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Preoperative knee deformity and kinematics impact postoperative knee kinematics in total knee arthroplasty

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ABSTRACT

Background: The purpose of this study was to evaluate the relationship between the preoperative knee deformity/kinematic pattern and the postoperative knee kinematic pattern in posterior cruciate ligament substituting (PS)-total knee arthroplasty (TKA).

Methods: This study involved 39 patients with medial osteoarthritis who underwent a primary PS-TKA using a computed-tomography-based navigation system. All the operations were performed by a single surgeon using a subvastus approach, modified gap technique and the same PS type of prosthesis (Genesis II™ total knee system, Smith & Nephew, Memphis, TN, USA). Knee deformity, kinematic pattern after capsule incision (preoperative knee kinematics), and kinematic pattern after implantation (postoperative knee kinematics) in PS-TKA were measured. Kinematic patterns were divided into two groups: a medial pivot group and a non-medial pivot group.

Results: Preoperative varus knee deformity was significantly larger in the non-medial pivot group than in the medial pivot group (femorotibial angle: 184.7 ± 6.4° vs. 180.8 ± 3.9°, $P < 0.05$). In addition, preoperative knee kinematics were conserved postoperatively, at a rate of 82% ($P < 0.01$).

Conclusions: The severity of varus knee deformity and the preoperative knee kinematic pattern might have affected the postoperative knee kinematics in PS-TKA. This must be confirmed with a randomized controlled trial on a large population study. Level of evidence: case control study, Level III.

1. Introduction

Generally, normal knees show a medial pivot kinematic pattern, characterized by femoral external rotation relative to the tibia with movement from full extension to mid-flexion and bicondylar rollback motion from mid-flexion to maximum flexion [1–4]. In contrast, there are large variations in knee kinematic pattern after conventional total knee arthroplasty (TKA), including the medial pivot [5,6], lateral pivot [7,8], and parallel motion pattern [7]. This knee kinematic discrepancy before and after TKA may cause inferior clinical outcomes compared with total hip arthroplasty [9].

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The clinical–functional outcome and complications were highly influenced by the kinematic pattern of prosthesis [10,11]. In addition, we have previously reported that patients who demonstrate a medial pivot kinematic pattern after TKA had better clinical results than those with a non-medial pivot pattern in conventional TKA [12]. A medial pivot knee was superior to a non-medial pivot knee in functional activities, patient satisfaction as indicated in the new Knee Society Score and the knee flexion angle after posterior cruciate ligament substituting (PS)-TKA [12]. All these results suggest that achieving medial pivot kinematics after TKA is a target to aim for in the improvement of postoperative clinical outcomes.

The medial pivot kinematics are desirable compared to other kinematic patterns for better clinical results. However, it is difficult to achieve the medial pivot pattern in all cases after conventional TKA (not guided-motion TKA) [8]. In particular, it is not known which preoperative factors affect postoperative knee kinematics. There have been no reports concerning the relationship between preoperative factors and the postoperative knee kinematic pattern in TKA.

Therefore, we hypothesized that preoperative factors of the knee affect the postoperative knee kinematic pattern in TKA. The aim of this study was to evaluate the relationship between preoperative factors and the postoperative knee kinematic pattern in PS-TKA.

2. Materials and methods

2.1. Patients

The present study involved 50 patients with medial osteoarthritis (Kellgren–Lawrence grade 4) who underwent a primary PS-TKA using a computed tomography (CT)-based navigation system between July 2010 and September 2012. Exclusion criteria were lateral osteoarthritis (valgus knee deformity), severe bony defect, revision TKA, and patients who could not acquire all kinematic data from 0° to 120°. Finally the 39 patients who obtained complete kinematic data were assessed in the present study. Based on our previous study [12], we concluded that the required sample size in this study and the minimal sample size to achieve more than power 0.8 was 36. Thus, 39 samples were sufficient to evaluate for this study.

The mean age at the time of operation was 72 ± 8.4 years (range 50–88 years old) (means ± standard deviation (SD)), and there were three men and 36 women. The mean body mass index (BMI) was 26 ± 4.4 kg/m^2 (range 19–37 kg/m^2). The mean postoperative follow-up period was 52 ± 6.8 months (range 38–64 months). Institutional review board approval by Hokkaido University Graduate School of Medicine was obtained prior to initiation of this study.

2.2. Surgical technique

All operations were performed by a single surgeon (T.M.) using a subvastus approach to eliminate the effect of the approach to muscle balance and the same PS type of prosthesis (Genesis II™ total knee system, Smith & Nephew, Memphis, TN, USA). In all cases, a CT-guided navigation system (Vector Vision 1.6, Brain LAB, Heimstetten, Germany) was used for accurate bone cutting and implantation with a standardized navigated TKA technique. The procedures were performed using the navigation system according to the manufacturer's instructions. The air tourniquet was inflated to 280 mm Hg in all cases during surgery. The proximal tibial resections and the distal femoral resections were set on the navigation system perpendicular to the mechanical axis in the coronal plane with a three degree tibial posterior inclination in the sagittal plane. The coronal plane ligament imbalance was corrected until the gap imbalance was less than two millimeters. This extension gap balance was checked using a ligament balancer (Smith & Nephew) at 80 N in the medial and lateral compartments of the knee. The flexion gap was checked at 90° knee flexion using the navigation system with the balancer compensated for three millimeters thick in the lateral part, because Genesis II has an externally rotated femoral implant design that thickened three millimeters on the lateral posterior condyle (equivalent to three degree external rotation). The rotational alignment of femoral component was decided based on balanced gap technique. The patella was resurfaced to equalize the preoperative thickness, and a lateral retinaculum release was not performed in any patients. The tibial anterior–posterior (AP) axis of the tibial tray was placed parallel to Akagi's line, connecting the middle of the posterior cruciate ligament to the medial border of the patellar tendon attachment [13].

2.3. Kinematic measurement

Each kinematic pattern was measured using the navigation system, immediately after capsule incision (preoperative knee kinematics) and after implantation (postoperative knee kinematics) in TKA. In order to minimize an effect of the capsulotomy, we temporarily sutured on the lower pole level of the patella and on the enthesis level of vastus medialis oblique before kinematic measurements were taken. Passive range of motion (ROM) was performed from maximum extension to maximum flexion. The flexion movement began by initially supporting the heel posteriorly to record the position of full extension. While supporting the heel with an open palm to avoid tibial rotation, the surgeon used his opposite hand to gently lift the thigh, flexing the hip and knee. The surgical epicondylar axis (SEA) was defined as the flexion axis, based on previous reports [5,12]. Knee kinematics were measured from 0° to 120° at 10° intervals. All positions of the SEA were projected to the tibial axial plane. The node of the SEA of each 10° measurement was defined as the center of rotation (COR) [12]. The average COR was calculated between 0° and 120° (Figure 1). Subjects were divided into two groups based on kinematic patterns. Patients with an average medial COR were defined as the medial pivot group (group M). Other kinematic patterns were defined as the non-medial pivot group (group N). Group N included those with a lateral pivot and parallel motion. Two senior orthopedic surgeons who were not