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Assessment of the Patellofemoral Joint Condition and the Possibility of Its Functional Improvement after the Closed Fractures of the Patella

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Abstract

Background. The patellar fractures are relatively rare. Their clinical significance is associated with the fact that they can cause the development of severe patellofemoral pain syndrome. Lateral retinaculum release was introduced into clinical practice in 1970s for treating this syndrome and since was widely used. The biomechanical validity of this operation has been proven experimentally, but the role of lateral release in the prevention of patellofemoral arthritis progression and concomitant pain after patellar fractures remains poorly understood. ***The purpose of the study*** was to improve the results of the patellar fractures surgery by combining osteosynthesis with lateral retinaculum release. ***Materials and Methods.*** This was a non-randomized, cohort, open-label prospective study with retrospective control. The treatment results of the patients with closed patellar fractures were analyzed. The prospective group (n = 45) was formed sequentially during 2018–2019. The retrospective control group (n = 41) was selected from the database of the city center of traumatology according to the inclusion criteria. The difference between both group was that in the patients of the prospective group, open osteosynthesis of the patella with wire segments and a stretching wire loop was combined with minimally invasive release of the lateral retinaculum. The function of the operated knee joint was assessed in 12 months after the surgery by the KOOS. The magnitude of the patellar articular surface discongruence was measured by X-rays; the stage of patellofemoral arthritis was classified by Iwano. The statistical analysis included the calculation of medians, means, absence/presence differences in groups indicators, correlation analysis of the measured variables. ***Results.*** The comparing groups were heterogeneous in gender, age, and types of fractures: the prospective group comprised 18 women (49.7±14.7 years), 27 men (45.1±11.2 years), the retrospective — 13 women (50.2±12.3 years), 28 men (41.9±10.7 years). In the prospective group, compared with retrospective, the 34-C1, 34-C2 fractures were prevailed. The null hypothesis about the equality of KOOS indicators and the stage of patellofemoral arthritis in both groups was rejected at the p<0.05 significance level. The patients of the prospective group had better KOOS indicators. The Spearman's correlation analysis revealed a positive relationship between KOOS scores in the range 0.26 to 0.41 and a negative correlation between the stage of arthritis (-0.29) and lateral release. ***Conclusion.*** Testing the null hypothesis that there was no difference between the KOOS scores between the prospective and control groups confirmed its inconsistency. The beneficial effect of lateral release on the knee function was demonstrated in the mid-term results of the patellar fractures osteosynthesis.

Keywords: patellofemoral arthritis, patellar fractures, KOOS, lateral release.

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Patellar fractures, considered as the cause of post-traumatic patellofemoral arthritis (PFA), account for 0.7 to 1.0% of all skeletal injuries [1], but they are a factor that increases the risk and the rate of knee osteoarthritis on average by 7 times [2]. The X-ray signs of isolated PFA are detected in 17.1 to 34.0% of the female patients and in 18.5 to 19.0% of the male patients aged 60 years and older [3]. Inaccurate reposition of the patellar fragments leads to the disruption of the patellar trajectory along the distal surface of the femur, uneven distribution of the pressure on the articular cartilage, degeneration of the latter, and the appearance of pain. It was proved that reposition error resulted in the bone step of more than 1 mm increased the risk of post-traumatic PFA [4].

The purpose of this study was to improve functional outcomes after the treatment of closed patellar fractures in patients of working age.

Materials and Methods

The study design

It was a non-randomized cohort open-label prospective study with retrospective control, which analyzes the results of the patients with closed patellar fractures (ICD-10 S82.0) treatment (Fig. 1).

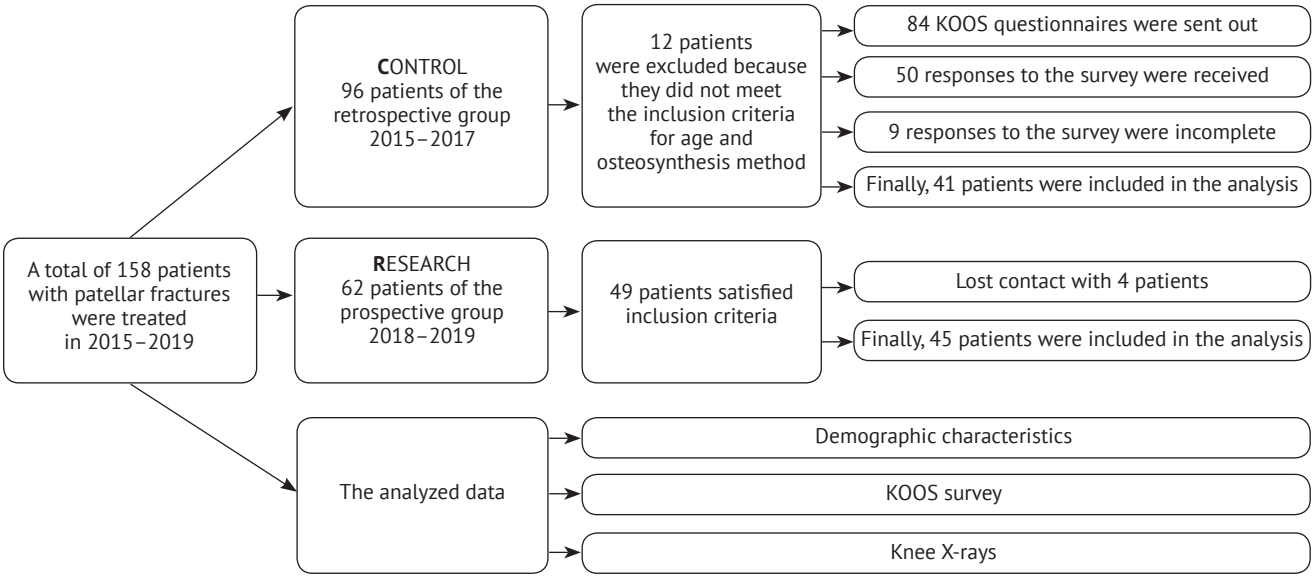

Figure 1. The study flowchart.

Criteria for the inclusion of the patients in this study:

– men and women of working age 20 to 65 years old;

– no history of traumas to the injured knee and adjacent joints, habitual patellar dislocations;

– the absence of anamnestic information about the treatment of knee osteoarthritis, including dysplastic; the decision on this and the previous point was made if there were codes of concomitant pathologies in the documentation;

– closed patellar fracture, surgery in the first 6 to 12 hours from the moment of injury;

– the absence of signs of nonunion or fixing elements injury at the time of the final assessment;

– consent to medical treatment and participation in research.

Patients

The patients included in the control retrospective group were selected from the database of the Semashko Rostov-on-Don City Hospital No. 1 following the specified criteria and encodings in force in 2015–2017. We requested the information about the trauma patients of working age with patellar fractures, hospitalized, and undergone urgent surgery. Our request returned the data from 96 patients. These patients were sent KOOS questionnaires, instructions for working with them, and a consent form for for participation in the study.

The prospective group patients were included in the study sequentially during 2018–2019. On admission, the patients underwent a general clinical examination and a knee X-ray in frontal and lateral planes. In the absence of contraindications associated with concomitant diseases, all patients underwent open osteosynthesis of the patella in the next 6 to12 hours after hospitalization. The detailed name of the performed surgery was "The open reposition of the patellar fracture and osteosynthesis with segments of Kirschner wires with a pulling wire loop [5, 6] the code of operation A16.03.028.005".

Surgery technique

The patella was approached by a midline incision. After the completion of the reduction and osteosynthesis, a mini-invasive lateral release of the retinaculum was performed using a pulling loop. The technique of release consisted of a 15 to 20 mm long approach parallel to the skin folds at the level of the patellar superior pole at a distance of 10 mm from its lateral edge. The edges of the wound were parted. The retinaculum was dissected longitudinally within the wound. The curved scissors were inserted under the retinaculum, and the latter was peeled off from the synovium to the level of the Gerdy's tubercle. The direction of movement was parallel to the patellar lateral edge at a distance of about 10 mm. The scissors were returned to the incision and their jaws were slightly parted so that the retinaculum was placed between them. The lateral retinaculum was dissected by moving the scissors in the distal direction. The criterion for the operation correctness was the appearance of free patellar movement in the lateral directions. The surgical wound was closed. The described technique is a modification of the original method proposed by B. Unal et al. and A.C. Merchant et al. [7, 8].

Assessment of the results

In both groups, the functional state of the operated knee was assessed in 12 to 14 months after the moment of injury and surgery. The self-questioning method was applied using the KOOS scale [9, 10]. This well-validated questionnaire makes it possible to comprehensively, by 5 criteria groups, assess not only the condition of the operated joint but also the patient's quality of life. The patients of the control group completed the questionnaire once. The patients of the research group were handed over these questionnaires at discharge for a report in 6 and 12 months. Some patients preferred to check in the electronic version of the questionnaire. The data from the questionnaires were transferred to an Excel workbook, where they were processed following the algorithm recommended by the author of the scale [10, 11].

At the final examination, the axial knee X-ray was performed laying in the prone position with knee flexion up to 30°. This was achieved by adjusting the position of the leg support. The choice of the angle of flexion of 30° was chosen due to the information that it was the most informative angle for assessing the state of the patellofemoral joint [12]. The X-ray images were classified according to the A.C. Merchant et al. [13] and T. Iwano et al. [14] criteria for the patellofemoral joint evaluation (Table 1). The X-ray analysis was carried out by the assessment of the patellofemoral joint space symmetry in the skyline plane. In the case of poor-quality reduc-

tion, the size of the "step" was measured with an accuracy of 1 mm. Measurements were rounded up if necessary. We followed the X-ray assessment technology described by S.M. McDonnell et al. [15]. The X-ray analysis in frontal and lateral planes was not performed due to it proven low specificity for the early PFA stages [5].

The anonymized demographic results, data from the KOOS questionnaire, the results of the final X-ray assessment at the time of the contact termination with the patients in both groups were saved in the workbook. The data structure is shown below (Table 2).

To conduct the study, the permission from the local ethical committee of the Rostov-on-Don State Medical University of the Ministry of Health of Russia No. 2/16 of June 28, 2016, was obtained.

Table 1

The X-ray criteria of patellofemoral arthritis by T. Iwano [14]

Stage	X-ray signs
1 — mild	Joint space > 3 mm
2 — moderate	Joint space < 3 mm without contact of the articular surface
3 — severe arthritis	Bone surfaces touch is less than a quarter of the joint surface
4 — very severe arthritis	Bones contact over the entire joint surface

Table 2

The study data structure

Indicator	Variable	Data type	
Study group	Group	String	Binary
Year of the operation	Year	Integer	Discrete
Patient ID FULL NAME 99M(F)	ID	String	Nominal
Patient's gender	Gender	String	Nominal
Age on the day of admission, years	Age	Integer	Discrete
KOOS, pain	Pain	Integer	Discrete
KOOS, signs	Sympt	Integer	Discrete
KOOS, daily activity	Activity	Integer	Discrete
KOOS, sports activity	Sport	Integer	Discrete
KOOS, the quality of life	Qlife	Integer	Discrete
KOOS, overall	sum	Integer	Discrete
Fracture type by AO classification	AO	String	Nominal
Arthritis stage by Merchant	Merch	Integer	Ordinal
Incongruence value, mm	XrStep	Integer	Continuous
Group code: 1 – control, 2 – research	f.gr	Integer	Discrete
Gender code: 1 – male, 2 – female	f.gen	Integer	Discrete
Fracture code: 34 – (A1 – 1, B1 – 2, B2 – 3, C1 – 4, C2 – 5)	f.a1	Integer	Discrete

Statistical analysis

The statistical processing of the obtained data included the calculation of ranges, median, mode, mean values, quantiles, standard deviations. The testing of the continuous indicators distribution for its normality and the study of the indicators connections by the correlation analysis were carried out.

The primary data processing was carried out using the Excel workbook (Microsoft ® Excel v.18.2005.1191.0). The data were exported to RStudio (Version 1.1.463 - © 2009–2018 RStudio, Inc.) and processed using the tidyverse package [16]*.

Results

The data from 86 patients for the period 2015–2019 were collected and analyzed. The patients distribution by gender, types of fractures and the average values of quantitative signs are presented in Tables 3 and 4. The functional state of the knee was reflected by the KOOS profile, defined as a combination of points in the sections Pain, Symptoms, Daily activity, Sport and Quality of life [17]. Table 4 shows the average KOOS scores by category in the groups depending on the type of fracture. The change in the KOOS scores mean values in the patients of both

Table 3

The patients distribution by groups, gender, age and types of fractures

Group	Gender	Number of patients	Mean age, years	SD, ±, years	AO fracture type, number of patients				
					34-A1	34-B1	34-B2	34-C1	34-C2
Control, retrospect	Females	13	50.2	12.3	6	6	1	0	0
	Males	28	41.9	10.7	9	9	0	8	2
Research, prospect	Females	18	49.7	14.7	2	5	4	8	3
	Males	27	45.1	11.2	5	6	0	9	3

Table 4

The average KOOS scores by the type of fracture

Group	AO fracture type	Number of patients	Mean age, years	SD	Pain, points	SD	Signs, points	SD	Daily activity, points	SD	Sports, points	SD	Quality of life, points	SD
C	34-A1	15	48	12.5	83.6	11.3	73.5	11.6	82.3	13.7	29.5	18.1	55.8	13.9
C	34-B1	15	44	11.8	80.5	15.8	74.8	16.3	80.3	13.8	52.7	14.5	54.7	19.8
C	34-B2	1	32	NaN	36.0	NaN	39.0	NaN	35.0	NaN	22.0	NaN	34.0	NaN
C	34-C1	8	43	11.1	79.4	9.81	72.0	5.73	79.8	9.07	49.6	18.5	49.2	21.2
C	34-C2	2	42	12.0	72.5	6.36	60.5	2.12	68.5	9.19	23.5	2.12	46.5	3.54
R	34-A1	7	49	12.4	91.3	14.4	89.6	13.4	84.9	21.6	45.6	24.7	68.6	23.0
R	34-B1	11	41	12.7	89.7	11.7	81.0	13.9	87.8	9.58	53.8	26.3	70.2	18.4
R	34-B2	4	47	7.94	57.2	15.2	66.0	11.8	50.8	27.4	38.8	10.2	69.8	15.0
R	34-C1	17	44	14.6	88.7	11.1	84.3	14.9	90.6	12.6	68.2	16.1	62.4	19.7
R	34-C2	6	47	11.4	94.3	5.4	84.0	10.3	95.2	5.34	34.7	7.74	64.2	17.9

C - control group, R - research group, NaN - calculation is impossible due to insufficient data

* The study data file in csv format is available at URL: https://yadi.sk/d/bThxBYptfg3_Qw

groups one year after the surgery is shown in Figure 2.

It is obvious that the KOOS profiles for the analyzed groups have a similar shape with some excess of values in the control group (Fig. 3).

The null hypothesis (there were no differences between the groups) with a probability of type I error p <0.05 was tested using the Student test in Welch's modification for the data with an abnormal distribution. The probability of obtaining the same scores on the KOOS questionnaire in the research group as in the control group did not exceed 0.05 (Table 5). Therefore, the null hypothesis that there were no differences between indicators should be rejected.

From a comparison of the KOOS profiles, it followed that the lowest scores of the patients in both groups had sports activity and quality of life. The range diagrams for these features are shown in Figure 4.

It can be noted on the diagrams that the values of the assessments ranges of sports and recreational activity in both groups were similar. This means that there is greater variability in patients' assessments of their fitness and recreational activity. The assessment medians of sports activity and quality of life in the research group were higher than in the control, but they both were significantly lower than the corresponding medians in the healthy men aged 35 to 54 years, in whom they reached 87.5 [18].

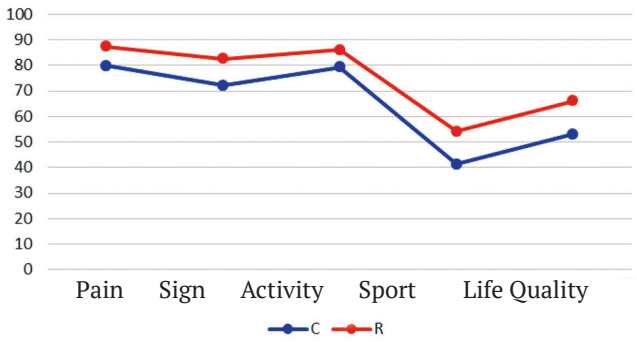

Figure 2. KOOS profile of the patients in groups C (control) and R (with lateral release) in 12 months after the surgery.

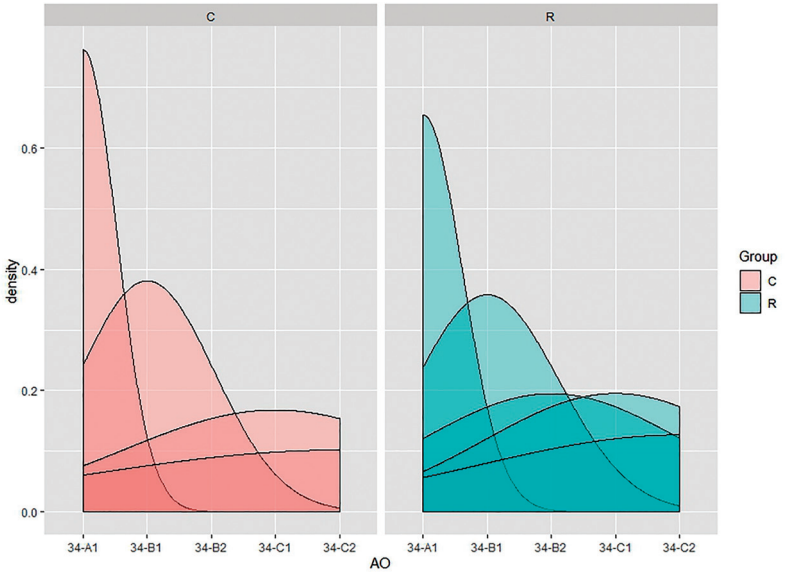

Figure 3. The density of AO-type fractures distribution in the control (left) and research (right) groups.

Table 5

Testing the null hypothesis of no difference between both groups by Welch test, mean scores

Indicators	Control group	Research group	p-value
Pain	80	87	0.0210
Signs	72	83	0.0009
Daily activities	79	87	0.0177
Sports	41	54	0.0068
Quality of life	53	66	0.0013
PFA by Merchant	2.15	1.64	0.0050

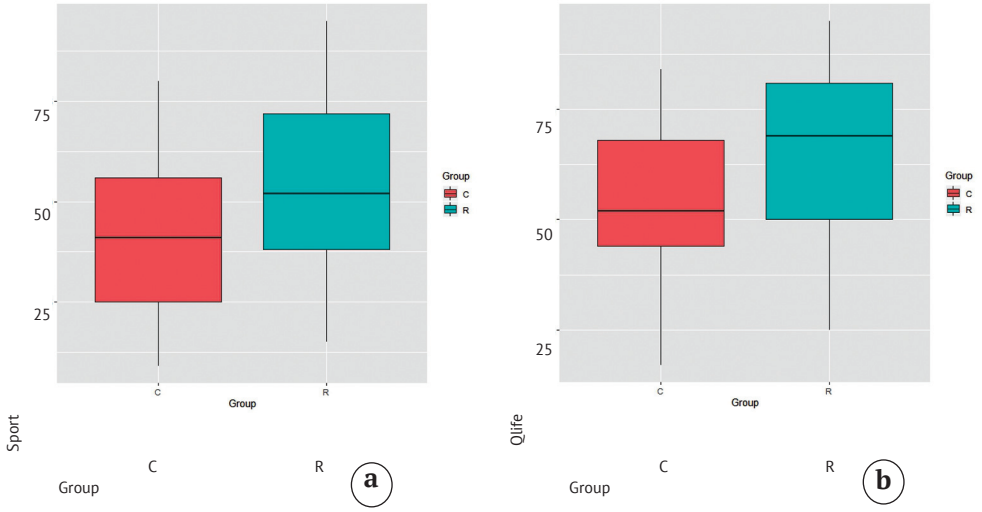

Figure 4. Diagrams of the attributes "Sport" and "Quality of life" ranges in the control and research groups.

Arthritis is generally recognized as a factor causing pain and dysfunction of the knee [19]. The ratio of the arthritis and reposition defects rate can be assessed on the distribution density diagrams of the Iwano arthritis stage and the size of the "steps" between the matched articular surfaces of the patella (Fig. 5).

The analysis of the distribution density of the PFA stage and the magnitude of incongruence presented in Fig. 5 allows us to state that although the number of the patients with reposition defects was approximately comparable in both groups, the distribution of the PFA stages in the research group was shifted to the left. Thus, it can be argued that the research cohort was dominated by the patients with a lesser stage of arthritis.

Here is an example of comparing the KOOS profiles of the female patients in the control group (fracture 34–A1, Iwano 2 arthritis, step size 1 mm) and research group (fracture 34–C1, Iwano 2 arthritis, step size 1 mm). The lateral release in the research group patient, all other things being equal, improved her quality of life assessment (Fig. 6).

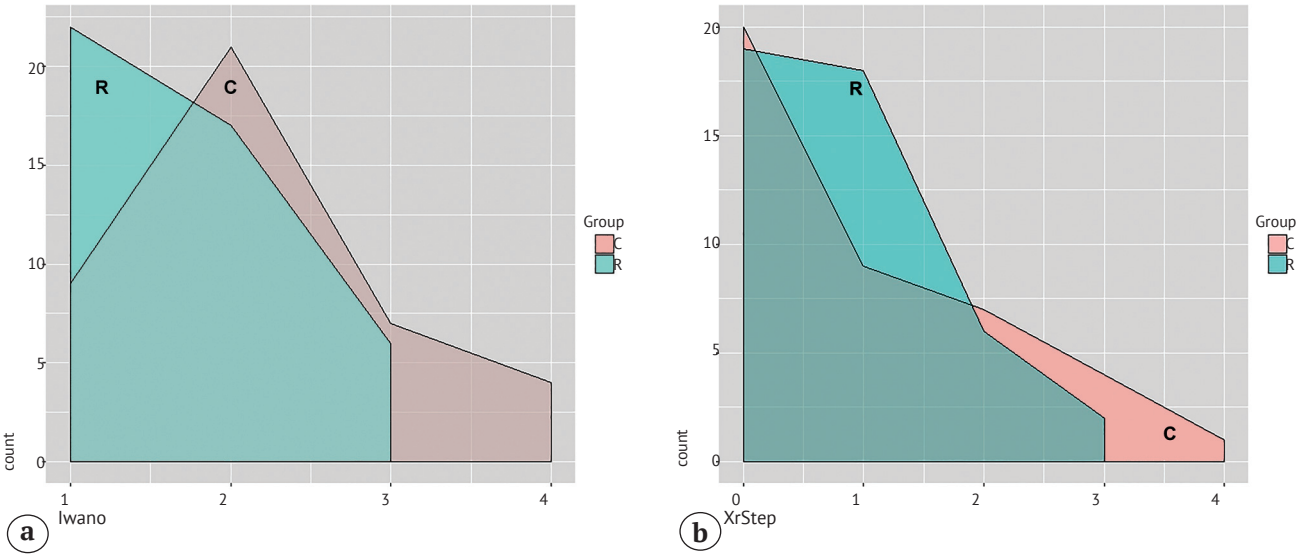

Figure 5. The density of distribution of the stages of patellofemoral arthritis by Iwano (a) and the size of the "step" in millimeters (b) in the control and research groups .

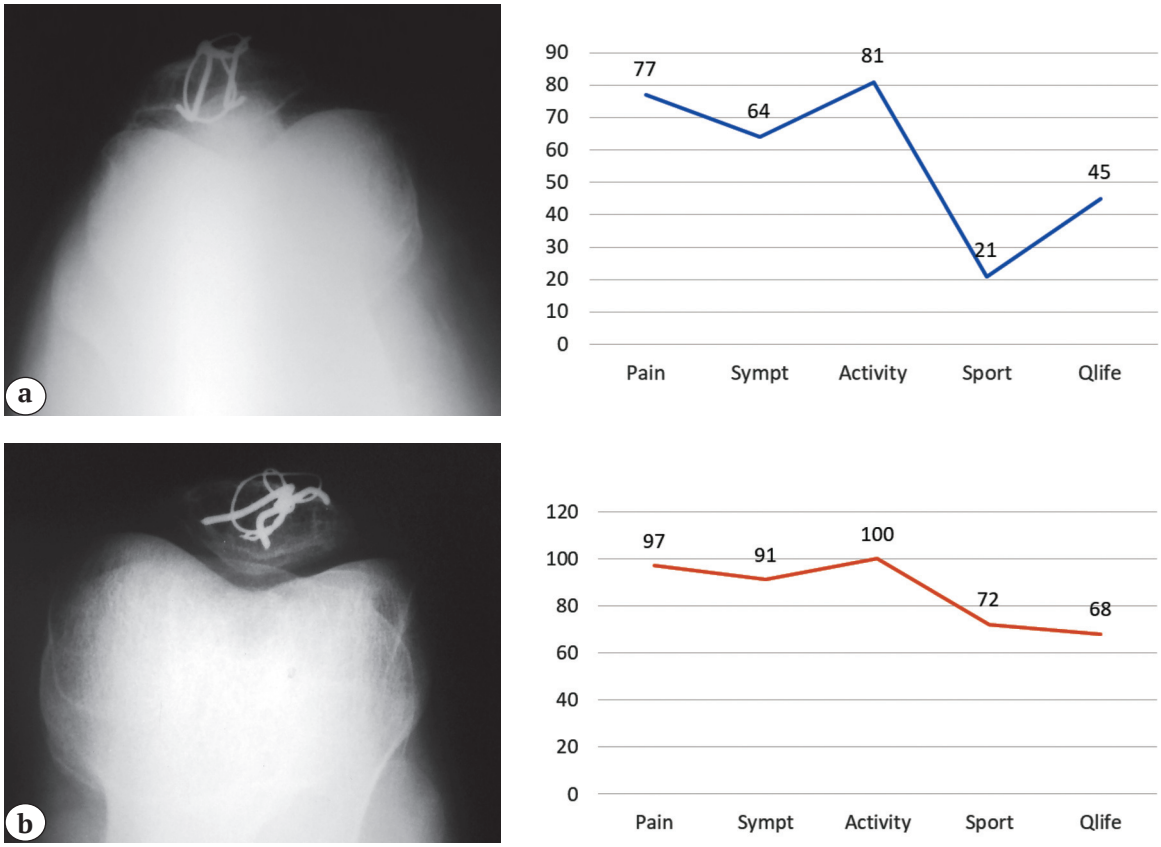

Figure 6. The comparison of mid-term results of the treatment of the patellar fractures with reposition errors: a – female patient of the control group; b – female patient of the research group.

Of particular interest is the interaction of KOOS indicators, the type of patellar fracture, the quality of reduction, the presence of the PFA signs, and the fact of lateral release carrying out. For this purpose, the correlations between the indicators that characterized the result of the patellar fracture surgery were evaluated (Spearman correlation coefficients). The relationship between the stage of arthritis and the size of the "step" on the articular surface, a negative correlation between incongruence, the stage of arthritis and indicators of knee function by the KOOS scale were revealed (Table 6).

The tracing connections between the type of fracture and KOOS scores are difficult to interpret due to the small number of observations in each group. Assessing the inclusion in the research group (f.gr) as a factor reflected the performance of the lateral release, we can note a positive weak relationship between it and indicators of knee function.

Table 6

The correlation matrix (Spearman) of the study quantitative characteristics

	f.gr	f.gen	f.a1	Age	Pain	Sympt	Activity	Sport	Qlife	Merch	XrStep
f.gr	1.00										
f.gen	–0.79	1.00									
f.a1	0.83	0.78	1.00								
Age	0.18	–0.03	0.12	1.00							
Pain	0.31	–0.27	0.31	–0.10	1.00						
Sympt	0.37	–0.25	0.35	0.07	0.80	1.00					
Activity	0.35	–0.33	0.32	–0.16	0.89	0.68	1.00				
Sport	0.21	–0.18	0.24	–0.06	0.41	0.47	0.42	1.00			
Qlife	0.34	–0.26	0.29	0.25	0.67	0.67	0.54	0.36	1.00		
Merch	–0.26	0.30	–0.27	0.18	–0.44	–0.42	–0.54	–0.24	–0.28	1.00	
XrStep	–0.02	0.11	0.04	0.18	–0.41	–0.33	–041	–0.05	–0.33	0.56	1.00

Discussion

The patella is the largest sesamoid bone in the body. The rate of the patellar fractures ranges from 11.4 to 14.7 per 100,000 population per year and is about 1% of all skeletal fractures [1]. The rate of the different types of the patellar fractures depends on the gender and age of the patients, as well as season [1, 20].

The treatments of the patellar fractures and the means of their outcomes improvement are still areas of interest. On average, 68 research articles on the theme have been published annually since 2000 according to the US National Library of Medicine*[2]. The strategy of the surgery method option, as a rule, is determined by the surgeon on duty and depends on his/her experience, technical capabilities, type of the fracture, availability of metal constructions, age and functional needs of the patient [21, 22]. There are a large number of osteosynthesis methods which are employed cannulated screws or Kirschner wires in combination with a

*[2] URL: https://pubmed.ncbi.nlm.nih.gov/?term=fracture of patella&filter=years.2000-2020&pos=1.

tension wire loop, biodegradable implants, compression plates and extrafocal osteosynthesis [6, 23, 24, 25]. However, none of the above methods has advantages either in the number of fracture nonunions or in the quality of functional outcomes. Therefore, the choice of the osteosynthesis method remains with the surgeon [24]. The search for means to improve the results of the patellar fractures treatment should be carried out in the direction of assessing and comparing the function of the operated knee, depending on the method of osteosynthesis and the combination of various surgical and rehabilitation technologies [26].

The proposed and tested combination of the patellar fractures osteosynthesis in a proven way, namely segments of pins with a tensioning wire loop and lateral retinaculum release seemed logical, not significantly increasing the operative time and trauma. The biomechanical and clinical efficacy of the lateral release in the PFA and the patellar maltracking treatment has been repeatedly demonstrated [27]. Direct measurements of the patellar pressure forces on the femoral lateral and medial articular facets showed that the retinaculum lateral release had an unloading effect, reduced frictional forces, and slowed down the rate of chondromalacia [28, 29].

To objectify the assessment of the knee function and the surgery X-ray results, the KOOS scale and the Merchant X-ray metric were used in this study. KOOS is a generally accepted well-validated scale suitable for monitoring treatment outcomes for the knee pathology and developing scientifically-based treatments [30, 31].

We found that the KOOS profile of the patients of the research group in all parameters exceeded the corresponding values of the control group. The obtained KOOS indicators did not reach the values for the corresponding age populational groups [32, 33]. The greatest functional deviation was registered in both groups in the assessments of sports and recreational activity and quality of life. This phenomenon was also noted in some studies, where it was emphasized that the majority of the patients report a deterioration in the quality of life in the next few years after the patellar fracture [17, 34, 35].

Most authors associated the development of PFA with unsatisfactory reposition or breakage of fixators during the surgery. And PFA, in turn, leads to prolonged rehabilitation and, ultimately, to poor functional outcomes [6, 17, 23]. In our study, the proportion of the patients with AFF above Merchant 1 reached 78% and 51% in the control and research groups, respectively. The similar data were obtained in a rather old study, which stated that 53% of the patients developed post-traumatic PFA [36]. The proportion of the patients with a registered displacement of the articular surfaces equal to or greater than 1 mm was 51% and 58% in the control and research groups, respectively. In combination with a larger number of true intra-articular fractures in the research group, the inverse ratio of the number of patients with PFA and incongruence suggested that the lateral release was a factor preventing the PFA progression. The prophylactic and therapeutic role of the lateral release was also reported in some publications [6, 28].

In our study, we evaluated the role of the patella lateral release as a factor that reduced the likelihood of developing post-traumatic PFA and improved the functional results of the surgical treatment. The correlation analysis demonstrated a positive relationship between the lateral release of the patella and the improvement in KOOS scores in the research group, despite a similar incidence of reposition defects.

The study limitations. Interpreting the results of this study, it should be borne in mind that it is not without several limitations. The study includes the prospective group with retrospective control, which results in the heterogeneity of the groups age and the structure of fractures. In addition, the ab-

sence of randomization did not allow us to exclude the subjectivity of the choice of the surgery method even at the stage of recruiting the research group. In the present study, an attempt was made to assess the correlation of functional scores with X-ray findings. We tried to show how imprecise reduction in combination with lateral release can affect the functional outcomes, but the small sample size limited the ability to differentiate the scores for any type of the patellar fracture. In addition, we do not overestimate the accuracy of measuring the articular alignment by X-ray, since the errors in the patient positioning for the X-ray and the X-ray focal length distorted the true dimensions. Another vulnerable position of our study may be the absence of information about patients rehabilitation programs which our patients undergone or missed. We have no data on recovery of the quadriceps, deficits in strength and head volume, which are also the factors in the PFA progression [37, 38].

The authors are aware that a year follow-up cannot be considered as the complete evidence of the significant role of the lateral release in the prevention of the PFA development. The further follow-up of both groups at intervals of 3 to 5 years are required to confirm the preventive efficacy of the described technology.

In the available literature, no studies were found that used validated scales, in particular KOOS, in combination with X-ray analysis to assess the mid-term results of the patellar fractures treatment. The findings from this study may be useful for informing the patients about likely outcomes and comparing different treatments of the patellar fractures.

Testing the null hypothesis that there was no difference between the KOOS scores in the control and the research groups confirmed its inconsistency. Therefore, the lateral release, combined with open osteosynthesis, is positively associated with better mid-term outcomes of patellar fractures treatment.

Consent

The patients gave voluntary informed consent for the participation in this study and publication of its clinical results

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Competing interests: The authors declare no conflict of interest.

Authors' contributions

G.Sh. Golubev – research design, data structure development, literature analysis, preparation of the "Discussion" section.

A.A.M. Al-hababi – collection, accumulation and processing of the data, the direct participation in the surgery of the research group patients, communication with the patients over the postoperative period, X-ray processing.

R.A. Khadi – development of mathematical processing algorithms and data visualization, interpretation of the results of statistical processing.

All authors made a significant contribution to the research and preparation of the article and read and approved the final version before its publication. They agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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