences which were statistically significant. Similar observations were made by Plant *et al.* [17]. Other authors suggested setting higher age threshold when functional outcomes were irrespective of treatment method, such as 55 years [9] 65 years [19] and 70 years [8].

Interestingly we found that patients treated nonoperatively remained on sick leave significantly longer than those who were treated surgically. This may be explained by prolonged immobilization and lack of proper rehabilitation. Contrary to these findings, Egund *et al.* found that patients treated operatively have spent significantly longer time on medical leave, moreover, they reported positive and significant correlation between duration of sick leave and DASH score, meaning that the longer the medical leave, the worse the functional outcomes measured by DASH questionnaire [20].

Complications

We did not find any significant differences in total number of complications between operative and nonoperative groups which is in accordance to Zhao and Qiu observations [21, 22]. However Chung *et al.* did observe such differences [23]. We found that the most common long-term complication after DRF was pain syndrome, but the difference between operative and nonoperative groups was not significant. Contrary to our findings, several researchers described malunion as the most frequent DRF complication [24, 25]. In our study malunion was second most common complication, furthermore we found statistically significant difference between surgically and nonsurgically treated patients, meaning that subjects treated operatively were less susceptible to malunion, which is in accordance with observations made by Chung [23]. It is worth noting that malunion was not correlated with higher pain rates or DASH results. Moreover, we did not observe any statistically significant differences between studied groups concerning loss of motion and arthritis, which respectively were third and fourth main reported complications. In addition, we found that 31.9% of our cohort developed arthritis, which is in line with Lameijer *et al.*, where prevalence of arthritis amounted 31% at a twelve months follow up [26].

Radiological parameters

We found that radiological outcomes: radial length, ulnar variance, volar tilt, teardrop angle, anteroposterior distance, did not correlate with functional outcomes (DASH, PRWE), which is in line with studies conducted by Young *et al.* [27] and Synn *et al.* [28]. However, studies conducted by Wilcke *et al.* proved correlation between radial length and clinical outcomes, described by DASH [29]. In addition McQueen and Caspers [30] also found significant association between long-term radiological and clinical outcomes. Various recent studies indicate that malalignment may not to lead to inappropriate outcomes, and subjects may have satisfactory functional results [31–33]. Abovementioned findings were confirmed in our cohort, radiological parameters not influenced final functional long-term results in study groups.

Functional outcomes

We found that mean grip strength among patients with DRF treated operatively was significantly higher than in the nonoperative group. Similar results were presented in meta-analysis prepared by the Ochen *et al.* where 971 subjects were evaluated [34]. However, studies conducted by Song *et al.* [35] and Ju *et al.* [36] did not point any statistically significant differences in grip strength between operative and nonoperative cohorts after DRF. Moreover, we found that tip pinch strength among patients with DRF treated operatively was significantly higher than among patients from the non-operative group. Grip strength results achieved by patients treated surgically were comparable to healthy counterparts as described by Ziv *et al.* [37]. Worth acknowledging is the fact that non-operative patients after 12 months from DRF significantly more often developed posttraumatic arthritis (80%) than subjects treated surgically (34%) [7], which may explain observed differences in strength among our participants.

We did not observe any statistically significant differences in 9-hole peg test (9-HPT) between patients treated operatively and nonoperatively. To our knowledge our study is the first, where 9HPT was used to asses hand dexterity in patients with DRF, treated both surgically and non-surgically.

We found that patients treated surgically had significantly better results of wrist flexion and radial and ulnar deviation. Similar results were described by Lameijer *et al.* [26]. Moreover, Tsitsilonis *et al.* found that ulnar deviation after DRF is an important prognostic factor of life quality [38]. In addition Toon *et al.* [39] observed significant difference in ulnar deviation after 12 months post-injury, in favor of surgically treated patients, which is in line with our findings. However, several researches did not find any statistically significant differences in wrist range of motion between groups treated operatively and nonoperatively [7, 40, 41]. We found that patients treated operatively had relevantly better functional outcomes than their counterparts from nonoperative group, which was confirmed by Ochen *et al.* in meta-analysis [34].

Study limitations

The study has limitations. Firstly, study design was retrospective, but all consecutive cases of distal radius fractures were identified and randomly assigned to subgroups. Randomization was of good quality because basic characteristics such as age, sex, energy of trauma, fracture type distribution and others were similar and differences between subgroups non significant. Secondly, another limitation that should be considered is that we haven't used a systematic validated complications checklist, for example that proposed by McKay [42]. The abovementioned validated checklist is not currently available in Polish population.

Conclusions

To conclude, restoration of anatomic and thus radiologic parameters of radius may not be obligatory to achieve satisfactory functional outcome in patients with distal radius fracture aged 50 years or above. Complications should be carefully considered when taking into account treatment method. Patient is the most important 'factor' in determining appropriate and successful treatment method of distal radius fractures.

Conflict of interest

None declared.

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