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Revision Interventions for Failed Proximal Interphalangeal Joint Arthroplasty: Causes and Outcomes

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Abstract

Background. In recent decades, interest in proximal interphalangeal joint (PIPJ) arthroplasty has significantly increased around the world. At the same time, a growing number of operations entail an increase in the number of reinterventions.

The aim of the study — to determine the causes and evaluate the outcomes of revision interventions for proximal interphalangeal joint arthroplasty based on the data from a federal center for trauma and orthopedics.

Methods. We analyzed gender and age distribution of patients, the number of revisions, possible causes of implant failure, its localization and type, survival rate of the construct, surgical approaches. The study covers a 15-year period.

Results. Among 95 performed primary PIPJ arthroplasties, 15 (15.8%) cases of failure were observed in 14 patients. There was 1 periprosthetic fracture; 2 cases of implant fracture; instability of implant components — 12 cases associated with injury, increased physical activity and other causative factors. The maximum failure rate was detected in the II finger (31.6% of the number of initially implanted prostheses). After primary arthroplasty, instability was most often observed in hinged implants (SBI D.G.T. PIP joint implant and the RM Finger Mathys). The option for reintervention in 2 (16.7%) cases was PIPJ arthrodesis, in 11 (83.3%) — revision arthroplasty.

Conclusions. Despite the significant (15.8%) rate of adverse outcomes after proximal interphalangeal joint arthroplasty, most frequently caused by implant instability, the survival rate of the implants reaches up to 10 years in some cases and depends both on the type of prosthesis and the patient's occupation. Overall, revision proximal interphalangeal joint arthroplasty allows for joint mobility preservation and statistically significantly reduces pain.

Keywords: proximal interphalangeal joint, implant failure, instability, revision arthroplasty, proximal interphalangeal joint arthrodesis, periprosthetic fracture, implant fracture.

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Причины и результаты ревизионных вмешательств после эндопротезирования проксимального межфалангового сустава кисти

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Реферат

Актуальность. В последние десятилетия в мире значительно возросло количество выполненных первичных операций эндопротезирования проксимального межфалангового сустава, что повлекло за собой увеличение числа ревизионных вмешательств.

Цель исследования — определить причины и оценить результаты ревизионных вмешательств после эндопротезирования проксимального межфалангового сустава кисти на примере федерального травматолого-ортопедического центра.

Материал и методы. Проведен анализ половозрастного состава пациентов, количества ревизионных операций, возможных причин несостоятельности эндопротеза, его локализации и типа, срока службы конструкции, хирургических подходов. Глубина исследования — 15 лет.

Результаты. Среди 95 выполненных операций первичного эндопротезирования проксимального межфалангового сустава выявлено 15 (15,8%) случаев неблагополучных исходов у 14 пациентов. Зарегистрированы один перипротезный перелом; 2 случая перелома имплантата; 12 случаев нестабильности компонентов, связанных с травмой, повышенной физической нагрузкой и другими причинными факторами. Максимальная частота неудач выявлена на II пальце (31,6% от числа первично установленных эндопротезов). После первичного эндопротезирования нестабильность чаще всего выявлялась после установки связанных эндопротезов (SBI D.G.T. PIP joint implant и RM Finger Mathys). Вариантом повторного вмешательства в двух (16,7%) случаях явился артродез проксимального межфалангового сустава, в 11 (83,3%) — ревизионное эндопротезирование.

Заключение. Неблагополучные исходы составляют значительную долю (15,8%) первичного эндопротезирования проксимального межфалангового сустава. Наиболее частой причиной является нестабильность эндопротеза. В то же время срок службы конструкций достигает в ряде случаев 10 лет и зависит, вероятно, и от типа эндопротеза, и от рода занятий пациента. Ревизионное эндопротезирование проксимального межфалангового сустава позволяет сохранить подвижность сустава, статистически значимо уменьшая интенсивность болевого синдрома.

Ключевые слова: проксимальный межфаланговый сустав, несостоятельность эндопротеза, нестабильность, ревизионное эндопротезирование, артродез проксимального межфалангового сустава, перипротезный перелом, перелом имплантата.

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INTRODUCTION

Injuries and diseases of the proximal interphalangeal joint (PIPJ), particularly osteoarthritis, affect approximately 15.5% of the population. Currently, PIPJ arthroplasty is becoming the preferred and most promising surgical option for restoring joint and overall hand function [1, 2, 3].

The concept of PIPJ arthroplasty first emerged in 1940 when M. Burman described the outcomes of Vitallium cup arthroplasty for the metacarpophalangeal and interphalangeal joints of the fingers [4]. Total PIPJ arthroplasty originated in the 1960s and was initially performed in patients with end-stage rheumatoid arthritis [5]. Early studies reported severe complications, including infection, periarticular fibrosis, and bone resorption. Over time, the indications for arthroplasty expanded to include severe post-traumatic damage, idiopathic osteoarthritis, and rarer systemic diseases such as juvenile idiopathic arthritis, gouty arthritis, and others [6, 7, 8, 9, 10].

Interest in this topic increased in the early 1970s, with the publication of studies focusing on the technological aspects, challenges, and initial outcomes of primary PIPJ arthroplasty. Since 2014, the number of annual publications on this subject has grown to 20-30 per year.

In recent decades, the global rise in primary PIPJ arthroplasty procedures has led to an increase in revision operations. Following implant removal, significant bone loss is often observed, which considerably limits the possibilities for re-operation. Revision arthroplasty demands a high level of surgical expertise and advanced implant systems.

The aim of this study was to determine the causes and evaluate the outcomes of revision interventions following proximal interphalangeal joint arthroplasty based on the data from a federal center for trauma and orthopedics.

METHODS

Study design: a retrospective continuous single-center study.

The study is based on the data from the medical information system regarding 95 PIPJ arthroplasty procedures performed at the Federal Center for Traumatology, Orthopedics, and Arthroplasty of the Ministry of Health of Russia (Cheboksary). The study covers a 15-year period (2009-2024).

We analyzed patient demographics (age and gender distribution), the number of revision operations, potential causes of implant failure, its localization and type, implant survival rate, and surgical approaches.

Revision PIPJ arthroplasty was defined as the replacement of at least one implant component (proximal or distal). Patients who underwent other interventions on the same joint after the primary arthroplasty were excluded.

Periprosthetic fractures, mechanical implant failure, and aseptic loosening were evaluated radiologically and, when necessary, using computed tomography.

A dorsal surgical approach was used along the previous operative scar, with proximal or distal extension if necessary. After implant removal, the final assessment of bone defects was performed. If cortical integrity was preserved, a larger prosthesis with cemented or cementless fixation was selected. In the early years of our experience, we did not prioritize intraoperative extensor mechanism reconstruction, relying instead on immobilization for 2-3 weeks postoperatively. However, with growing experience, we now consistently restore the extensor tendon, performing refixation of the central bundle to the base of the middle phalanx and, if necessary, reinforcing it by suturing the lateral bundles. Early rehabilitation is initiated in such cases. In cases of significant cortical bone defects following implant removal, PIPJ arthrodesis was performed.

PIPJ implant failure occurring within 2 years after primary arthroplasty was considered an early failure (Group I), and after 2 years – a late failure (Group II). Thus, all cases were divided into early and late failure groups.

For patients who underwent multiple revision operations, the total number of revisions was recorded. Implant survival rate was measured as the interval from primary to revision operation or, in cases of multiple revisions, from the previous to the current revision.

Follow-up evaluation of revision interventions included both objective (range of motion measured with a goniometer before and after surgery; X-ray examination) and subjective (pain severity according to the VAS criteria).

Statistical analysis

Statistical analysis was performed using Microsoft Excel 2007 and GraphPad software. Categorical data (gender, implant localization and type, causes of instability) were encoded as unordered categorical variables. Continuous variables were tested for normality using the Shapiro-Wilk test. Normally distributed variables were described using the mean value and standard deviation (SD), while non-normally distributed variables were expressed as the median and the lower and upper quartiles Me (Q1-Q3). In both cases, 95% confidence intervals (CI) were applied. Comparisons between groups were performed using the Mann-Whitney U test and Fisher's exact test.

RESULTS

The gender composition of the sample included 44 (46.3%) men and 51 (53.7%) women. At the time of the primary operation, the mean age of the patients was 41.6 years (SD = 12.5; 37.4-42.6).

Among 95 performed primary PIPJ arthroplasties, 15 (15.8%) cases of adverse outcomes were identified in 14 patients (one woman underwent revision twice), including 6 (42.9%) men and 8 (57.1%) women, with an age range of 18-62 years and a mean age of 43.5 years (SD = 12.3; 41.2-54.8).

An assessment of the age composition of patients undergoing primary and revision PIPJ arthroplasty at the time of surgery revealed a significant predominance (60%) of patients aged 18 to 50 years (Figure 1).

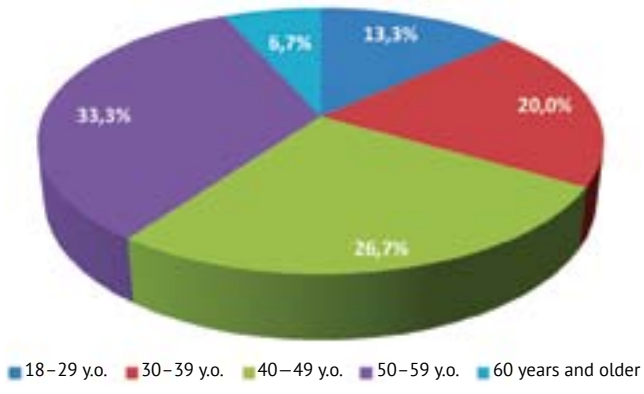

Figure 1. Age distribution of patients at the time of surgery

Among 95 performed primary PIPJ arthroplasties, 15 (15.8%) cases of failure were observed in 14 patients. Among the causes of adverse outcomes, there was 1 (6.7%) periprosthetic fracture and 2 (13.3%) implant fractures. The most common reason for re-operation was component instability – 12 cases (80%), of which 3 were trauma-related, 4 were associated with high physical loads, and in 5 cases, the cause of implant failure remained undetermined. Thirteen (86.7%) operations were performed; two patients are awaiting planned hospital admission.

Among the identified cases of PIPJ prosthesis instability, 6 cases were classified as Group I (including one patient awaiting planned hospital admission), and 9 cases as Group II (including one patient also awaiting revision surgery).

PIPJ arthroplasties for the fingers from the II to the V were performed in the center. The highest number of operations was carried out on the III (42.1%) and the IV (35.8%) finger. However, the highest failure rate (PIPJ prosthesis instability) was observed in the II finger (6 out of 19 – 31.6% of the initially implanted prostheses) (Table 1).

Instability was most frequently observed with hinged prostheses (SBI D.G.T. PIP joint implant and RM Finger Mathys).

The distribution of failed implants by type was as follows: SBI D.G.T. PIP joint implant (n = 11), RM Finger Mathys (n = 1), Moje ACAMO PIP (n = 1), and Swanson silicone implant (n = 2).

In two cases (16.7%), arthrodesis of the PIPJ was performed as a revision procedure, while in 11 cases (83.3%), revision arthroplasty was carried out. One patient underwent two revision arthroplasties: the first 3 years after the primary procedure and the second 7 years after the previous revision (Table 2).

Postoperatively, all patients reported reduced pain ($p<0.05$). The range of motion in each group either remained unchanged or decreased; however, achieving the maximum possible range of motion during follow-up was not feasible (Table 3).

The mean survival rate of the removed implants during revision procedures was 4.5 years (SD = 3.3; 1.2-4.8), ranging from less than a year to 10 years.

Table 1

Failure rate of PIPJ prostheses

Parameter	Finger							
	II		III		IV		V	
	Number of primary operations	Number of failures	Number of primary operations	Number of failures	Number of primary operations	Number of failures	Number of primary operations	Number of failures
Right hand, n	12	5	29	3	16	–	–	–
Left hand, n	7	1	11	3	18	3	2	–
Total	19	6	40	6	34	3	2	–
Failure rate, %	31.6		15.0		8.8		–	

Table 2

Causes of PIPJ prosthesis failures and outcomes of surgical treatment

Parameter	Implant fracture		Periprosthetic fracture	Cause											
				Trauma			High physical loads				Undetermined etiology				
Number	2		1	3			4				5				
Removed implant	Mathys	Silicone	DGT SBI	DGT SBI	DGT SBI	DGT SBI	DGT SBI	DGT SBI	DGT SBI	DGT SBI	Moje	DGT SBI	DGT SBI	DGT SBI	Silicone
Implanted prosthesis	Moje	Moje	–	DGT SBI	DGT SBI	Moje	DGT SBI	–	DGT SBI	DGT SBI	–	DGT SBI	Silicone	–	Silicone
Treatment modality	RA	RA	AD	RA	RA	RA	RA	AD	RA	RA	–	RA	RA	–	RA
Survival rate, years	10	8	2	1	3	7	<1	1	2	3	2	3	7	10	7

RA – revision arthroplasty; AD – arthrodesis.

Table 3

Evaluation of functional outcomes of revision PIPJ arthroplasty

Parameter	Group I (n = 5*)		p	Group II (n = 8*)		p
	Before operation	During follow-up		Before operation	During follow-up	
Pain severity according to the VAS scale, points	6.4 (4.6-9.4)	0.6 (0.3-1.7)	0.0014**	5.5 (3.7-7.3)	0.5 (0.0-1.0)***	0.0002**
Range of motion, deg.	9.0 (0.8-19.2)	11.0 (0.8-19.2)	0.6811	8.8 (4.2-15.8)	16.9 (7.0-23.0)	0.0747

* – one patient in each group is awaiting planned hospital admission for revision operation; ** – statistically significant differences; *** – Me (Q_1-Q_3).

DISCUSSION

The proximal interphalangeal joint plays a crucial role in full hand grip function, providing 85% of the flexion arc of the fingers, while the remaining 15% is provided by the distal interphalangeal joint [11, 12, 13]. The main advantage of arthroplasty is the preservation of motion despite the high rates of complications and revision operations [14, 15].

According to our study, the majority of patients were of working age with high physical activity levels, where both the aesthetic appearance of the hand and its optimal functionality were crucial, making joint mobility preservation particularly important.

It is worth noting that the variability in primary PIPJ arthroplasty outcomes depended on location. Our data indicate that PIPJ prosthesis failure is most frequently observed in the II finger. Literature suggests that the feasibility of PIPJ arthroplasty in the II finger remains controversial due to the significant lateral and axial rotational stresses during grip. Some authors report a fourfold increased risk of complications and advocate for arthrodesis as the method of choice for this joint pathology [16, 17]. However, T. Richards et al. dispute the preference for the PIPJ arthrodesis of the II finger as a default operation and support arthroplasty, particularly with silicone implants [18].

M.T. Milone et al. compared the II finger with three other fingers and concluded that the rate of deformities and complications associated with instability in case of the PIPJ arthroplasty of the III finger may be similar to that of the second one. E.R. Wagner et al. and M.T. Milone et al. suggest that the complication rate presents a relative contraindication for the PIPJ arthroplasty of both the II and the III finger [19, 20]. Our data show an increasing prevalence of the PIPJ prosthesis instability from the V to the II finger – 0.0%, 8.8%, 15.0%, and 31.6% for the V, IV, III, and II fingers, respectively.

Revision PIPJ arthroplasty presents a significant challenge. Minimal cortical bone remains after implant removal, and trabecular bone is largely absent in the medullary canals [21]. In our practice, we perform a dorsal surgical approach with subsequent refixation of the central bundle of the extensor tendon for both primary and revision procedures. However, literature actively discusses alternative approaches, such as palmar and lateral surgical approaches, along with their advantages and disadvantages [22, 23]. Selection of implant and surgical strategy remains a key issue in primary PIPJ arthroplasty [12, 24], as well as in case of revision interventions.

The aims of both primary and revision PIPJ arthroplasty include the reduction of pain, increased range of motion, restoration of the fingers' biological axis, and improvement of hand function [25, 26, 27]. The present study demonstrated that revision arthroplasty statistically significantly reduces pain and preserves PIPJ mobility, confirming the findings of our previous study [28].

It should be noted that the change in the range of motion after revision surgery compared to preoperative levels is minimal, and arthrodesis remains the method of choice when bone integrity is compromised due to implant removal or periprosthetic fractures.

Several surgical methods exist for both arthrodesis and PIPJ fixation. Compression screw osteosynthesis has shown great results in terms of nonunion rates compared to Kirschner wire fixation. Over the past 10 years, there has been a growing number of publications on compression techniques, suggesting a shift toward compression-based approaches. The limited data available on PIPJ arthrodesis lack clear indications for alternative techniques. Kirschner wire osteosynthesis remains relevant in cases of acute trauma with soft tissue defects or extensive bone loss following failed PIPJ arthroplasty [29, 30, 31, 32, 33]. Only large multicenter randomized controlled trials can determine the optimal PIPJ arthrodesis technique.

Study limitations

Limitations of this study are the small sample size and the insufficient amount of literature available for performing a meta-analysis of the issue.

CONCLUSIONS

The analysis of PIPJ arthroplasty outcomes in the federal center for trauma and orthopedics demonstrated the demand for this treatment, primarily among younger patients, likely due to their high functional requirements.

Despite the significant (15.8%) rate of adverse outcomes after primary operation, most frequently caused by implant instability, the

survival rate of the implants reached up to 10 years in some cases and depended both on the type of prosthesis (hinged implants were more prone to instability) and the patient's occupation (more than one-third of patients requiring revision intervention were engaged in heavy physical labor).

A notable trend was the increasing failure rate from the V to the II finger, reaching 31.6% for the latter, likely due to higher everyday functional loads. The primary surgical treatment for PIPJ prosthesis failure remains revision arthroplasty (83.3%), though arthrodesis is also justified in certain cases. Overall, re-operation for the failure of the proximal interphalangeal joint implant allows for joint mobility preservation and statistically significantly reduces pain.

The limited number of scientific papers on this issue highlights the need for further investigation through multicenter studies.

DISCLAIMERS

Author contribution

Fedotov P.V. — data acquisition, analysis and interpretation; drafting and editing the manuscript.

Kovalev D.V. — data acquisition, analysis and interpretation; drafting and editing the manuscript.

Nikolaev N.S. — study concept and design, editing the manuscript.

Mikhailov A.S. — data acquisition, analysis and interpretation; drafting and editing the manuscript.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear responsibility for all aspects of the study to ensure proper consideration and resolution of all possible issues related to the correctness and reliability of any part of the work.

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