Clinical case
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Overcorrected lower limb axis as an outcome of unicompartmental knee arthroplasty

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Abstract

Introduction Unicompartmental knee arthroplasty (UKA) is an effective surgical procedure used in patients with gonarthrosis with a part of the knee being severely affected. Insufficient or excessive correction of the lower limb axis can cause a poor outcome of partial arthroplasty.

The **objective** was to evaluate ways that would help prevent insufficient or excessive correction of the lower limb axis with UKA and demonstrate techniques preventing and solving the surgical problem using a clinical example.

Material and methods A patient presented with valgus deformity at the knee level, knee pain and inability to walk without support was seen at the Vreden National Medical Research Centre for Traumatology and Orthopedics. The patient underwent UKA three years ago. The radiographs showed sparing resections of the femur and tibia, the working surface of the polyethylene liner/tibial implant component being 5 mm proximally to the articular surface of the lateral condyle of the tibia.

Results and discussion The limb axis was corrected by 6° during revision arthroplasty. The patient had no limping at one year and the result of the operation was rated as excellent measuring 45 OKS scores. The authors reviewed prerequisites of the complication in question and ways to prevent it. Iatrogenic causes primarily associated with surgical technique are reviewed.

Conclusion Inadequate mechanical alignment is characterized by a heterogeneous identity in UKA and can be caused by ineffective preoperative planning and specific anatomy of the patient, intraopereative technical failures.

Keywords: knee joint, unicompartmental knee arthroplasty, UKA, partial arthroplasty, overcorrected limb axis, complications of total joint replacement.

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INTRODUCTION

Unicompartmental knee arthroplasty (UKA) is generally recognized with many benefits including a minimally invasive procedure, organ-preserving approach, the possibility of rapid recovery and easy rehabilitation with the effect of a “forgotten knee joint” [1]. It appears to be logical towards expanding indications for the surgical intervention in patients with gonarthrosis and the general increase in partial arthroplasties worldwide [2]. Current indications for UKA formulated by Goodfellow [3] and reported by other authors include simple clinical and radiological criteria for patient selection, which are identical for any implant model. However, a personalized approach to knee arthroplasty suggests a greater number of factors to be considered preoperatively including the axis of the patient's limb, geometry of the bones that form the knee joint, the extent and nature of wear of the articular surfaces of the condyles, the elasticity of soft tissue stabilizers, the degree of meniscus damage and the extent of the extrusion, the presence, size and localization of osteophytes [4]. Differences in the parameters can influence the success or failure of UKA.

Postoperative limb alignment is one of the most important factors that would influence the long-term outcome of UKA. The overloaded lateral portion of the joint after partial medial arthroplasty and overcorrected axis would lead to persistent pain, associated ligament imbalance and other mechanical factors causing rapid lateral wear of the cartilage and progression of gonarthrosis and the need for revision [5, 6]. Numerous studies have shown that the optimal surgical outcome can be achieved with the limb realigned to pre-arthritis condition in medial involvement and often expressed in the preservation of residual varus deformity [7, 8]. In contrast to this, insufficient correction of deformity is a generally recognized risk factor for a poor outcome at a mid-term in patients with medial gonarthrosis treated with periarticular osteotomies and total replacement. The scenario is different with partial arthroplasty: the more the limb realigned to the “average population” values, the faster the arthrosis progresses in the contralateral portion of the joint [9, 10]. The deformity correction with partial arthroplasty should be the sum of the replacement of the remnants of the cartilaginous cover of the affected subchondral bone, meniscus and marginal osteophytes removed being minimally necessary for endoprosthetic positioning. Exceeding the limit and the release of intact soft tissue stabilizers, would result in overcorrection of the limb axis after UKA. This study is devoted to the analysis of the causes of such errors.

The **objective** was to evaluate ways that would help prevent insufficient or excessive correction of the lower limb axis with UKA and demonstrate techniques preventing and solving the surgical problem using a clinical example.

MATERIAL AND METHODS

A 52-year-old patient G. presented with valgus deformity of the right lower limb, knee pain increasing with ambulation and inability to walk without support was seen at the Vreden National Medical Research Centre for Traumatology and Orthopedics. Her history showed that she suffered moderate pain in the right knee joint in the last three years and aggravated during intense physical activity and walking. Complex conservative treatment she had as an outpatient provided no lasting effect. The patient was examined in one of the regional specialized medical institutions and was diagnosed with the right-sided medial gonarthrosis that was repaired with UKA of the medial portion of the right knee joint using an implant with a fixed polyethylene liner. The patient developed severe pain in the operated knee post op with a change in the characteristics compared to preoperative condition. She had a visible change in the limb axis, significant difficulties in walking and bending the knee joint. First her complaints were interpreted as a normal course of the early postoperative period, and the patient underwent comprehensive rehabilitation. There was no improvement in the intensity of the above symptoms throughout the postoperative period, she had poor quality of life and could walk only with additional support, which necessitated revision surgery. Upon admission to the hospital, the patient could ambulate with additional support on crutches and had significant, gentle, right-sided lameness. The valgus deformity of the right lower limb at the knee joint level measured 8°. Tibia adduction test with the knee slightly flexed to relax the posterior capsule showed rigid deformity that could not be corrected to bring the limb to the neutral axis. There was diffuse pain in the right knee being more severe in the lateral portion, and extension contracture with a range of motion 0°/0°/85°. The function was rated with modified Oxford Knee Score (OKS) measuring 11 indicating a significantly impaired function. Radiographs showed UKA with the medial portion of the right knee replaced (Fig. 1). Economical resections of the femur and tibia were seen and telerentgenography demonstrated valgus alignment of the limb 8° (MAD = 29 mm), posterior tilt of the tibial component within the reference values (Fig. 2). The working surface of the polyethylene liner module/tibial component of the implant was 5 mm proximal to the articular surface of the lateral condyle of the tibia. There were no radiographic signs of instability of the endoprosthetic components or wear of the liner.

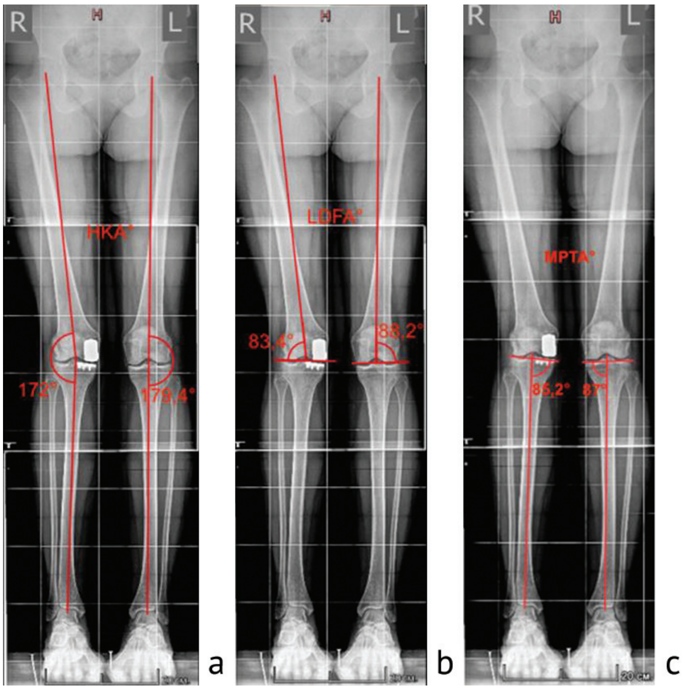

Fig. 1 Reference angles and lines measured after UKA using full length standing AP showing (a) valgus alignment of the right lower limb; (b, c) decreased LDFA and MPTA due to inadequately positioned components in the frontal plane

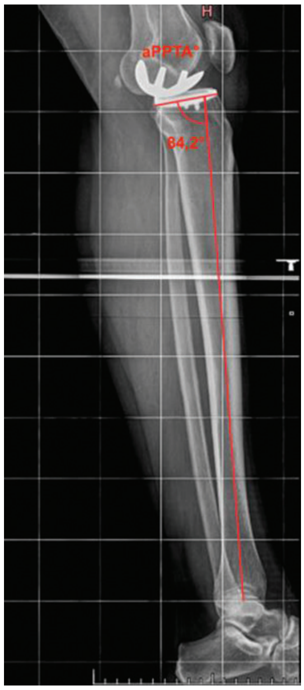

Fig. 2 The index of the inclination angle of the articular surface of the tibial component in the sagittal plane after UKA

Clinical and radiological findings of the patient revealed that the pain was caused by overcorrected limb axis during the previous UKA, "overtightened" medial ligaments and hyperpressed lateral part of the knee joint, imbalance of the extension and flexion gaps leading to a limited range of motion in the right knee joint. Revision procedure of the right knee joint was performed using a standard primary instrumentation system (Fig. 3). The limb axis was corrected by 6° during revision arthroplasty. The posterior tilt of the tibial component was within the reference values (Fig. 4). Bone cuts were made at the bottom of the defects formed after the removal of the UKA components, and a standard primary knee replacement was applied to preserve the posterior cruciate ligament with an all-polyethylene (all poly) tibial component, 1 mm thick, cemented fixation.

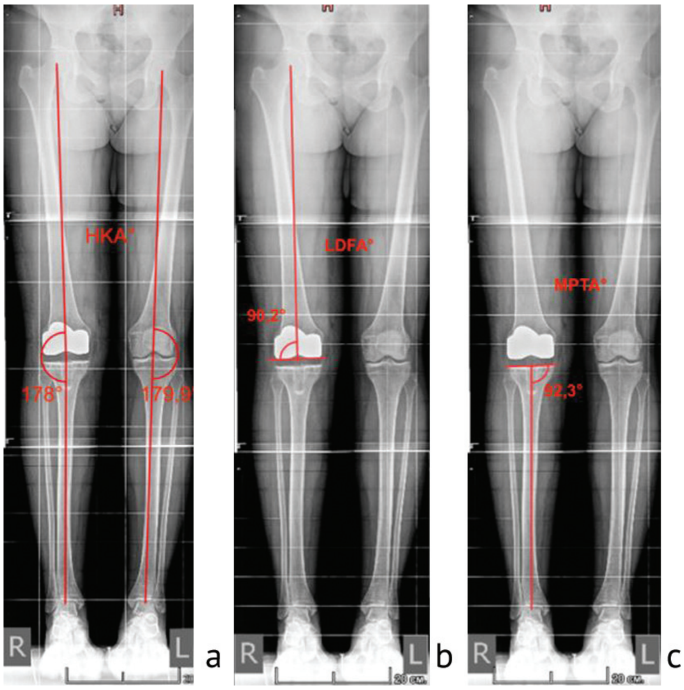

Fig. 3 Reference angles and lines measured after TKA showing (a) the limb axis corrected by 6°; (b, c) reference values of LDFA and MPTA restored

Fig. 4 The index of the inclination angle of the articular surface of the tibial component after TKA

Full range of passive movements was intraoperatively achieved in the right knee joint. The postoperative period was uneventful, the postoperative wound healed by primary intention. The patient regained the ability to move independently without additional support at 4 weeks of standard rehabilitation as an outpatient, and restored the range of motion in the knee joint to an acute angle of flexion with ROM of 0°/0°/110°. The patient had no limping at a year of the revision surgery and the outcome was rated as excellent with 45 scores measured with the modified OKS scale.

DISCUSSION

Marketing of implants complicates the task for the orthopaedic surgeon who starts partial arthroplasty practice. Implants with a mobile liner are nearly identical with different manufacturers using the Oxford concept, while endoprostheses with a fixed liner have heterogeneous design. Developed in 1982, the Oxford UKA is one of the most commonly used implants worldwide [11, 12, 13]. The original and repeatable technology, numerous scientific studies on various aspects on the use of the implant [14, 15, 16], a significant number of training technical videos on professional video resources,training opportunities with theoretical courses, biomannequins and in the operation theater facilitate a sufficient understanding for the surgeon of how to implant this type of artificial joint properly. In contrast, fixed platform endoprostheses are not a unified model differing only in name. This is a very heterogeneous group of implants, significantly different in surgical technique, in implantation philosophy, tribology and biomechanics. The circumstance creates space for a large number of surgical nuances, which being neglected make the surgical intervention extremely labor-intensive, with a low degree of repeatability [17]. Despite the apparent simplicity, the learning curve for a surgeon using even the most modern instrumental systems for partial arthroplasty with a fixed liner can reach hundreds of procedures, in contrast to a mobile one, where a couple of a dozen can be sufficient [18].

Adherence to individual surgical traditions formed during professional training and daily practice would involve a routine surgical technique to include the length of access, trauma of manipulations with soft tissues that affect the knee balance, for example, a deep portion of the tibial collateral ligament with the attachment to the plateau to be maintained during UKA, and the complete removal of the osteophytes from the condyles of the femur and tibia. If a surgeon commonly uses TKA in his daily surgical practice, then the hyperrelease of medial stabilizers, popularized in the arthroplasty manuals of the last century, being aggravated by excessive removal along with osteophytes and intact bone, will automatically lead to a clinically significant increase in the flexion and/or extension gaps. The manipulations would result in the use of a polyethylene liner of excessive thickness compared to the resections performed in order to create optimal tension of the capsular-ligamentous apparatus during UKA, which will serve as a mechanical substrate for hypercorrection of the mechanical axis of the limb [19]. Then soft tissue dissection should not reach the middle of the tibial condyle at the resection level during UKA. It is important to remember that the ideal candidate for UKA of the medial knee is a patient with a morphological stage of gonarthrosis with the wear of the articulating “bone on bone” surfaces and varus deformity of the limb up to 15° formed [20, 21, 22].

What about a significant group of patients who suffer terminal degenerative lesions of the medial knee and maintain a neutral axis of the limb due to the specific geometry of the diaphyses and/or metaphyses of the femur and/or tibia? The answer seems obvious: the presence of a “bone on bone” scenario in the tibiofemoral joint that we plan to replace is important for us. And this is the group of patients that are at risk of hypercorrection of the limb axis [23]. This is because the medial proximal tibial angle of 90° or more requires asymmetric resection of the tibial plateau, which can be accomplished intraoperatively with insufficient precision. A deep cartilaginous defect of the loaded portion of the medial femoral condyle in combination with meniscus extrusion will lead to translation of the mechanical axis of the limb into a valgus alignment due to excessive mobility of the medial joint, attempts to create optimal tension of the soft tissues intraoperatively and constitutional valgus deformity of the limb will become an insurmountable obstacle to successful partial arthroplasty. The ways to overcome the circumstance do not seem obvious: whether to perform a cut of the tibial plateau taking into account the so-called “Cartier angle” [24] with 3° varus relative to the mechanical axis of the tibia, or to perform UKA in the cohort of patients using robotic systems or computer navigation [25, 26] or TKA? The options can be largely debatable. In this clinical scenario, cutting the tibial plateau at 3° varus would aggravate the situation with the flat surface between the femoral component and the liner of a fixed-liner implant. The cut will cause the femoral component to “roll” along the uneven plateau in the medial direction and lead to a greater “tightness” of the medial portion. There is a large number of modern studies reporting the results of robotic surgery or joint replacements using navigation systems, and even these factors allow for errors in the positioning of endoprosthetic components in 10–11 % of cases [27]. With the use of standard instrumentation systems, this deviation from the ideal position can be even more pronounced. The surgeon factor cannot be underestimated speaking about the results after UKA [28]. Hamilton et al. [29] conducted a meta-analysis to assess outcomes of UKA depending on the surgeon's experience. The best results and a decreased frequency of revisions are observed with surgeons who perform more than 24 UKAs per year. More than 20 % of a surgeon's knee replacement surgeries should be UKA to achieve optimal results. Initial experience of orthopaedic surgeons performing partial arthroplasty was associated with the criteria of Kozinn, Scott [18], according to which patients with a body weight of less than

82 kg were considered ideal candidates for UKA. The procedure was technically more difficult in obese patients placing the extramedullary guide and cutting blocks due to technical limitations related to the definition of bone landmarks. The high load in the bone-implant interface in obese patients was also considered as one of the reasons for a decrease in implant survival. Over time, the concept changed and a large number of studies indicated that obesity should not be considered a contraindication [30, 31, 32].

There is no negative effect of high BMI on this parameter reported in the publications analyzing predictors of the risk of hypercorrection of the mechanical axis of the limb in UKA [17, 33]. Hip-knee ankle angle (HKA) is essential for predicting the accuracy of component positioning and correction of the limb axis in the frontal plane in UKA [34, 35, 36, 37]. A slight hypocorrection of the mechanical axis is recommended despite the continuous debate on the target HKA angle after partial knee arthroplasty. Patients who had varus deformity before surgery and who retain a residual deformity of 3° after UKA demonstrate the best functional results [38, 39, 40, 41]. Nakano et al. [42] reported an arithmetic hip-knee-ankle angle (aHKA) as a new method of morphological assessment. The following formula is used to measure aHKA: 180° — LDFA° (lateral distal femoral angle) + MPTA° (medial proximal tibial angle). The authors showed that aHKA correlated more accurately with postoperative LDFA° angles. The cuts were produced using a portable accelerometer-based navigation system to achieve target values. Kokubu et al. [43] conducted a retrospective study and reported an improvement in functional results early postop in patients with a change in the postoperative aHKA angle within ± 3°.

Shih et al. [44] and Asada et al. [34] reported accurate positioning of the femoral and tibial components in UKA by measuring FCCA (femoral coronal component angle) and TCCA (tibial coronal component angle). FCCA is the angle between the axis drawn through the middle of the femoral component and the mechanical axis of the femur. TCCA is the angle between the line parallel to the tibial component and the line perpendicular to the mechanical axis of the tibia. Khow et al. [45] explored implant survival depending on the accurate positioning of the femoral and tibial components and concluded that patients with FCCA from 0°to 2° and TCCA from 2° to 4° had the best functional results at 10 years. Patients with optimal measurements (FCCA 0° to 2° and TCCA 2° to 4°) had a significant advantage with 15-year implant survival. The lack of assessment of the accurate component positioning in the sagittal plane is a significant limitation of these studies. The thickness of the insert and the depth of the resected medial tibia during UKA are the intraoperative signals about the degree of postoperative correction of the mechanical axis of the limb. Kuroda et al. [46] reported a correlation between the magnitude of a changed HKA angle before and after surgery, the thickness of the liner, and the depth of resection of the medial tibia. The choice of liner size is based on the surgeon's assessment of the "tension" of the medial collateral ligament during surgery. However, this assessment may be subjective. The surgeon may choose a thicker liner to avoid apparent intraoperative instability, for example, in patients with hyperelastic soft tissue stabilizers, which may lead to overcorrection of the mechanical axis of the limb and valgus deformity after surgery [47]. Extrusion of the medial meniscus can cause valgus hypercorrection of the limb axis after UKA in patients with preoperative varus deformity. Resection of the extruded meniscus leads to a loss of “tension” of the medial collateral ligament increasing the mobility of the medial portion of the knee joint with a need of a thicker liner.

Ishibashi et al. [48] conducted a retrospective study and reported the impact of medial meniscus extrusion on preoperative magnetic resonance imaging on the mechanical axis of the limb after UKA. The degree of extrusion was measured according to the method described by Costa et al. [49] with the use of the PACS system. The authors reported a direct correlation between the postoperative changes in the HKA angle and the preoperative degree of meniscus extrusion. The average distance of meniscus extrusion was (8 ± 2) mm. Liu et al. [47] reported similar results. The geometry of the anterior tibia may entail errors in determining the resection depth during UKA. The shape of the tibial plateau is complex and asymmetrical. Hashemi et al. [50] reported a large variability in the depth of concavity of the medial plateau and the slope of the tibia in the frontal and sagittal planes in patients with gonarthrosis. The tilt of the tibia to the medial side in the frontal plane varies from –1° to +6°, and the depth of concavity of the medial section can vary from 1.2 to 5.2 mm. A cut above the bottom of the defect of the tibial plateau can be one of the common mistakes in determining the level of resection. This may result in inadequate orientation of the tibial component and a change in the TCCA angle beyond the normal values.

There have been more publications reporting staged UKA of the adjacent portion of the knee joint, instead of conversion to TKR. Fuchs et al. [51, 52] reported maintained joint proprioception being comparable to that of healthy people of the same age as a significant benefit of bicompartmental endoprosthetics (BCE) over total replacement to be achieved due to preserved cruciate ligaments. The issue of better kinematics after BCE compared to TKA remains controversial. Some authors support this hypothesis [53], while others believe that there are no significant differences in kinematics of patients who underwent BCE and TKR, in contrast to UKA [54]. Pandit et al. [55] reported outcomes of 27 knee joints with significant improvement in functional results and the absence of revisions after staged BCE, the transition to arthroplasty of the adjacent section was not applicable in the clinical case with a contracture of more than 10° and a deformity in the frontal plane of more than 5° being a contraindication for staged BCE [56, 57].

CONCLUSION

Inadequate mechanical alignment during UKA can be caused by deficient preoperative planning, individual elasticity variations in soft tissue stabilizers and technical intraoperative errors. Adequate patient selection, careful preoperative planning based on the radiographs and long-standing films, the morphological type of the limb deformity, magnetic resonance imaging of the joint, taking into account the nature of bone wear, the preservation and position of the meniscus at the contact site between the femur and tibia and the parameters of the marginal osteophytes, hypermobility of the affected portion of the knee joint, accurate surgical technique are essential for prevention of the complication.

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Funding *Not declared.*

Ethical standards *The study was conducted in accordance with the ethical standards of the Declaration of Helsinki of the World Medical Association.*

Informed consent *The patient gave informed consent for publication of the study results.*

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