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Mid- and Long-Term Results of Total Elbow Arthroplasty: Post-Traumatic Consequences and Rheumatoid Arthritis

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Abstract

Purpose of the study*:** 1) to identify differences in the functional outcomes of total elbow arthroplasty in patients with post-traumatic and rheumatoid arthritis; 2) to determine the factors affecting the outcomes; 3) to identify the frequency and patterns of complication. ***Materials and Methods. A retrospective study included a total of 269 patients who underwent a primary total elbow arthroplasty (TEA) — 100 males (37.2%), 169 females (62.8%). The first group included 191 patients with post-traumatic arthritis (191 elbows). The mean postoperative follow-up period was 6.9 years (from 0.5 up to 21 years). The second (compared) group included 78 patients (81 elbows) operated on for rheumatoid arthritis (RA). These were followed for an average of 3.8 years (0.4 to 16.5 years). ***Results.*** TEA significantly improved joint function (mean values for post-trauma group on the Mayo score were 73.8±14.1, on the Oxford questionnaire — 30.5±8.9, DASH — 40.3±18.4, EQ-5D — 0.536±0.234; in patients with rheumatoid arthritis, on the Mayo score — 75.4±15.5, DASH — 38.6±15.8, OES — 35.5±7.9, EQ5D — 0.580±0.2). In the *first* group, the frequency of postoperative complications requiring a revision was significantly higher than in the compared group (23.8% and 13.6%, respectively, OR 3.2 95%, CI 0.7–3.0). In the *first* group, a statistically significant risk of aseptic loosening of the implants was observed in patients operated on for pseudarthrosis of the distal humerus (OR 8.5, 95% CI 1.7–43.6) and post-traumatic deformity (OR 10.5; 95% CI 1.3–88.5). The use of some endoprostheses is also associated with a high risk of aseptic instability (OR 3.5: 95% CI 0.9–13.3). A significant risk of a deep periprosthetic infection was observed in patients with post-traumatic bone defect (OR 7.0; 95% CI 1.2–40.1) and post-traumatic deformity of the elbow joint (OR 14.0; 95% CI 2.5–77.8). Risk factors for endoprosthetic loosening in patients with RA were: defective cementation of humeral component (OR 35.0; 95% CI 3.8–325.0), valgus deviation of the humeral component ≥ 9° (OR 9.2; 95% CI 1.0–82.2), low constructive reliability of the endoprosthesis (OR 13.6; 95% CI 2.3–79.4), patient age ≥59 years (OR 12.8; 95% CI 1.5 — 113.0), BMI ≥32 kg/m^2 (OR 8.4; 95% CI 1.5–47.5), and CRP level ≥36.1 mg/l (OR 4.8; 95% CI 0.4–65.8). ***Conclusion.*** Mid- and long-term results showed that TEA helps restore the amplitudes of elbow movement and the function of the limb, both in patients with post-traumatic consequences and with RA. However, the frequency of postoperative complications requiring a revision is significantly higher in the group of patients with consequences of injuries than in the group of patients with RA.

Keywords: elbow arthroplasty, elbow post-traumatic osteoarthritis, elbow rheumatoid arthritis.

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Background

Elbow fractures constitute about 7% of all skeletal injuries [1, 2]. Distal humerus fractures account for 2–3%, or 5–6 cases per 100 000 persons [3]. The standard technique to treat such fractures is an open reduction, internal fixation with early joint mobilization [4, 5]. Performing osteosynthesis in elderly patients with metabolic diseases, impaired blood circulation in the upper limb and poor bone quality does not always allow for complete reposition and stable fixation of fragments, even using the insertion of modern plates with angular stability. According to some data, the frequency of complications and unsatisfactory outcomes of such operations reaches 20% [6–8]. Subsequently, post-traumatic osteoarthritis develops, accompanied by severe pain and contracture of the joint.

There are various surgical treatment options for *osteoarthritis*: arthrodesis, interposition arthroplasty and arthroplasty. The elbow arthrodesis leads to a significant dysfunction of the upper limb and diminishes the quality of life [9]. Resectional arthroplasty also cannot ensure proper restoration of function, since it reduces the stability of the joint [10]. According to numerous studies, total elbow arthroplasty (TEA) with modern constrained prosthesis leads to better functional results in the long-term follow-up period [11, 12]. However, TEA in patients with post-traumatic arthritis as compared with those operated on for rheumatoid arthritis is accompanied by a rather high frequency of complications in the long-term period (up to 45%) [13, 14].

In the foreign and domestic literature, the mid- and long-term data on the frequency and patterns of complications after TEA in, as well as on the factors influencing them, are extremely heterogeneous.

The purpose of the study is to identify differences in the functional outcomes of TEA in patients with consequences of injuries and rheumatoid arthritis, factors affecting them, as well as the frequency and patterns of complications.

Materials and Methods

A retrospective study included 269 patients (272 elbows) who underwent a primary TEA between 1994 and 2017: 100 male patients (37.2%) and 169 female patients (62.8%).

The *first* (post-traumatic) group consisted of 191 patients (191 elbows): 87 males (45.5%) and 104 females (55.5%). The mean postoperative follow-up was 6.9 years (from 0.5 to 21 years). The average age of patients at the time of surgery was 45.5 years (±16.3), the average BMI — 30.0 kg/m^2 (±7.5); 26 (13.6%) patients had an open elbow fracture. The development of infectious inflammation in elbow as a result of injury or osteosynthesis was observed in 24 (12.6%) patients. At the time of admission, 107 patients (56.2%) already underwent operations on elbow. The mean period from trauma to TEA was 4.4 years (±6.5) (Table 1).

The RA group included 78 patients (81 elbows) who underwent surgery. According to the Larsen grading scale for RA [14], stage III was observed in 57 cases, stage IV — in 13 cases, stage V — in 11 cases. The mean postoperative follow-up period was 3.8 years (from 0.4 to 16.5 years. The average age of patients at the time of surgery was 53.4 years (±13.7), the average BMI was 27.0 kg/m^2 (±4.8). In 8 (10.3%) cases, elbow debridement and synovectomy surgery was noted in the medical history. This operation is performed in patients with rheumatoid arthritis to reduce pain, improve the range of movement and, in some cases, reduce ulnar nerve compression (Table 2).

The surgery was performed using nerve block with side position, while the operated limb was fixed to an armboard. Approach to elbow was performed by Farabeuf and the Bryan-Morrey techniques. Bryan-Morrey approach was used in patients without previous operations on the elbow and bone integrity

preserved. This approach is preferable when performing primary TEA in standard anatomical situations, since the isolation of the ulnar nerve significantly reduces the likelihood of developing persistent neuropathy in the postoperative period. In addition, the preservation of the triceps gives optimum expectation for the best function of the limb in the long-term period. In contrast, in cases of defects, deformities and the presence of metal devices from previous surgeries, the posteromedial approach provides a broader view.

All patients included in the study underwent a primary TEA using constrained or unconstrained, cemented endoprostheses: Coonrad-Morrey (Zimmer, USA), Arete (Russia), GSB III (Biomet, UK), Ortho-L (Russia), Sivash Endoprosthesis (Russia), Johnson-Schlein (DePuy, USA), Osteonic-L (Russia) (Table 3).

Table 1

The distribution of patients of the first group by diagnosis

Primary diagnosis	Males		Females		Total	
	n	%	*n*	%	*n*	%
Post-traumatic osteoarthritis	45	23.5	49	25.7	94	49.2
Non-union of the distal humerus	18	9.4	29	15.2	47	24.6
Post-traumatic defect	11	5.7	7	3.7	18	9.4
Post-traumatic deformity	7	3.7	8	4.2	15	7.9
Bone ankylosis	5	2.6	5	2.6	10	5.2
Fibrous ankylosis	0	0	3	1.6	3	1.6
Acute comminuted fracture of the distal humerus	0	0	3	1.6	3	1.6
Olecranon pseudoerthrosis	1	0.5	0	0	1	0.5
Total	87	45.5	104	54.5	191	100

Table 2

Features of patients in both groups

Index		First group (*n* = 191)	Second group (*n* = 78)	*p*
Gender	Male	87 (45.5%)	13 (16.7%)	
	Female	104 (55.5%)	65 (83.3%)	
Age, years (Me [25%;75%])		46.7 (47.5 [34;58])	53.4 (56 [46;64])	<0.01
BMI, kg/m^2 (Me [25%;75%])		30.0 (29.9 [26;32])	27.0 (26.5 [23;31])	>0.05
Number of previous surgeries		107 (56.2%)	8 (10.3%)	<0.01
Duration of TEA, min (Me [25%;75%])		127.5 (120 [100;150])	95.6 (95 [80;100])	<0.01
Blood loss, ml (Me [25%;75%])		276.0 (200 [200;350])	193.1 (150 [150;200])	<0.01

Table 3

Approaches and implants used in patients of the studied groups

Approaches and endoprostheses		First group (n = 191)		Second group (n = 81)	
		n	%	*n*	%
Approach	Farabeuf	73	38.2	49	60.5
	Bryan-Morrey	118	61.8	32	39.5
Endoprosthesis	Coonrad-Morrey	142	74.3	60	74.1
	Arete	29	15.2	18	22.2
	GSB III	5	2.6	3	3.7
	Ortho-L	10	5.2	0	0
	Sivash Endoprosthesis	3	1.6	0	0
	Osteonic-L	1	0.5	0	0
	Jonson-Shlein	1	0.5	0	0

In most patients Coonrad-Morrey or Arete prosthesis were implanted. Due to the small number of observations, other implants were excluded from the statistical analysis of the risk of complications.

Clinical results in the first group were followed in 147 (76.9%) patients, in the second group — in 68 (87.2%).

Outcomes assessment

The data acquisition was performed during patient checkup and questionnaire survey (by phone, mail). The TEA effectiveness was evaluated using radiological results, changes in the range of movement and functional scales.

The functional status assessment included measurement of range of movement of the operated joint and filling in four questionnaires: DASH, EQ-5D, Oxford Elbow Score (OES), Mayo Score. If necessary, computed tomography of elbow, laboratory blood tests, punctate, electroneuromyography of the upper extremity and etc were performed.

Radiological findings were analyzed with Roman 1.7 software. The quality of the cement mantle was rated according to B.F. Morrey score (if the top of the endoprosthesis component is not covered with a mantle, cementation is considered to be defective), and the stability of implants we assessed based on the severity of peri-implant osteolysis. Endoprosthetic loosening was confirmed by the migration of the endoprosthesis component or the presence of osteolysis lines more than 2 mm wide throughout the cement-bone interface [15]. The positioning of the endoprosthesis components was evaluated in two planes (frontal, sagittal) by measuring the distance from the rotation center of the endoprosthesis component to the mid-diaphyseal line (anterior, lateral offset), the angle of deviation of the component axis from the mid-diaphyseal line (version, valgus deviation), and the distance from the rotation center of the endoprosthesis to the articular surface of the ulna (seating height of the ulnar component) [16].

Risk factors

To study the risk of septic and aseptic loosening, the following factors were included in the statistical analysis.

Patient related factors:
- gender;
- age;
- body mass index;
- primary diagnosis;
- time from injury to TEA;

– type of the fracture (open/ closed);
– elbow infection;
– number of operations on this elbow;
– amplitude of flexion/extension;
– amplitude of pronation/supination;
– blood loss.

Factors associated with surgery:
– duration of operation;
– surgeon's experience;
– approach to elbow;
– type of endoprosthesis;
– type of cement.

Factors related to the positioning of components:
– quality of the humeral component cementation;
– quality of the ulnar component cementation;
– anterior offset of the humeral component;
– anterior offset of the ulnar component;
– lateral offset of the humeral component;
– lateral offset of the ulnar component;
– version of the humeral component;
– version of the ulnar component;
– valgus deviation of the humeral component;
– valgus deviation of the ulnar component;
– seating height of the ulnar component.

Statistical analysis

The study results were processed using the Past Software 3.17. The median and interquartile range (Me [25%;75%]) were used for the statistical description of the movement amplitude measurements and functional scales scores before and after the operation, and the assessment of these scores over time was performed with Mann-Whitney *U*-test. The frequency of complications in the groups was compared using the non-parametric methods χ^2, χ^2 with the Yates's correction (for small groups), and the Fisher criterion. The analysis of quantitative parameters in the studied groups was carried out using the Mann-Whitney *U*-test and the median χ^2 value.

Results

Assessment of the clinical and functional status of elbow before and in the mid-term period after surgery in patients of both groups and also questionnaire results indicate improvement in flexion/extension, pronation/supination of the forearm (Table 4).

According to the surveys with MEPS, OES, DASH, regardless of pathology, there was an almost twofold improvement in upper extremity function. On the contrary, the assessment of quality of life (EQ-5D, VAS) was not significantly different, since restoration of joint function is not the only factor in solving other problems of co-morbidity, especially in patients with systemic arthropathy (Tables 5, 6).

Also, a comparative analysis of the increase in the elbow movement was not statistically significantly different in both patient groups (Table 7). This indicates a high effectiveness of arthroplasty in restoring the range of motion regardless of the pathology that caused the joint replacement.

Complications

In patients of the first group, the total frequency of complications in a mean period of 6.9 years was 23.8%. Aseptic loosening of the endoprosthesis components was diagnosed in 16 (10.9%) patients in a mean period of 5.8 years (0.9–9.3), deep periprosthetic infection in 14 (9.5%) in a mean period of 1.8 years (0.7–5.3). In 2 (1.4%) cases, a fracture of the ulnar component of the endoprosthesis occurred 11 and 18 years after surgery, in one case (0.7%) — the humeral component 2.4 years after TEA. The dissociation of the endoprosthesis components with the destruction of the elements of the constrained mechanism after 0.9 and 4.9 years was observed in two patients (1.4%) (Table 8).

Table 4

The average elbow motion and functional scale scores before and in the mid-term period after TEA

Parameter	First group Mean follow-up period – 6.9 years (0.5–21)		Compared group Mean follow-up period – 3.8 years (0.4–16.5)	
	Before surgery *n* = 191	After surgery *n* = 147	Before surgery *n* = 81	After surgery *n* = 68
Flexion/extension				
Mean, standard deviation	48.4°	114.4°	59.1°	120.2°
Median (25%;75%)	50° (18.8; 82.5)	122.5°(93.5; 135)	65° (17.5; 90)	125°(97.5; 137.5)
Pronation/supination				
Mean, standard deviation	90.9°	124.6°	78.1°	124.8°
Median (25%;75%)	102.5°(37.5; 146.3)	130°(115; 152.5)	85° (20; 122,5)	130° (100; 145)
MEPS (Mayo Elbow Performance Score)				
Mean, standard deviation	27.1	73.8	36.7	75.4
Median (25%;75%)	25 (20; 35)	75 (65; 85)	35 (25; 50)	75 (65; 90)
OES (Oxford Elbow Score)				
Mean, standard deviation	17.8	30.5	19.6	35.5
Median (25%;75%)	17 (12.5; 23.5)	32 (25.8; 37.3)	21 (13;25)	36.5 (28.8;42.3)
DASH (Disability of the Arm, Shoulder and Hand)				
Mean, standard deviation	77.5	40.3	71.24	38.6
Median (25%;75%)	77 (68.5; 87)	37.4 (26.4; 50.3)	73.3 (60.1; 82.0)	36.7 (26.8;48.3)
EQ-5D				
Mean, standard deviation	0.446	0.536	0.461	0.580
Median (25%;75%)	0.437 (0.270; 0.654)	0.592 (0.360; 0.709)	0.438 (0.306; 0.609)	0.610 (0.416; 0.742)
EQ-5D (VAS)				
Mean, standard deviation	52.4	67.5	47.7	57.4
Median (25%;75%)	55 (40; 65)	70 (60; 80)	50 (35;60)	60 (50; 70)

Table 5

Functional scale scores in patients in the mid-term period (from 5 to 9 years after TEA)

Study group	Questionnaire			
	Oxford	Mayo	Dash	EQ-5D (VAS)
First (Consequences of injuries)	31.7	75.7	38.3	65.3
Second (RA)	37.0	74.1	41.9	55.0

Table 6

Functional scale scores in patients in the studied groups in the long-term period (more than 10 years after TEA)

Study group	Questionnaire			
	Oxford	Mayo	Dash	EQ-5D (VAS)
First (Consequences of injuries)	27.7	69.1	40.9	80.0
Second (RA)	44.0	78.5	22.4	62.5

Table 7

The dynamics of elbow movement after TEA in both groups, degrees

Indicator	First group Mean follow-up period – 6.9 years (0.5–21)	Compared group Mean follow-up period – 3.8 years (0.4–16.5)	*p*
Flexion	18.1°	20.5°	0.46
Extension	49.2°	33.2°	0.13
Flexion-extension	66.1°	61.1°	0.14
Pronation	14.3°	19.0°	0.49
Supination	12.9°	15.8°	0.82
Pronation-supination	33.7°	45.8°	0.50

Table 8

The risk of aseptic loosening depending on the primary diagnosis

Diagnosis (in comparison with post-traumatic osteoarthritis)	OR (95%CI)	SE	*p*
Non-union of the distal meta-epiphysis of the humerus	8.5 (1.7–43.6)	0.84	0.010
Post-traumatic defect of elbow	3.5 (0.3–42.6)	1.28	0.326
Post-traumatic elbow deformity	10.5 (1.3–88.5)	1.09	0.031
Bone ankylosis	5.3 (0.4–66.7)	1.29	0.201

In the second group, the overall frequency of complications was 13.6% (Table 9). In 7 (8.6%) cases, a mean period of 4.5 years (1.3–8.3) revealed aseptic loosening of the endoprosthesis components, 2 (2.5%) — deep infection 1.3 and 2 years after TEA, in 2 (2.5%) — dissociation of the endoprosthesis components at 3.8 and 6.6 years.

A statistically significant risk of aseptic loosening in the first group was observed in patients operated on for a non-union in the distal humerus (OR = 8.5; 95% CI 1.7–43.6; SE = 0.84; p = 0.01) and post-traumatic deformity of EJ (OR=10.5; 95% CI 1.3–88.5; S = 1.09; p = 0.03) (Table 8). The use of some models of the endoprosthesis was also associated with an increased risk of developing this complication. In particular, the use of the Arete endoprosthesis was associated with a higher risk of loosening (OR, 3.5; 95% CI 0.9–13.3; SE = 0.69; p = 0.02).

A significant risk of a deep periprosthetic infection was observed in patients with post-traumatic defect of elbow bones (OR, 7.0; 95% CI 1.2–40.1; SE = 0.89; p = 0.03) and post-traumatic deformity of EJ (OR, 14.0; 95% CI 2.5–77.8; SE = 0.88; p<0.01) (Table 8).

In assessing the impact of operational characteristics, as well as factors regarding the quality of the operation performed, including the positioning of the endoprosthesis components, no statistically significant risk of complications was identified in the first group.

In the compared group, risk factors for component loosening were errors in the surgical technique: defective cementation of the humeral component (OR 35.0; 95% CI 3.8–325.0), valgus deviation of the humeral component ≥9° (OR 9.2; 95% CI 1.0–82.2), low constructive reliability of the endoprosthesis (OR 13.6; 95% CI 2.3–79.4), patient age ≥ 59 years (OR 12.8; 95% CI 1.5–113.0), BMI ≥32 kg/m^2 (OR 8.4; 95% CI 1.5–47.5), as well as CRP level ≥36.1 mg/l (OR 4.8; 95% CI 0.4–65.8) [17].

Discussion

Evaluation of mid-term results of TEA showed significant positive changes with respect to the amplitude of movements of the operated EJ and functional scale scores, which is consistent with the data of domestic and foreign studies. At the same time, in the group of patients with trauma-related arthroplasty, a rather high frequency of complications was observed (23.8%) requiring revision surgeries. As seen in the literature, the overall frequency of surgical reinterventions after TEA in post-trauma patients varies widely, from 5% to 45% [18, 19, 20]. Thus, according to Slobodsky et al., the frequency of complications in patients with post-traumatic elbow defects was 8% [21], and Prokhorenko et al. found complications in 4.4% of patients [13] after studying the results of TEA for intra-articular fractures and the consequences of injuries. Kho et al. reported on the results of TEA in 66 post-trau-

Table 9

The risk of deep periprosthetic infection depending on the primary diagnosis

Diagnosis (in comparison with post-traumatic osteoarthritis)	OR (95% CI)	SE	*p*
Non-union of distal meta-epiphysis of the humerus	1.6 (0.3–10.2)	0.94	0.611
Post-traumatic defect of elbow	7.0 (1.2–40.1)	0.89	0.029
Post-traumatic elbow deformity	14 (2.5–77.8)	0.88	0.003
Bone ankylosis	3.5 (0.3–39.1)	1.23	0.309

ma patients who underwent a total elbow replacement. Complications were observed only in 5.3% [19]. Other publications indicate significantly higher numbers of complications and reinterventions. In an article by Cil et al., who studied 92 patients with TEA for a non-union of the distal humerus, the frequency of complications requiring reoperation was 43%, among which the most common cause of revisions was aseptic loosening (12 cases) [18]. In Throckmorton et al. the overall frequency of complications in patients with post-traumatic osteoarthritis was 34% [12]. Probably, this difference in the number of complications is due to the high heterogeneity of patients within the group with post-traumatic changes in the elbow joint.

The risk factors for complications and the likelihood of revision surgeries after TEA are actively discussed in the literature. Some authors consider the use of a questionable surgical approach and defects in its technique [22] as a possible reason for the high frequency of unsatisfactory results of TEA. However, in our study, factor analysis did not show a statistically significant effect of the performed approach on the frequency of postoperative complications, which is also consistent with the results of the work of King *et al.* [23].

Other risk factors for unsatisfactory outcomes and revisions are considered to be: diseases for which TEA was performed; implant design; and parameters characterizing the positioning of the endoprosthesis components. Thus, in the article by Peretta et al, the analysis of the outcomes of 102 primary TEAs indicated a higher risk of reinterventions in post-trauma patients versus those with elbow rheumatoid damage *(*OR – 4.3; % CI, 1.5–12; $p = 0.008$). Also, a comparison of different implants revealed a greater risk in the Coonrad-Morrey endoprosthesis group compared to Biomet Discovery endoprostheses (OR, 7.1; 95% CI, 1.3-38; $p = 0.024$) [24]. Park *et al.*, studying long-term results (mean follow-up period — 12 years) of 84 TEAs with constrained and unconstrained implants, found a greater frequency of revisions in the second group (22.4% and 34.3%, respectively) [25].

In our study, it was also found that patients with the Arete endoprostheses (Russia) compared with the Coonrad-Morrey endoprostheses (Zimmer, USA) showed a significantly more frequent development of infection. However, analyzing the intraoperative indicators in the two groups of implants, we found significant differences in the volume of blood loss (the Arete endoprosthesis group averaged 440 ml, the Coonrad-Morrey endoprosthesis group — 237 ml, $p<0.01$) and the duration of operation (138 min and 125 min, respectively, $p<0.01$), which could affect the frequency of complications. It should be noted that the Arete endoprostheses were used mainly from 2005 to 2011. This time interval is associated with the accumulation of experience in performing TEA and, as a result, with more frequent technical difficulties. Since 2012, the Coonrad-Morrey endoprostheses have been implanted. At that time, the experience of total joint replacement by the surgical team was more than 150 operations. Thus, the identified risk of the development of deep infection is probably associated not only with the design features of the endoprosthesis, but also with the applied surgical technique and possible patient-related factors.

The statistically significant differences in the groups regarding the number of prior surgeries, blood loss, and the duration of operation may explain the less favorable results in post-trauma patients. A serious limitation in this study was the difference in the follow-up time of the compared groups. However, deep infections developed in both groups of patients, in most cases within two years after the operation, and in this parameter, post-traumatic osteoarthritis is a prognostic adverse factor. At the same time, aseptic loosening was observed mainly at a later time, so for a final conclusion regarding the lesser frequency of loosening in the group of patients with RA, a longer follow-up

is required. In accordance with our data, the greatest risk for loosening occurs in patients with post-traumatic deformity of elbow. This may be associated with altered biomechanics of elbow, poor bone quality due to long-term existing contracture of the joint and muscular dysfunction. In turn, the risk factors for revision in patients with RA are errors in the surgical technique (defective cementation of the humeral component, valgus deviation of the humeral component ≥9°), low constructive reliability of the endoprosthesis, patient age ≥59 years, BMI ≥32 kg/m^2, and CRP level ≥36.1 mg/l.

Thus, mid- and long-term results showed that total arthroplasty is almost equally beneficial in restoring the elbow motion of and limb function in rheumatoid arthritis and post-traumatic cases. However, the frequency of postoperative complications requiring revision in the patient group with consequences of injuries is significantly higher than in patients with rheumatoid arthritis.

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