INTRODUCTION

The opening wedge high tibial osteotomy (HTO) has been usually recommended for a young and active population for treatment of medial knee osteoarthritis (OA). Its main principle is to shift the weight-bearing line from medial compartment to lateral compartment of the knee and decompress the degenerated cartilage [1]. Relatively good outcome of HTO has been reported in clinical short-term, mid-term, and long-term studies [2, 3].

The joint forces on human knee during normal walking are dominant on medial compartment due to external knee adduction moment [1]. Therefore, the conventional gait analysis based on three-dimensional (3D) limb motion has been usually performed to evaluate surgical outcome of HTO. Previous studies demonstrated that the HTO successfully reduce the varus angle and decrease the knee adduction moment which characterizes osteoarthritic gait [3]. However, the reduction of contact loading on the medial compartment and shift of those loading into lateral compartment of knee after medial opening-wedge HTO are also necessary to fully understand mechanism of HTO to the OA knee.

In this study, the effect of medial opening wedge HTO on medial-lateral contact force balance in tibiofemoral joint was quantitatively evaluated during stance phase of gait. Since the muscle force is determinant to calculation of contact force, we also tried to demonstrate difference between muscle forces in OA patient and subject with HTO surgery. The muscle forces and joint contact forces were obtained by two-step modeling technique that combined with conventional inverse dynamic analysis and multibody dynamic simulation (Fig. 1).

METHODS

Five patients, who have moderate medial knee OA (Mean age: 57.6 years, weight: 67.4 kg, and height: 157.2 cm), participated in this study. 3D motion data of lower extremity was recorded by motion analysis system (Hawk® Digital Real Time System, Motion Analysis System, Santa Rosa, CA, USA) using ten cameras and reflective skin markers. The external ground reaction forces were measured by four force plates (MP4060, Bertec Corporation, Columbus, OH, USA) during walking. The participants performed 5 trials of motion with a self-selected walking speed along six meter walk-way. All procedure described above was repeated for each individuals 12 month after the HTO surgery.

At the first step, the muscle forces, joint forces and moments were calculated based on the recorded joint motion and ground reaction forces using an inverse dynamic lower extremity model [4]. The lower extremity was modeled as a 6-segment, 18 degree of freedom (DOF) articulated linkages actuated by 52 muscles. The output of inverse dynamic model such as predicted muscle forces, ankle joint forces and moments were used as the input to the multibody lower limb model with anatomical representation of the knee joint.

At the second step, a multibody lower extremity model of each subjects before and after HTO were developed in a dynamic analysis software (RecurDyn ver.7, Function Bay Inc., Korea). The previously developed and validated knee joint model [5] with bones (femur, tibia and patella), cartilage layers, non-linear ligaments, and deformable contact in both medial and lateral tibiofemoral compartment was placed in the symptomatic leg.
For the contact force estimation, the quasi-static analysis was run at the time step of 0.05 second during the stance phase of gait. The muscle forces from inverse dynamic analysis were applied constantly via muscle force actuators and ankle joint forces/moments which calculated in inverse dynamic analysis were applied as external forces on the distal tibia. The compressive contact forces on the medial compartment, lateral compartment as well as the total tibiofemoral joint force were investigated. The contact force result of each subject was normalized to the body weight and the results for OA subjects were compared to those of post-HTO. The estimated quadriceps and hamstring muscle forces, and medial to lateral compartment load ratio were also analyzed.

The total tibiofemoral compressive force decreased after HTO due to reduction of quadriceps muscle activation. The medial to lateral load ratio showed that HTO significantly balanced the knee joint loading during normal walking. Our result indicates that the HTO surgery could improve the tibiofemoral contact force balance.

Figure 1: Diagram to explain the procedure for the estimation of tibiofemoral loading as well as muscle forces during normal walking

Figure 2: Mean compressive contact forces on medial compartment, lateral compartment and total tibiofemoral joint as well as medial-to-lateral load ratio before and after HTO during normal gait

REFERENCES

RESULTS AND DISCUSSION

Medial opening wedge HTO dominantly decreased the compressive contact force on the medial compartment during stance phase of gait (Fig. 2). The reduction in the first and second peaks of contact curve were about 0.8 BW. HTO increased the compressive loads on the lateral compartment, however the lateral compartment contact force was not higher than the medial contact force (Fig. 2).