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Evolution of knee kinematics three months after total knee replacement

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ABSTRACT

In patients with debilitating knee osteoarthritis, total knee replacement is the most common surgical procedure. Numerous studies have demonstrated that knee kinematics one year after total knee replacement are still altered compared to the healthy joint. However, little is known regarding impairments and functional limitations of patients several months after total knee replacement. The aim of this study was to describe the evolution of the knee gait kinematic in patients with knee osteoarthritis before and three months after a total knee replacement.

Ninety patients who were to undergo total knee replacement were included in this study. Twenty-three subjects were recruited as the control group. Three-dimensional gait analysis was performed before and three months after surgery. The spatio-temporal parameters and three-dimensional knee kinematics for the operated limb were evaluated during a comfortable gait and compared between groups (the before and after surgery groups and the control group).

Three months after surgery, patients always walk with a slower gait velocity and lower knee flexion–extension movements compared to the control group. However, a degree of progress was observed in term of the stride and step length, gait velocity and knee alignment in the coronal plane.

Our results suggest that the disability is still significant for most patients three months after total knee replacement. A better understand of the impairments and functional limitations following surgery would help clinicians design rehabilitation programs. Moreover, patients should be informed that rehabilitation after total knee replacement is a long process.

1. Introduction

In patients with debilitating knee osteoarthritis (OA), total knee replacement (TKR) is the most common surgical procedure to reduce pain, improve functional abilities and restore anatomical alignment of the tibiofemoral joint [1].

Three-dimensional (3D) motion analysis is often used in patients with knee OA to determine biomechanical information about gait or functional outcome [2–4]. Indeed, numerous studies have shown that knee kinematics one year after TKR are still altered compared to the healthy joint [2,5–8]. A common finding of these studies is that patients with TKR have a smaller knee flexion range and decreased knee extension during gait, with a reduced cadence and stride length compared to the control group [3]. The range of motion (ROM) of the knee is one of the most important clinical outcomes (with a knee flexion of 45–105° for healthy people during different activities of daily life) and is associated with postoperative patient satisfaction [9]. In addition, gait velocity has been used as a global indicator of health and function, and it has been shown to deteriorate over time, correlating with the level of disability [10]. Perry and Burnfield identified gait velocity categories that correlated with progressive levels of

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functional walking and disability [11]. Thus, the evolution of gait velocity before and after a TKR is an important factor in the evaluation of patients' recovering.

Currently, little is known about impairments and functional limitations of patients a few months after TKR [12–14]. Recently, knee kinematic evolution following a TKR has been identified as an important determinant of patients' functional abilities after surgery [8]. A better understanding of the evolution of knee kinematics earlier after TKR would be very useful for more specific clinical rehabilitation [8,15].

In this context, the aim of this study was to describe on a large database, the evolution of knee gait kinematics, in sagittal and frontal planes, in patients with knee OA before and three months after a TKR.

2. Methods

2.1. Participants

Ninety patients who were to undergo TKR for severe, symptomatic OA were included in this study (54 females, 36 males). The project was approved by the ethics committee of the Geneva University Hospital and written informed consent was obtained from all patients. Exclusion criteria were defined as follow: patients with previous knee, hip or ankle prosthesis, patients with a history of lower limb or back surgery and with neurological or orthopaedic disorders that could affect gait or balance. Furthermore, patients using crutches or walking aids were able to walk without during the test. Although the location of the knee OA (medial tibiofemoral: MTF, lateral tibiofemoral: LTF and patellofemoral: PF) was not an inclusion/exclusion criterion, it was assessed using full-length limb X-rays before TKR. In addition, patient with OA at the contralateral side were included in the study if they had no pain.

To characterize patients with knee OA, the lower limb alignment was quantified with the hip–knee–ankle angle (HKA) [16]. This angle was measured (when the information was available in the database) by full-radiography. The HKA angle and the knee OA localization were determined by an experienced orthopaedic surgeon. The HKA varied from varus (less than 180°) to valgus (more than 180°).

Moreover, at each of visits, patients were asked to estimate their level of knee pain using a visual analogue scale (VAS) (0–10 cm).

Thus, the age, weight, height, body mass index (BMI) and knee pain level of the patients were, respectively (mean $\pm$ SD): 68.0 $\pm$ 7.5 years, 83.5 $\pm$ 16.7 kg, 164.9 $\pm$ 10.0 cm, 30.7 $\pm$ 5.7 kg/m^2 and 4.0 $\pm$ 2.2 for knee pain level, at the first visit and 68.4 $\pm$ 7.6 years, 81.0 $\pm$ 16.1 kg, 164.9 $\pm$ 10.0 cm, 29.8 $\pm$ 5.6 kg/m^2 and 2.4 $\pm$ 1.5 for knee pain level at the second visit. Concerning the location of the knee OA, for 86 patients, it was MTF, for 73 patients it was LTF and for 62 patients, it was a PF. Moreover, 46 patients were operated in the left knee and 45 in the right knee. In last, from the HKA angles available in the database, it was found that for 61 patients the knee was defined as varus (mean $\pm$ SD: 172.7 $\pm$ 4.9) and for 22 patients, the knee was defined as valgus (mean $\pm$ SD: 189.5 $\pm$ 5.7).

In addition, 23 matched healthy subjects without any clinical signs of knee OA, no history of previous joint replacement or neurological or orthopaedic disorder that could affect their gait or balance and no recent history of lower limb or back pain were recruited as a control group (10 females, 13 males). The age, weight, height and BMI of the control group were 64.8 $\pm$ 8.3 years, 70.8 $\pm$ 12.2 kg, 169.6 $\pm$ 10.2 cm and 24.5 $\pm$ 3.4 kg/m^2, respectively.

2.2. Surgical procedure and postoperative management

Among the 90 patients a fix, posterostabilized (PS) TKR design was used in 80 patients: 66 had a PFC Sigma® TKR (Depuy Orthopaedics, Inc., Warsaw, IN, USA) and 14 patients had GMK System® TKR (Medacta, Inc., Castel San Pietro, Switzerland). Nine patients had an ultracongruent mobile bearing design: 8 GMK System® TKR (Medacta, Inc., Castel San Pietro, Switzerland) and 1 LCS TKR (Depuy Orthopaedics, Inc., Warsaw, IN, USA). Two patients had a unicompartimental knee replacement (Sigma HP Partial Knee, Depuy Orthopaedics, Inc., Warsaw, IN, USA).

The procedures were done by 23 different experienced surgeons working at our teaching hospital throughout the period of the study. All arthroplasties were performed through a medial parapatellar approach except for 2 patients with a lateral parapatellar approach for fixed valgus deformities. All components were cemented. A tibia first cut was routinely used by all surgeons. The independent bone cuts technique was used in 70 patients, and a ligament balancing technique in 20 patients with a PFC Sigma TKR (Depuy Orthopaedics, Inc., Warsaw, IN, USA) with the TRAM system (Depuy Orthopaedics, Inc., West Chester F). Resurfacing was performed in 52 patients. A lateral release was necessary in 9 patients.

After surgery, all patients went through a standard rehabilitation program, walking with crutches starting at day two with full weight bearing allowed. Routinely, a single shot antibiotic prophylaxis was given before skin incision and deep vein thrombosis prophylaxis with low molecular heparin was for 6 weeks.

2.3. Gait analysis

A 3D, 12-camera motion analysis system (VICON Peak, Oxford, UK) was used to capture full-body motion during gait the day before surgery (V1) and three months after surgery (V2). Reflective markers were placed on the pelvis and on both lower limbs according to the Davis protocol [17] and on the trunk as described by Gutierrez-Farewik et al. [18]. Joint kinematics was generated using the dynamic model (Vicon Plug-in-Gait). A minimum of 10 gait cycles was used.

All patients and control subjects were asked to walk barefoot at their self-selected comfortable speed. Additionally, the control subjects were asked to walk at a slower speed that was close to the average speed of the patient group (Table 1). Both speeds were used to analyze and compare the spatio-temporal parameters among patients and between patients and control subjects.

Because joint kinematics depend on gait speed [19], only the data captured at the matched speed from the control group were used in the comparison analysis [20]. Specific descriptions of these parameters (i.e., phases of gait and discrete values) are listed in Table 2.

2.4. Data analysis

The mean values and the standard deviations for all variables were obtained by averaging the discrete values for all participants. For control group, the two limbs ($n = 46$) were considered independently and used in the calculations. Gait velocity and knee ROM were chosen as the primary factors and used to observe the patients in terms of percentage of improvement between the two visits. Three categories were defined: improvement for values better than 10%, stable for values between 10% and −10% and degradation for values below −10% (Fig. 2).

To analyze the evolution of the symmetry between the operated and non-operated limb, the mean differences for several knee kinematic and spatio-temporal parameters were calculated as symmetry indices (Table 3). Values close to zero indicate good symmetry between the limbs. Negative values indicate that value of the operated limb was greater than non-operated limb. In contrast, a positive value indicates that value of the operated limb was below non-operated limb.