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Impact of personalized alignment technique on implant components position in total knee arthroplasty

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Abstract

Introduction Due to substantial rates of dissatisfaction in patients with mechanical alignment in total knee replacement, surgeons began searching for alternative techniques to improve functional outcome. In the recent decade, kinematic alignment that is not based on the mechanical axis of the femur has become the most popular alternative to mechanical alignment. Kinematic alignment technique development has led to creation of a personalized alignment technique.

Purpose To compare postoperative implant positions in full-length standing lower-leg radiographs between kinematic alignment and mechanical alignment groups of patients.

Materials and methods A prospective, single-center, randomized, controlled study was performed in 139 patients with grade 3–4 knee osteoarthritis (Kellgren – Lawrence). We collected data from 76 cases of mechanical alignment (66 women and 10 men) and 83 cases of personalized alignment group (60 women and 23 men). There were no patients with significant post-traumatic or other deformities of the lower limb which can alter the results in the study. All measurements were done on digital full-length standing X-rays of the lower legs with special MediCAD software.

Results The positions of the implant components in mechanical and personalized alignments did not differ significantly in many parameters after operations, despite the fact that the alignment was based on completely different principles. There were no differences between the average values of the angles after operations with mechanical and anatomical axes of the femur in both study groups (the difference was 0.1° at $p = 0.595$). The only difference in the groups was the position of the tibial component in relation to the horizontal surface in the standing position: in personalized alignment, the angle was 0.9°, and in mechanical alignment it was 2.4° valgus ($p < 0.001$).

Discussion The absence of significant difference in the postoperative leg alignment and implant position except in the joint line orientation between the groups demonstrates possibility to achieve good leg alignment with both techniques. In the personalized alignment group, the joint line orientation in the coronal plane was found nearly parallel to the ground which can result in a more balanced weight distribution compared to mechanical alignment.

Conclusion In patients who receive total knee replacement with the personalized technique, the postoperative lower limb alignment was found within the safe boundaries of 3° from the mechanical axis while the joint line orientation in the coronal plane was significantly closer to be parallel with the ground compared with mechanical alignment group.

Keywords: total knee arthroplasty, personalized alignment, kinematic alignment, mechanical alignment, knee osteoarthrosis

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INTRODUCTION

In the last decade, the global orthopaedic community has shown increasing interest in alternative methods of lower limb alignment in total knee arthroplasty that replace the classical method of mechanical alignment [1, 2]. Some techniques have been proposed, in particular kinematic alignment [3, 4, 5], which demonstrate significant improvement in functional results [6–15].

Among the supporters of traditional mechanical alignment, there are many opponents of kinematic alignment. Their main argument is that limb deformities caused by the disease remain present after the surgery due to "incorrect position of the endoprosthesis components" [16–20], and that such installation of components will inevitably have a negative impact on the service life of the implant and increase the incidence of revision [21, 22].

Proponents of kinematic alignment, given the significant variability in patient anatomy, believe that attempts to achieve the same limb axes and joint line for all patients in mechanical alignment may significantly disorder the distribution of joint loads, which in turn may affect clinical outcome [23–27].

Purpose of the study: to compare the position of knee joint endoprosthesis components after total knee replacement with the use of mechanical and personalized alignment methods

MATERIALS AND METHODS

A total of 76 cases (66 women, 10 men) of the mechanical axis alignment method (group 1) and 83 cases (60 women, 23 men) of personalized alignment (group 2) were analyzed. The patients in the first group underwent surgery with the conventional techniques involving soft tissue release and external rotation of the femoral component. In the second group, the surgery was performed using the author's personalized alignment method based on the principle of kinematic alignment and described in detail in the Russian Federation patent for invention [27].

Inclusion criteria were age of 18 years and over, clinically and instrumentally confirmed gonarthrosis grade III–IV, patients' written informed consent to participate in the study.

Non-inclusion criteria were age under 18 years, absence of clinically and instrumentally confirmed diagnosis of gonarthrosis, presence of severe concomitant pathology that caused refusal of surgical treatment (uncompensated diabetes mellitus, acute cerebrovascular accident and acute myocardial infarction suffered less than 4 months prior to referral).

Exclusion criteria were patient's refusal to participate further in the study, change of residence (patient's move to another region of the Russian Federation), infectious complications that developed in the postoperative period and required repeated surgical intervention.

Before the operation and 3 months after it, the patients filled out the KOOS and Oxford questionnaires, and at the same time-points the range of motion in the joint was studied.

The position of the endoprosthesis components and the limb alignment parameters were studied on panoramic radiographs using the MediCAD program (Hectec GmbH, Germany). The following parameters were assessed in the frontal plane: HKA angle — the angle between the mechanical axis of the femur and the mechanical axis of the tibia, the angle between the joint line and the horizontal surface, the angle of inclination of the tibial component of the endoprosthesis to the mechanical axis of the tibia (90° — mMPTA) and the angle between the mechanical and anatomical axes of the femur (Fig. 1). It should be noted that the assessment of implant component position was carried out automatically using the MediCAD program, thus the influence of the researchers on the results was excluded.

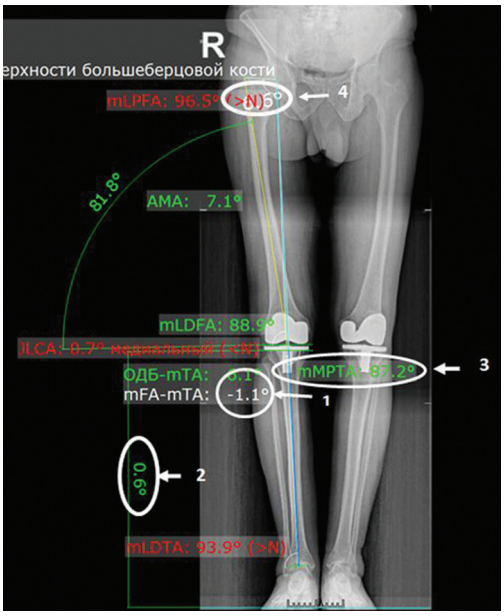

Fig. 1 Evaluation of total knee arthroplasty using the mediCAD program: 1) HKA angle between the mechanical axes of the femur and tibia; 2) angle between the line of the newly formed joint and the ground; 3) angle of deviation of the tibial component from the mechanical axis of the tibia; 4) angle between the mechanical and anatomical axes of the femur

Panoramic radiographs were taken at least 3 months after the surgery. When placing the patient on the platform, we abandoned the recommended distance of 30 cm between the feet, since for persons who are 150 cm and 190 cm tall, this is a completely different position in terms of comfort. The recommended distance is normal for a tall person, but for a short person, the legs are too wide apart, which is often impossible with very thick legs. Therefore, patients placed their feet on the platform in a comfortable for them position.

When assessing the initial condition before surgery, patients in both study groups had reliable differences only in age and average terms of follow-up examination after surgery. In all other parameters, patients in both groups were identical (Table 1).

Table 1

Patients' characteristics before the operation

Parameter	Group 1	Group 2	*p*
	Mechanical alignment	Personalized alignment	
BMI, Me [IQR]	32.30 [28.62; 34.92]	33.39 [27.70; 35.48]	0.701
Age (years), M (SD)	64 (8)	67 (8)	0.019*
Follow-up term (months), Me [IQR]	24 [4; 53]	7 [3; 11]	< 0.001*
KJ Oxford b/s, Me [IQR]	17.00 [12.00; 20.00]	17.00 [13.00; 22.00]	0.192
KOOS S b/s, Me [IQR]	36.00 [25.00; 46.00]	36.00 [25.00; 46.00]	0.638
Preoperative ROM (degrees), Me [IQR]	95 [90; 100]	95 [90; 105]	0.743

Operations with orientation to mechanical axes were performed according to the standard method. Joint balancing was performed by releasing soft tissues. During preoperative planning, the angle between the mechanical and anatomical axes of the femur was measured using special templates or by planning in the MediCAD program. The purpose of planning was to assess the general condition of the involved joint, the size of cartilage and bone tissue defects, and the condition of the ligamentous apparatus of the joint.

The Vicon motion capture system and the Neurocor stabilometric platform were used in the study. Statistical processing of the results was performed using the StatTech v. 4.1.7 software (StatTech LLC, Russia).

The study was approved by the Ethics Committee of City Clinical Hospital No 1. Before the study, each patient completed an informed consent for participation in the study and publication of its results.

RESULTS

Analyzing the results of the study, we first of all paid attention to the fact that the deviation of the mechanical axes of the femur and tibia of the involved limb did not differ between patients of the groups. The angles of inclination of the tibial component of the endoprosthesis in the mechanical and personalized alignment groups did not have statistically significant differences either (Table 2).

Table 2

Limb alignment and implant components position after the operation in the standing position

Parameter	Group 1 (mechanical alignment)	Group 2 (personalized alingment)	*p*
HKA (degrees), M (SD)	−2.3 (3.4)	−2.8 (3.2)	0.391
Actual Q angle (degrees), Me [IQR]	6.4 [5.9; 7.1]	6.5 [6.1; 7.1]	0.595
Horizontal angle (degrees), Me [IQR]	2.4 [0.6; 4.3]	0.9 [−0.3; 1.8]	< 0.001*
T varus (degrees), Me [IQR]	−0.5 [−2.2; 1.1]	−2.2 [−3.8; 1.7]	0.114

On postoperative radiographs, the angle between the mechanical and anatomical axes of the femur (Q angle) had very minor differences between the two groups of patients. In the first group of patients of the mechanical alignment method, the Q-angle was determined using a protractor or in the MediCad program during the preoperative planning process. In the second group of patients (personalized alignment), preoperative planning consisted of assessing the severity of wear of cartilage, subchondral bone, and the severity of osteophytes.

The relations of the lower limb axes were not evaluated. The difference in the mean values of the Q-angle between the groups was statistically not significant and was only 0.1°.

The most important thing in the position of the components in the studied groups was the significant difference in the angles of inclination of the joint line of the implant in relation to the horizontal line. The angle of inclination of the joint plane in the group with personalized alignment was significantly smaller than in the group of patients who underwent surgery with orientation to the mechanical axes (0.9° and 2.4°, respectively, $p < 0.001$) (Fig. 2).

A significant difference was that the permissible range of motion in the knee joint was significantly greater in the group of the personalized alignment method than in the group of mechanical alignment (Fig. 3).

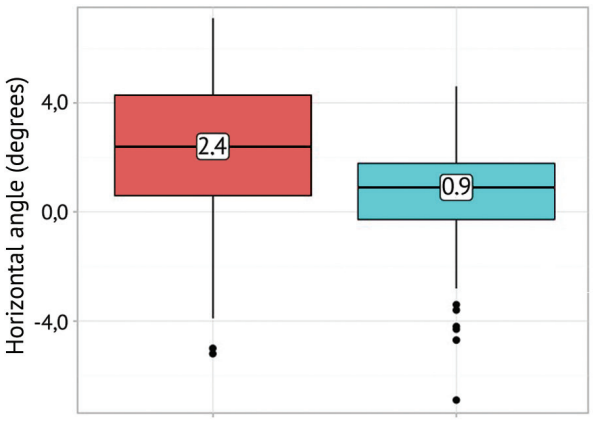

Fig. 2 Inclination of the joint line relative to the horizontal surface in a standing position

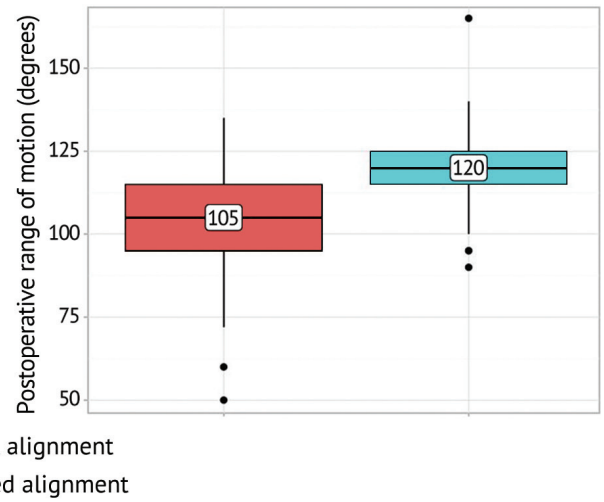

Fig. 3 Average range of motion at a time-point not earlier than 3 months after surgery

DISCUSSION

The positioning of the implant components in the two groups was carried out based on completely different principles. Despite this, a comparison of the postoperative position of the components in the mechanical and personalized alignment groups did not reveal significant differences. The mechanical axis of the femur determined before the operation in patients of the first group was the starting point from which the subsequent construction of the new joint was carried out. In personalized alignment, the joint wear severity and ligament balance were assessed before and during the operation. It should be emphasized that patients of both groups did not have statistical differences in all parameters, including the severity of the pathological process.

The absence of differences in the postoperative evaluation of the HKA demonstrates sufficient correction of the limb axis in personalized alignment. The postoperative limb axis is in the same range as in mechanical alignment. Similar results were obtained for the position of the tibial component in relation to the anatomical axis of the tibia: no significant difference was found between the groups.

Of particular interest was the fact that there was no difference in the angles between the mechanical and anatomical axes of the femur (the so-called Q-angle). In operations with orientation to the mechanical axis, this angle is the "cornerstone" and the first thing that is determined during preoperative planning. Everything can change during the operation, but only the Q-angle will remain unchanged. During preoperative planning for personalized alignment, we were not interested in the Q-angle; we did not determine it and, accordingly, did not take it into account in any way. However, the difference between the groups was 0.1° and was statistically not significant ($p = 0.595$). We did not find a complete, scientifically substantiated explanation. Thus, the data would have more differences in a significantly larger sample of patients. The mechanical axis of the femur determined during preoperative planning corresponded to the real axis of the limb in most patients and remained unchanged when the personalized alignment principle was used.

The only and most significant difference was the difference in the position of the tibial component and the line of the newly created joint in relation to the horizontal surface in the standing position. In mechanical alignment, the average angle of inclination of the joint line in the valgus position was 2.4°, and in personalized alignment it was 0.9° in valgus, that is with high statistical significance of the differences ($p < 0.001$). Similar data are described by other authors [28]. This result indicates that the line of the knee joint after total arthroplasty with a personalized alignment principle is reliably closer to the norm of 2–3° in varus than in performing an operation with orientation to mechanical axes, and does not lead to overload of the medial parts of the newly created joint [29].

CONCLUSION

It has been established that most parameters of implant components position in total knee arthroplasty do not depend on the principles of alignment, personalized or mechanical. The main difference is that in personalized alignment, the line of the reconstructed joint in the standing position reliably corresponds more to the line of the healthy joint, which may explain its better functional results after total knee arthroplasty that are presented in the literature.

Conflict of interest *Not declared.*

Funding source *The study was conducted within the framework of the Moscow Government Grant program.*

Ethical statement *the study was approved by the ethical board of City Clinical Hospital No 1.*

Informed consent *Before the start of the study, each patient completed an informed consent form for participation in the study and publication of the results.*

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