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Comparative analysis of the outcomes of high tibial osteotomy performed with different techniques

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Abstract

Introduction Opening- and closing wedge osteotomies are the two most commonly used variants of high tibial osteotomy in medial gonarthrosis associated with varus deformity.

Purpose Based on a retrospective analysis of the results of surgical treatment of patients with medial gonarthrosis associated with varus deformity of the proximal tibia, to evaluate functional and radiological outcomes of high tibial osteotomy performed with two different surgical techniques.

Material and methods The study included 37 patients (26 men and 11 women) aged 20 to 54 years (42.84 ± 9.1) with meadial gonarthrosis associated with varus deformity in the frontal plane. The first group included 23 patients with 25 operated limbs who underwent open wedge osteotomy (OWO), the second group included 14 patients who underwent closed wedge osteotomy (CWO).

Results Comparison of MPTA, LDTA, aPPTA and MAD in both groups after surgery did not show a statistically significant difference ($p > 0.05$), but in the closing wedge group, the recorded values had an extremely wide range. The results on the Lisholm-Tegner scale after surgery compared between the two groups showed a statistically significant difference ($p = 0.05$), this parameter showed that the opening-wedge osteotomy was more effective.

Discussion Opening wedge osteotomy is a more predictable surgical procedure compared to closing wedge osteotomy. In opening wedge osteotomy, there are significantly fewer cases with excessive or insufficient correction of reference angles and lines than after closing wedge osteotomy.

Conclusion Absence of specific surgical complications in the studied patients demonstrates the safety of both surgical techniques. The study showed an extremely wide range of MPTA and LDTA values in the closed wedge osteotomy group, which were beyond the preoperative planning. The CWO group had the highest number of patients who underwent hypercorrection of the mechanical limb axis, which was beyond the reference values. It is possible to use a small allograft or not to use it at all in OWO, which makes it a more manageable technology for correcting limb bone deformity.

Keywords: high tibial osteotomy, medial gonarthrosis, opening wedge osteotomy, closing wedge osteotomy

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INTRODUCTION

Osteoarthritis (OA) of the knee joint is a common and multifactorial disease that can lead to severe joint dysfunction due to cartilage wear, limb axis changes, and disorders in normal joint biomechanics [1]. In most OA patients, degenerative changes in the knee joint are associated with varus deformity, leading to overload of the medial compartment of the knee joint and terminal wear of the articular cartilage [2]. To eliminate the "mechanical" OA symptoms in the knee joint and, first of all, pain, various surgical techniques are used: corrective osteotomy of the proximal tibia (PT), total knee arthroplasty, unicompartmental knee arthroplasty, and arthroscopic surgery. Among them, corrective PT osteotomy is the method of choice in young and active patients with a high level of functional requirements [3, 4]. Corrective PT osteotomy allows the patient to get rid of pain, restore the impaired axis of the limb and delay the need for total knee arthroplasty [5].

The most commonly used methods for performing this operation in practice are closing wedge osteotomy (CWO) and opening wedge osteotomy (OWO). Excellent results have been reported using both methods, each with its own potential advantages and shortcomings [6, 7].

Purpose To evaluate functional and radiographic outcomes of high tibial osteotomy performed with two different surgical techniques for medial gonarthrosis associated with varus deformity of the proximal tibia.

MATERIALS AND METHODS

Study design: retrospective continuous cohort single-center study.

The study included patients who underwent corrective PT osteotomy in the period from 2021 to 2023 for medial gonarthrosis and associated varus deformity of the knee joint due to disordered reference angles of the proximal tibia, confirmed by clinical and radiographic findings.

Patient exclusion criteria were post-traumatic osteoarthritis, previous knee joint infections and systemic connective tissue diseases, aseptic osteonecrosis, absence of knee joint deformity in the frontal plane, varus deformity at the level of the knee joint due to the femur, age over 60 years, flexion contracture > 10°.

The study excluded patients who had knee joint radiographs taken in wrong positions in the postoperative period that did not allow assessment of reference angles and lines, or who did not have full lower-limb length radiographs.

All patients included in the study had anteroposterior full length radiographs of both lower limbs, and radiographs of the knee joint in two projections. For radiographic analysis, the medial proximal tibial angle (MPTA), lateral distal tibial angle (LDTA), and the degree of displacement of the mechanical axis of the limb (MAD) were measured. In plain radiographs of the knee joint in the lateral projection, the angle of inclination of the articular surface in the sagittal plane (aPPTA) was determined.

The study included 37 patients (26 (72.2 %) men and 11 (29.8 %) women), who underwent surgery on 39 knee joints. The average age of OWO patients was (43.04 ± 9.9) years and (42.5 ± 7.8) years of CWO patients.

The patients were divided into two groups according to the method of the surgical intervention. The first group included 23 patients (25 operated limbs, who underwent opening wedge osteotomy, the second group were 14 patients who underwent closing wedge osteotomy.

Preoperative planning was performed using the BoneNinja tablet multimedia application or the Weasys computer application using the Miniaci method.

Surgical technique Surgical interventions were performed under spinal anesthesia in both groups, using a pneumatic tourniquet on the affected limb. In the group of OWO patients, the surgical approach was performed through two skin incisions of 5 cm and 3 cm, placing the larger approach in an oblique direction coinciding with the course of the tendons of the pes anserinus muscles at a level of 4–5 cm from the edge of the articular surface of the tibia. The shorter approach was performed at the level of the lower third of the bone plate for its fixation with screws. According to the technique described by Lobenhoffer [8], multiplanar osteotomy of the proximal tibia and reduction of bone fragments were performed using special reduction gussets and expanders. The resulting gap was filled with a proportionate allograft from the head of the femur. Osteosynthesis was performed using a special proximal tibial medial bone plate fixed with screws with angular stability (special T-plate). In case of CWO, an anterolateral surgical approach to the proximal tibia was performed, a wedge osteotomy was performed in the frontal plane with removal of the bone wedge, the size of which was determined at the preoperative stage during radiographic planning of the osteotomy. To perform reduction from the same surgical approach, resection of the fibula was performed at the border of its upper and middle thirds. Osteoclasia was used to bring the bone fragments together and fix them with a lateral tibial plate fixed with screws with angular stability. In both techniques, the postoperative wounds were sutured tightly, without wound drainage.

Postoperative care The rehabilitation of patients in both groups included unloading of the limb for 6 weeks after surgery with early function. From the day of surgery, patients were verticalized and began to recover the impaired range of motion in the knee joint. Plaster or other immobilization of the limb was not used. Regardless of the knee radiographic findings, patients after surgery began to increase the axial load from postoperative week 6 to 8, bringing it to full weight-bearing within another 4–8 weeks.

Assessment of results In the postoperative period, patients filled out the Lysholm-Tegner questionnaire [9] remotely in Google forms, starting from the first year after the operation.

Statistical analysis Based on the initial data of the patients included in the study, Microsoft Excel spreadsheets were created. For statistical processing of the obtained data, we used the Past ver. 4.15 program. All data were checked for compliance with the normal (Gaussian) distribution using the Shapiro – Wilk and Kolmogorov – Smirnov criteria. Data that did not correlate with the normal distribution were examined using nonparametric statistics methods. Samples were compared using the Mann – Whitney and Kruskal – Wallis criteria.

Limitations of the study Significant limitations of the study were its retrospective nature, small sample size, assessment of joint function using the specialized Lysholm – Tegner scale only in the postoperative period, and the performance of surgical interventions by different surgeons, which could affect such parameters as the duration of the operation, its reproducibility, and a number of others. Moreover, the most important limitation of all so-called "industrial", or standardized types of osteotomies, is that the correction of the deformity is performed beyond its apex, so an undesirable change in adjacent reference angles is a natural consequence of violating osteotomy rules [10], what is also confirmed by our study.

RESULTS

Comparison of MPTA before surgery in both groups revealed that the values were almost equal, whereas after surgery, despite the absence of a statistically significant difference ($p > 0.05$), in the group with a closing wedge the values were in an extremely wide range (Table 1). This effect was equally representative for LDTA (Table 2).

Table 1

MPTA (°) values

Statistical parameters	MPTA (before surgery)		MPTA (after surgery)	
	Opening wedge	Closing wedge	Opening wedge	Closing wedge
P value	0.5488		0.4719	
Mean	87.32	86.307	91.72	90.96
Median	87.1	86.25	91.55	90.55
Max	99.7	91.9	98.7	99.2
Min	81.3	80.1	84.6	82
Stand. dev.	3	3.3	3.5	4.5

Table 2

LDTA (°) values

Statistical parameters	LDTA (before surgery)		LDTA (after surgery)	
	Opening wedge	Closing wedge	Opening wedge	Closing wedge
P value	0.0825		0.837	
Mean	88.79	91.035	92.04	91.675
Median	89.4	91.1	92.05	91.05
Max	95.5	96.1	97.4	99.4
Min	81.5	82	85.7	83.9
Stand. dev.	2.7	3.7	2.9	4.4

As stated above, the change in LDTA being an adjacent reference angle of the operated limb is explained by the peculiarity of all variants of standardized osteotomies of the femur or tibia, which are performed not at the level of the deformity apex (which is often at the level of the knee joint), but outside it, thus adapting to the requirements of the implant used during the operation. This effect requires further study, especially for assessing the function of the ankle joint after surgical interventions.

Having compared the angle of inclination of the articular surface in the sagittal plane (aPPTA) after surgery, a higher variability of the indicators was found for osteotomy with an opening wedge (Table 3). Evaluation of this parameter is extremely important since the inclination of the articular surface in the sagittal plane, often referred to in foreign orthopedic literature as a slope, is of great importance for correct functioning of the anterior cruciate ligament and has a significant impact on the sagittal stability of the knee joint.

Table 3

Values of aPPTA (°)

Statistical parameters	aPPTA (before surgery)		aPPTA (after surgery)	
	Opening wedge	Closing wedge	Opening wedge	Closing wedge
P value	0.3126		0.314	
Mean	79.21	80.44	77.25	78.88
Median	77.4	79.6	76.85	79.5
Max	90.2	88.3	87.7	83.7
Min	74.1	76.2	68.1	73.4
Stand. dev.	4.1	3.8	6.6	3.7

The parameter of displacement of the mechanical axis of the limb (MAD) did not show a significant difference ($p > 0.05$) in the results obtained when comparing the two groups after surgery. In both study groups, translation of the limb axis from the varus to the valgus was detected. However, in the closing wedge osteotomy group, this parameter changed in an extremely wide range with a low degree of repeatability from operation to operation (Table 4).

Table 4

MAD Values

Statistical parameters	MAD (mm)	
	Opening wedge	Closing wedge
P value	0.1221	
Mean	27.535	38.8
Median	26.45	35.95
Max	56.3	71.4
Min	11.1	16.1
Stand. dev.	10.9	18.9

At the same time, despite similar radiographic results which did not show significant differences in their analysis, the data of the Lysholm – Tegner questionnaire after the operation showed a statistically significant difference ($p = 0.05$) between the two groups. It was revealed in assessing this parameter, that the most effective was the osteotomy operation with an opening wedge after which the patients showed better functional postoperative results (Table 5).

Table 5

Data from the Lysholm – Tegner questionnaire

Statistical parameters	Lisholm scores	
	Opening wedge	Closing wedge
P value	0.054	
Mean	85.5	55.8
Median	89.5	50.5
Max	100	95
Min	50	39
Stand. dev.	15.4	20.7

In addition to filling out a validated questionnaire, patients answered three additional questions in the postoperative period:

— Are you satisfied with the surgical intervention performed?

— If you had to decide again about the need for this operation, would you agree to have it performed?

— Have you “forgotten” about the operation performed and are you able to live a full life without physical limitations associated with the operated knee joint?

If in OWO group, the "forgotten knee" effect was reported in almost 70 % of patients, in the CWO group this effect was reported by only 17 % of patients (Table 6). The obtained results do not allow us to draw unambiguous conclusions, since a valid and tested tool is required to evaluate such a complex parameter as "function of the operated joint", and the three separate questions we formulated are not such. The use of questionnaires developed for knee arthroplasty, such as FJS 12, or the new ones adapted for reconstructive surgery would allow us to more accurately answer questions about patient satisfaction after corrective osteotomy in the planned scientific studies.

Table 6

Rating of answers to additional questions

Questions	Opening wedge, %		Closing wedge, %	
	yes	no	yes	no
Are you satisfied with the surfery?	89	11	67	33
Would you repeat it if required?	89	11	71	29
Did you forget about the surgery?	65	35	17	83

Complications The results of our study show no specific perioperative complications (damage to the peroneal nerve, intraoperative fractures of the proximal tibia, osteotomy nonunion, septic complications, or others [11–14, 33]) detected in the patients, what may be explained by the small sample. We assessed the change in reference angles and lines beyond the reference values, but it was not considered as a complication in the course of this study. In the future, we plan to study the correlation between the precision of intraoperative correction of the mechanical limb axis and other reference angles and lines and the functional treatment results.

DISCUSSION

Corrective osteotomy of the proximal tibia is a valuable surgical method for bone deformity correction, normalization of reference lines and angles of the limb segment, and unloading the damaged part of the joint. One of the debatable points in discussing the operation of tibial osteotomy is the choice between the most common in practice surgical techniques. This means what the place is to intersect the bone and then fix it for subsequent consolidation. It is important to understand here that the choice of the osteotomy option with which the bone deformity will be corrected is not as important as compliance with general orthopedic rules. In particular, the goal of osteotomy can be considered achieved not only in case of subjective improvement of the patient's condition, but also provided that adequate values of the limb axis and reference angles and lines are restored. "Industrial" osteotomy of the proximal tibia, that is, an operation focused primarily on the used internal fixator in the vast majority of cases violates the so-called "rules of osteotomy" [10]. In simple terms, they can be formulated as follows: osteotomy must be performed at the deformity apex. Otherwise, restoration of reference angles and lines will require translation of bone fragments. All surgical variants of osteotomy of this segment (opening wedge, closing wedge, combination of opening and closing ones, and hinged osteotomy) are a compromise between these rules and the requirements of the implant used to fix the bone [32].

The choice of a particular surgical technique in the patients included in this study depended on the surgeons' preferences and was determined mainly by the traditions at the clinical department. Ideal candidates for surgery were physically active patients with arthrosis of the medial compartment of the knee joint with its varus deformity without terminal wear of the articular cartilage. The physiological age of the patients was no more than 60–65 years.

At the present stage of corrective osteotomies technologies at the knee joint there is a search in the scientific community for expansion of possibilities of this type of operations and analysis of unsatisfactory results of treatment associated with the choice of one or another surgical technique. Kuwashimo et al. conducted a study of 31 patients and 40 operated knee joints. The work compared the influence of the type of osteotomy on the rotational profile of the tibia. After analysing computed tomography findings, the authors came to the conclusion that in the group of patients who underwent CWO, excessive external rotation of the distal fragment of the tibia was observed, while in the group of patients with OWO no significant rotational changes were observed [15]. Similar results are presented in other scientific publications [16, 17]. This is obvious, since the integrity of the lateral cortical layer of the tibia and fibula is not violated during OWO, thus providing axial stabilization.

Of particular interest is the comparison of methods for changing the length of the limbs [18]. Thus, the conclusion of the meta-analysis by O-Sung et al. is that the average change in leg length before and after surgery with OWO was 6.96 mm. The average change between preoperative and postoperative leg length in CWO is 1.95 mm. Thus, the change in the length of the lower

limbs after OWO is greater than after CWO. At the same time, 70 % of patients after OWO had a subjective feeling of discrepancy in the length of the lower limbs, whereas after CWO only 20 % noticed a discrepancy in length. A feeling of discomfort was felt in 37 % after OWO, and in 7 % of patients with CWO [19].

One of the observations obtained in the course of our study is that the change in MPTA, LDTA and MAD after surgery has an extremely wide range with a low degree of repeatability in closing-wedge osteotomy. Similar data were obtained by Hao et al. in a meta-analysis of studies comparing two methods of performing corrective PT osteotomy. Having analyzed the radiographic results, the authors concluded that there were significantly fewer cases of over- and undercorrection in opening-wedge osteotomy than in CWO patients [20].

Of interest is the influence of the type of surgical technique on the angle of inclination of the proximal tibia in the sagittal plane (aPPTA). Schubert et al. analyzed the results of surgical treatment of 279 knee joints, of which 179 joints were operated on using opening wedge osteotomy and 89 with a closing wedge. When comparing the parameters before and after surgerythere were virtually no changes in the parameters in the OWO group, with a minimal tendency of increase in the slope. However, in the CWO group, the surgery led to a significant decrease in the proximal tibial slope. The authors associate the decrease in the slope in CWO with the fact that after osteotomy, less bone tissue is resected in the dorsal direction than in the anterolateral direction. As a result, the osteotomy gap narrows in the dorsal direction [21]. Ji et al. reported the results of a study that included 440 knee joints, of which 50 with CWO and 390 with OWO. When comparing the tibial slope before and after surgery, there were no changes in the OWO group, while in the CWO group, a significant decrease in the proximal tibial slope was observed after surgery [22].

Our study of functional results established that patients who underwent OWO received a statistically significant improvement in the function of the operated joint according to the Lysholm – Tegner scale compared to patients who underwent closing-wedge osteotomy ($p < 0.05$). Scientific publications show no statistically significant difference in the functional results between the methods of proximal tibial osteotomy [23–30]. The authors associate the difference in the functional results of surgical treatment of patients revealed in the present study performed at the Vreden NMIC for TO with the small sample of patients. Some patients were excluded from the evaluation according to the relevant criteria. A more objective evaluation of the results requires a prospective study on larger samples.

The CWO group had a larger number of patients who underwent hypercorrection of the mechanical axis of the limb during surgical treatment, beyond the reference values. According to the authors, this may be due to the fact that in CWO it is important to reduce the proximal and distal fragments after wedge removal. Moreover, it is necessary to consider such a parameter as insufficient precision when performing filing associated with an oscillatory saw (excessive blade thickness, uneven oscillation, "beating" of the blade). This leads to the fact that after removal of a large wedge, hypercorrection of the mechanical axis of the limb occurs.

High variability of the parameters revealed in the course of the present study shows the need for a more thorough analysis of the surgical technique used in the clinic of our Center in order to make both methods as effective and safe as possible. Also, the question what was the reason for the significantly higher level of functional treatment results revealed in the course of the study in the OWO group requires further study, and how to make this parameter as stable as possible for patients of the studied profile.

Each of the variants of the PT osteotomies has its advantages and shortcomings. Further high-quality scientific studies using large samples of patients and including the method of controlled transosseous osteosynthesis in the comparative analysis would allow formulating a consensus on what to consider the method of choice and what approaches to surgical treatment of patients of the studied profile should be considered the most rational.

CONCLUSION

Corrective osteotomy of the proximal tibia is a current and effective method of surgical treatment of monocompartmental knee OA combined with frontal deformity. The absence of specific surgical complications in the patients studied demonstrates the safety of both surgical techniques assessed in this study.

Our study showed an extremely wide range of MPTA and LDTA values in the CWO group, which were beyond the preoperative planning. This group also had a greater number of patients who had hypercorrection of the mechanical axis of the limb during surgical treatment which was beyond the reference values. Thus, the surgeon has no right to make a mistake in performing this technique.

On the contrary, in OWO performance, there is always the possibility of using a smaller allograft or not using it at all. This circumstance makes OWO a more manageable technology for correcting limb bone deformity. In the OWO group, there is low repeatability of the sagittal inclination of the articular surface of the tibia from operation to operation.

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