

DOI: <https://doi.org/10.17816/vto83921>

# Long-term results of reconstructive surgery in posttraumatic deformities of the proximal epimetaphysis of the tibia

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## ABSTRACT

**BACKGROUND:** Tibial plateau fractures (TPF) are common and account for up to 1% of all fractures. The most unfavorable results of their treatment occur with nonunion, malunion, and malunion of TPF fractures. Unfavorable functional results of treatment are due to the occurrence of stiffness in the joint, the development of post-traumatic osteoarthritis, instability in the joint and the presence of infectious complications. In this case, there are indications for surgical treatment of intraarticular fractures of TPF.

**AIM:** to evaluate long-term results and factors leading to knee arthroplasty after reconstructive surgery for post-traumatic deformities of the proximal tibial epimetaphysis.

**MATERIALS AND METHODS:** The long-term (in terms of 5 to 10 years) treatment results were assessed in 46 patients with malunion of intra-articular fractures of the tibial plateau, operated in the period from 2010 to 2015. The average age of patients was  $47.6 \pm 11$  years. We considered both cases of neglected conservative treatment (87%) and cases with unsuccessful surgical fixation (13%).

**RESULTS:** The KOOS pain score was 75.0 [66.6; 94.0] points, which corresponds to a good result. Satisfactory results were observed during the examination on the basis of “daily physical activity” (66.1 [51.5; 85.3] points) and on the basis of “symptoms and stiffness” (65.4 [53.6; 86.0] points). Average scores for the attribute “physical activity while playing sports, games and entertainment” and for the attribute “quality of life” — 53.75 [25.0; 81.0] and 53.8 [25.0; 81.0] points, respectively, were assessed as unsatisfactory. In terms of up to 10 years, 5 out of 46 patients (10.9%) underwent knee arthroplasty. A statistically significant relationship was determined between the varus deformity more than  $3^\circ$  persisting after reconstructive surgery ( $r=0.664$ ,  $p < 0.0001$ ), the time period between injury and reconstructive surgery ( $r=0.262$ ,  $p=0.007$ ) and the appearance of indications for TKA.

**CONCLUSION:** The study revealed a statistically significant direct correlation relationships between persisting varus deformity more than  $3^\circ$ , as well as a long time interval between injury and the performed reconstructive surgery with the emergence of indications for arthroplasty.

**Keywords:** intra-articular fractures; knee joint; osteotomy; varus deformity; post-traumatic deformity; reconstructive surgery.

## To cite this article:

Malyshev EE, Zykin AA, Gorbatov RO, Trifonov AM, Illarionova TV. Long-term results of reconstructive surgery in posttraumatic deformities of the proximal epimetaphysis of the tibia. *N.N. Priorov Journal of Traumatology and Orthopedics*. 2021;28(4):5–12. DOI: <https://doi.org/10.17816/vto83921>

Received: 01.11.2021

Accepted: 22.12.2021

Published online: 24.03.2022



DOI: <https://doi.org/10.17816/vto83921>

# Отдаленные результаты реконструктивных операций при посттравматических деформациях проксимального эпиметафиза большеберцовой кости

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## АННОТАЦИЯ

**Обоснование.** Переломы проксимального отдела большеберцовой кости (ПОББК) часто встречаются и составляют до 1% от всех переломов. Наиболее неблагоприятные результаты их лечения возникают при несросшихся, неправильно срастающихся и неправильно сросшихся переломах ПОББК. Неблагоприятные функциональные результаты лечения обусловлены возникновением тугоподвижности в суставе, развитием посттравматического остеоартроза, нестабильностью в суставе и наличием инфекционных осложнений. При этом возникают показания к хирургическому лечению внутрисуставных переломов ПОББК.

**Цель исследования** — оценить отдаленные результаты и выявить факторы, влияющие на неблагоприятный исход оперативного лечения пациентов с посттравматическими деформациями проксимального эпиметафиза большеберцовой кости.

**Материалы и методы.** Выполнена оценка отдаленных (в сроки от 5 до 10 лет) результатов лечения 46 пациентов с неправильным сращением внутрисуставных переломов плато большеберцовой кости, оперированных в период с 2010 по 2015 г. Средний возраст больных составил  $47,6 \pm 11$  лет. Рассматривались как случаи запущенного консервативного лечения (87%), так и случаи с неудачной оперативной фиксацией (13%).

**Результаты.** Оценка в категории «боль» по шкале KOOS (Knee Injuries and Osteoarthritis Outcome Score) составила 75,0 [66,6; 94,0] баллов, что соответствует хорошему результату. Удовлетворительные результаты наблюдали при обследовании по признаку «ежедневная физическая активность» (66,1 [51,5; 85,3] балла) и по признаку «симптомы и тугоподвижность» (65,4 [53,6; 86,0] балла). Баллы по признаку «физическая активность при занятиях спортом, играми и развлечениях» и по признаку «качество жизни» были оценены как неудовлетворительные (53,75 [25,0; 81,0] и 53,8 [25,0; 81,0] балла соответственно). В сроки до 10 лет у 5 из 46 пациентов (10,9%) было выполнено эндопротезирование коленного сустава. В результате исследования выявлена статистически значимая прямая корреляционная взаимосвязь между сохраняющейся варусной деформацией более  $3^\circ$  ( $r=0,664$ ,  $p < 0,0001$ ), а также длительным временным интервалом между травмой и проведенной реконструктивной операцией ( $r=0,262$ ,  $p=0,007$ ) с возникновением показаний к эндопротезированию.

**Заключение.** Результаты проведенного нами анализа хирургического лечения последствий внутрисуставных переломов проксимального отдела большеберцовой кости позволили выявить взаимосвязь между сохраняющейся варусной деформацией оси нижней конечности более  $3^\circ$ , длительным временным интервалом между травмой и реконструктивно-восстановительной операцией и необходимостью эндопротезирования коленного сустава.

**Ключевые слова:** внутрисуставные переломы; коленный сустав; остеотомия; варусная деформация; посттравматическая деформация; реконструктивная операция.

## Как цитировать:

Малышев Е.Е., Зыкин А.А., Горбатов Р.О., Трифонов А.М., Илларионова Т.В. Отдаленные результаты реконструктивных операций при посттравматических деформациях проксимального эпиметафиза большеберцовой кости // Вестник травматологии и ортопедии им. Н.Н. Приорова. 2021. Т. 28, № 4. С. 5–12. DOI: <https://doi.org/10.17816/vto83921>

## BACKGROUND

Tibial plateau fractures (TPFs) are severe injuries of the lower extremities and account for 1%–3% of all skeletal fractures and 6%–12% of all intra-articular fractures [1]. Surgical treatment of intra-articular TPFs requires an extraordinary approach in surgery [2]. Fracture reduction is a difficult task even for an experienced surgeon, and soft tissues are intolerant of careless and massive dissection [3]. Improper restoration of the articular surface of the tibial plateau and limb axis results in early arthrosis. According to various estimates, the prevalence of post-traumatic osteoarthritis after intra-articular TPFs reaches 30%. Moreover, the most unfavorable outcomes occur with non-united, maluniting, and malunited bones in TPFs [4]. Unresolved impression of fragments of the articular surface and malunion with angular deformity in the frontal or sagittal plane lead to knee joint instability, excessive load on certain parts of the joint, and functional failure [5]. Endoprosthesis replacement of the knee joint is an effective method of treatment in such cases; however, it is associated with technical difficulties in the presence of severe angular deformities and bone defects [6].

Moreover, the question of an alternative method of treatment in young patients and middle-aged patients always arises. In such cases, reconstructive corrective surgeries are necessary to improve the functional state of the knee joint [7]. The surgical approach and technique depend on the deformity type and severity, presence of pre-existing implants, and condition of the soft tissues. Corrective surgery in such cases is always difficult; the strategy involves the restoration of the articular surface congruence, normalization of the limb axis, and elimination of the knee joint instability.

**The study aimed** to evaluate long-term outcomes and identify factors that affect the unfavorable outcomes of the surgical treatment of patients with post-traumatic deformities of the proximal tibial epimetaphysis.

## MATERIALS AND METHODS

The study was conducted from 2010 to 2020. It included patients with maluniting, malunited, and nonunion of intra-articular TPFs, aged 18–70 years. Surgical treatment was performed in the traumatology and orthopedic department of the Institute of Traumatology and Orthopedics of the Privolzhsky Research Medical University of the Ministry of Health of Russia.

The treatment outcomes of 46 patients who underwent reconstructive and restorative treatment of proximal tibial fractures from 2010 to 2015 were analyzed. The mean age of the patients was  $47.6 \pm 11$  years. The study included patients with neglected conservative treatment (87%,  $n=40$ ) and patients with unsuccessful surgical fixation (13%,  $n=6$ ) of a TPF. The period from injury to reconstructive surgery was 10–72 weeks.

In 60% of the cases ( $n=28$ ), abnormal union of fractures was noted with up to 16 weeks after injury. Six (13%) patients with malunion of medial condylar fractures and 25 (54%) patients with lateral condylar fractures were treated. Moreover, 15 (33%) patients received treatment for type C bicondylar fractures with malunion according to the AO/ASIF classification. Of these patients, eight had varus deformity and seven had valgus deformity of the limb axis. The anatomical femorotibial angle according to radiographs before treatment was  $160^\circ$ – $194^\circ$ . Two types of osteotomies (intra-articular and extra-articular) were used to correct the position of osteocartilaginous fragments. Patients became active after 48 h. Axial load during intra-articular osteotomy was excluded for 10–12 weeks; with extra-articular osteotomy, the axial load was limited for 8–12 weeks, followed by its gradual increase.

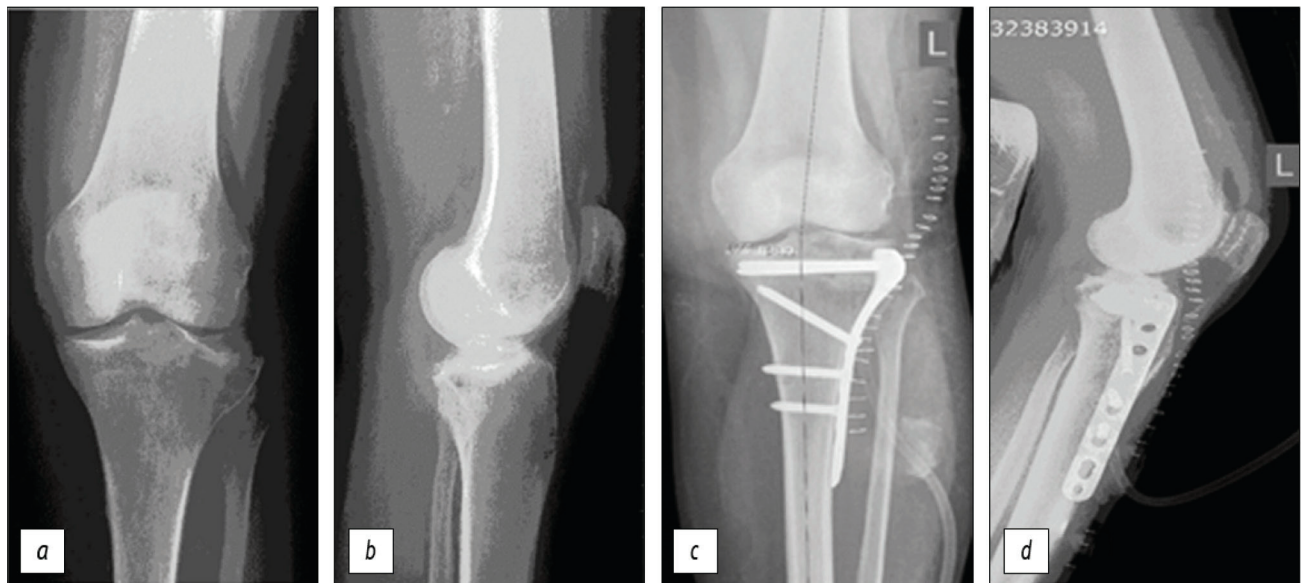
Long-term outcomes were followed for 7.5 [5–10] years after surgery. The treatment outcomes were evaluated based on X-ray imaging, clinical examination, and questionnaire survey using the modified Knee Injuries and Osteoarthritis Outcome Score (KOOS) scale. The outcomes were assessed as excellent with a score of  $\geq 85$  points, good with 84–70, satisfactory with 69–60, and unsatisfactory with  $< 60$ .

The study was conducted in accordance with the Declaration of Helsinki (adopted in June 1964 in Helsinki, Finland, and revised in October 2000 in Edinburgh, Scotland) and was approved by the Ethics Committee of the Privolzhsky Research Medical University of the Ministry of Health of Russia (minutes of the Local Ethics Committee of the Privolzhsky Research Medical University of the Ministry of Health of Russia No. 2 dated 11/05/2012). Informed consent for study participation was obtained from each patient.

**Surgical technique.** In the case of valgus deformity, intra-articular osteotomy of displaced osteocartilaginous fragments with bone defect replacement with an allograft and fixation with locking compression plate proximal tibia plate was most often performed ( $n=25$ ) (Fig. 1).

With limited impressions of the posterocentral sections of the lateral condyle of the tibia, a corrective osteotomy was performed from the lateral approach along the edge of the external collateral ligament with its isolation and external release. Fixation was performed with stress-locked wires or a fragment of the foot plate. Such surgeries were performed in 7 (15%) patients. Moreover, in 3 (7%) cases, we used an original method of replacing an osteocartilaginous defect of the proximal tibia with an autograft from the posterior sections of the lateral femoral condyle, which showed high efficiency and allowed complete restoration of the knee joint function at a level that ensured the patient's sports loads.

In the case of long-term damage of the medial condyle and varus deformity of the tibia, intra-articular osteotomy was performed with bone defect replacement and fixation with a TomoFix plate (DePuy-Synthes, Switzerland). These surgeries were performed in 8 (17%) patients.



**Figure.** Radiographs of the knee joint of a 65-year-old female patient: *a, b* — on admission: malunion of the proximal tibia fracture. On radiographs of the knee, valgus deformity with impression of the lateral condyle of the tibia was determined; *c, d* — intra-articular osteotomy of the posterior and central part of the lateral condyle was performed, osteotomy and reduction of the osteochondral fragment, filling of the bone defect formed during the elevation of the articular surface with an allograft, fixation with an LCP PTP. The congruity of the articular surface was restored, the deformity was corrected.

In cases of bicondylar fractures, the surgical treatment was determined by the type of deformity, while we performed both isolated intra-articular and extra-articular osteotomies. In the case of improper consolidation of bicondylar fractures with the displacement of the medial part of the joint, or with the lateral part impression, corrective osteotomies were performed from two approaches with two-plate fixation. Such surgeries were performed in 7 (15%) patients.

In 1 (2%) case of nonunion with severe chronic varus deformity of the proximal tibia, a distraction apparatus for external fixation was used and internal osteosynthesis of bone fragments was performed sequentially.

**Data processing.** Statistica 10.0 program (StatSoft, USA) was used for statistical processing of collected data. Statistical hypotheses were tested using nonparametric criteria. Median (*Me*) and 25th and 75th percentiles were used. Independent samples were compared using the Mann–Whitney test,  $\chi^2$  with Yates correction, and Fisher’s exact test. The Wilcoxon test was used to assess the dynamics of indicators during follow-up. The correlation study was performed according to the Spearman method (*r*).

## RESULTS

The functional outcomes of surgical treatment were evaluated according to the international KOOS scale. The “pain” score was 75.0 [66.6; 94.0] points, which corresponded to good outcomes. Satisfactory outcomes were obtained during the examination on the aspect of “daily physical activity” (66.1 [51.5; 85.3] points) and “symptoms

and stiffness” (65.4 [53.6; 86.0] points). The average scores on “physical activity in sports, games, and entertainment” and on the “quality of life” were 53.75 [25.0; 81.0] and 53.8 [25.0; 81.0] points, respectively, which were rated as poor because most of the patients had progressive post-traumatic osteoarthritis and an active lifestyle before knee joint injury, and their function could not be restored to pre-injury levels because of surgical treatment. The range of motion, except for the case of arthrodesis of the knee joint, was up to 108.7° [90.0°; 130.0°] for flexion and 2.8° [0.0°; 5.0°] for extension, which corresponds to good and excellent outcomes. A purulent-septic complication was registered in 1 (2%) female patient with concomitant diabetes mellitus and morbid obesity.

During the follow-up period of 5–10 years, 5 of 46 (10.9%) patients underwent total knee replacement (TKR). Indications for endoprosthesis replacement were functional disorders in the knee joint (Table).

A significant direct correlation ( $r=0.262$ ,  $p=0.007$ ) was found in the period between injury and surgery and occurrence of indications for endoprosthesis replacement. The interval between injury and surgery was 35.2 [24.0; 48.0] weeks in patients who required further knee arthroplasty and 13.5 [12.0; 14.0] weeks in patients who did not have indications for joint replacement.

A correlation was also noted between the occurrence of indications for endoprosthesis replacement and varus deformity remaining after reconstructive surgery ( $r=0.321$ ;  $p=0.001$ ), whereas the correlation coefficient value increases by two times in the presence of varus deformity of  $>3^\circ$  ( $r=0.664$ ,

**Table.** Comparison of the functional state of the knee joint in patients, *Me* [25p; 75p] (Mann–Whitney criterium)

Index	Indications for TKR ( <i>n</i> =5)	No indications for TKR ( <i>n</i> =40)	<i>p</i>
KOOS symptoms, points	28.7 [10.7; 50.0]	73.7 [60.7; 92.9]	0.0046
KOOS pain, points	44.4 [30.6; 50.0]	83.5 [72.2; 94.4]	0.0136
KOOS daily physical activity, points	35.5 [28.1; 50.0]	76.4 [68.0; 95.6]	0.0017
KOOS physical activity when playing sports, games and entertainment, points	15.0 [5.0; 20.0]	52.3 [20.0; 85.0]	0.0135
KOOS quality of life, points	25.2 [12.5; 30.0]	61.1 [43.8; 87.5]	0.0122
Flexion, °	86.0 [80.0; 100.0]	116.2 [110.0; 130.0]	0.0035
Extension deficit, °	10.0 [10.0; 10.0]	1.8 [0.0; 2.5]	0.0016

Note: TKR —total knee replacement; KOOS — Knee Injuries and Osteoarthritis Outcome Score; *p* —statistically significant calculation.

$p < 0.0001$ ). Varus deformity could not be completely eliminated in 8 of 46 (17.4%) patients, whereas varus deformity of  $>3^\circ$  was registered in 3 of 8 (6.5%) patients.

Moreover, valgus deformity did not show significant relationships ( $p > 0.05$ ) with the occurrence of indications for TKR. In addition, no significant relationship ( $p > 0.05$ ) was found between the patient's age and the need for endoprosthesis replacement after reconstructive and restorative surgeries.

## DISCUSSION

Abnormal union of tibial condylar fractures may result from advanced cases treated with a plaster cast; surgical treatment, when satisfactory reposition and fixation of the fracture was not achieved; and early axial load leading to secondary displacement of osteocartilaginous fragments.

In our opinion, indications for surgery are pronounced deformities of the proximal tibia in all three planes, residual intra-articular deformities causing significant incongruence of the articular surfaces, pronounced axial deformities, and significant instability of the knee joint caused by depression of the intra-articular fragments.

In a study of factors that influence poor treatment outcomes of patients who underwent corrective osteotomy, a correlation was found between a limited range of motion in the knee joint and a poor treatment outcome of a patient who received intra-articular osteotomy of the tibia [8]. A similar conclusion was made by Christiano et al. (2020). The investigators have established that patients with a history of corrective osteotomy for TPF malunion often have a limited range of motion in the knee joint, which led to poor clinical outcomes [9].

In a study by Sundararajan et al. (2016), six patients had undercorrection of varus deformity by  $>5^\circ$  with a mean value of  $9.06^\circ$  (range  $6^\circ$ – $14.9^\circ$ ). However, despite insufficient correction, all patients had excellent to good functional outcomes [10]. On the contrary, in our study, incompletely corrected varus deformity of  $>3^\circ$  in some patients led to poor functional outcomes and conversion to TKR.

Given that osteotomies are performed in the area with spongy bone tissue, structured grafts and plates with angular stability of screws are required to achieve stable fixation. Post-traumatic bone defects and bone tissue defects after deformity correction, in almost all cases, require plastic replacement [11]. In the case of the knee joint instability, ligamentous apparatus reconstruction should be performed after removal of depressed intra-articular fragments. With pronounced retraction and displacement along the length, the use of external fixation devices is reasonable. Post-traumatic osteoarthritis with persistent pain is more common with significant incongruence of the articular surface or severe deformity, especially varus. The early restoration of movements in the knee joint with long-term limitation of axial load is necessary to achieve good outcomes [7].

We believe that a carefully planned surgical correction, corresponding to the type and severity of the deformity, and the quality of the bone in the case of intra-articular TPF malunion, provides good treatment outcomes in most patients, prevents the progression of post-traumatic arthrosis by eliminating the incongruence of the articular surfaces, restores the limb axis, and stabilizes the knee joint. Surgical reconstruction in the case of malunion of tibial condylar fractures is technically complex, requires careful planning and extraordinary treatment approaches to obtain good functional outcomes, prevents or delays endoprosthetics surgery, or creates favorable conditions for it.

When planning the surgical treatment of the consequences of intra-articular fractures of the proximal tibia, not only all of the above factors should be considered, but also, based on the study findings, the individual anatomical aspects of the patient to achieve a normal mechanical axis of the lower limb.

## CONCLUSION

When evaluating the long-term outcomes of surgical treatment of patients who underwent reconstructive and restorative surgeries for post-traumatic deformities of the

proximal tibial epimetaphysis, all patients achieved good outcomes based on the KOOS scale on “pain,” satisfactory outcomes on the “daily physical activity” and “symptoms and stiffness” scales, and poor outcomes on the “physical activity in sports, games, and entertainment” and “quality of life” scales. The range of motion in the knee joint in all patients was up to 109° [90°; 130°] in flexion and 3° [0°; 5°] in extension, which corresponds to good and excellent outcomes.

The study revealed a significant direct correlation between persistent varus deformity and a long time interval from injury to reconstructive surgery, with unfavorable functional outcomes after surgery on the proximal tibia and indications for endoprosthesis replacement.

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## ADDITIONAL INFO

**Author contribution.** Thereby, all authors made a substantial contribution to the conception of the work, acquisition, analysis, interpretation of data for the work, drafting and revising the work, final approval of the version to be published and agree to be accountable for all aspects of the work. Concept and design of the study — E.E. Malyshev; data collection and processing — E.E. Malyshev, A.A. Zykin, A.M. Trifonov; statistical processing of the data — E.E. Malyshev; text writing — E.E. Malyshev, T.V. Illarionova; editing — R.O. Gorbатов, T.V. Illarionova.

**Funding source.** Not specified.

**Competing interests.** The authors declare that they have no competing interests.

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