Influence of Cruciate Ligament Preservation on Knee Joint Moments: A Comparative Study between Bi-Cruciate Retaining and Bi-Cruciate Stabilized Total Knee Arthroplasty

Satoshi Hakukawa, Kengo Harato[1], Kohei Nishizawa, Shu Kobayashi, Takeo Nagura, Masaya Nakamura[1], Yasuo Niki[2]
[1]Keio University, [2]Dept of Orthopaedic Surgery, Keio University

INTRODUCTION: Total knee arthroplasty (TKA) is a widely used treatment method for knee osteoarthritis, with advancements in technology enhancing patient quality of life. Notably, the ability to customize implants based on the patient's condition and the utilization of robot-assisted surgical systems have gained attention. However, challenges still remain in TKA postoperative care, including rehabilitation, managing complications, and ensuring the durability of artificial joints. In particular, the longevity of prostheses is a subject of debate due to the impact of patient activity levels on prosthetic loosening. Therefore, our focus is on joint moments, which indicate the load on the knee joint. Among these moments, the knee adduction moment (KAM) is known to exert the greatest load on the bone-implant interface. While cruciate ligaments are believed to optimize joint moments, there have been no studies comparing joint moments caused by implant differences with or without cruciate ligaments in the same subjects. The aim of this study is to compare knee joint moments, particularly the KAM during gait, between bi-cruciate retaining (BCR)-TKA, which preserves both cruciate ligaments, and bi-cruciate stabilized (BCS)-TKA, in which both cruciate ligaments are removed.

METHODS:

The subjects were selected from 29 participants who underwent bilateral TKA and were able to walk independently for more than 180 days postoperatively. Among these, 18 participants (mean age, 73.2 years; range, 53 to 80, mean height, 156.6 cm; range, 142.7 to 171.5, mean weight, 66.4 kg; range, 50.6 to 90.6, mean body mass index (BMI), 26.9 kg/m^2; range, 22.2 to 34.2) in which BCR-TKA was performed on one side and BCS-TKA on the other were included. All surgeries were performed by the same surgeon using a robot-assisted surgical system following the kinematic alignment method, and the choice of the implant was made based on the visual assessment of ligament strength during surgery. Knee joint evaluation was performed by measuring joint angles and evaluating X-ray images, while pain and functional evaluation were carried out using patient-reported outcome measures (PROMs). Gait analysis was performed using a three-dimensional motion capture system, and knee joint angles, joint moments, and ground reaction forces were calculated.

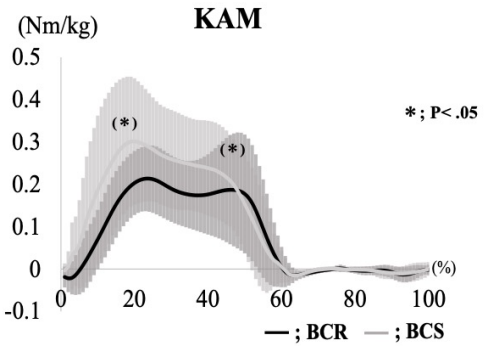
Statistical analysis was carried out using paired t-tests and Wilcoxon signed-rank tests to compare BCR-TKA and BCS-TKA. The relationship between knee joint moment and gait parameters was examined using Spearman's rank correlation coefficient and Pearson's product ratio correlation coefficient, and factors that showed significant differences were included in a multiple regression analysis with the independent variable and KAM as the dependent variable. The significance level was set at less than 5%.

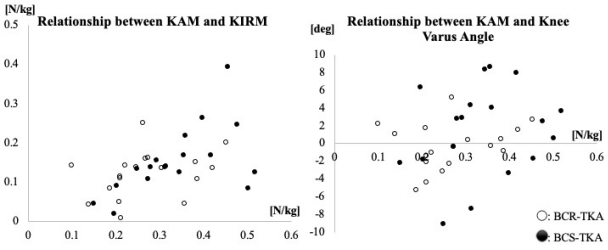
RESULTS:

When comparing BCR-TKA and BCS-TKA, the radiographic assessment showed that the preoperative femoro-tibial angle (FTA) and Hip-Knee-Ankle angle (HKA) were significantly smaller in BCR ($P < 0.05$), but there was no significant difference in postoperative values. No significant difference was observed in PROMs. In gait analysis, BCR-TKA showed a significantly lower KAM during the heel contact phase and loading response phase compared to BCS-TKA ($P < 0.05$, Figure 1). Additionally, a correlation was observed between KAM, Knee Internal Rotation Moment (KIRM) ($P < 0.05$, Figure 2). Therefore, a multiple regression analysis was performed with KAM as the dependent variable, and the type of implant, KIRM, and knee varus angle as independent variables. Significant effects were observed for KIRM ($\beta = 0.71$, $P < 0.01$).

DISCUSSION AND CONCLUSION:

The knee cruciate ligaments contribute not only to rotational stability but also to mediolateral stability during gait. This is a unique role of the ligaments that cannot be replaced by prostheses. In this study, KAM significantly decreased in BCR-TKA compared to BCS-TKA, which is thought to be due to the preserved anterior cruciate ligament during the heel contact phase. As the multiple regression analysis indicated that KAM was influenced by KIRM, controlling femoral external rotation by the anterior cruciate ligament may contribute to KAM reduction. The clinical significance of this study is that BCR-TKA contributes to reduced KAM and may improve prosthetic longevity.


KAM
(Nm/kg)
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
20
40
60
80
100
(%)
(*)
(*)
*; P< .05
—; BCR
—; BCS


[N/kg]
Relationship between KAM and KIRM
[N/kg]
[deg]
Relationship between KAM and Knee Varus Angle
[N/kg]
○: BCR-TKA
●: BCS-TKA