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Total knee arthroplasty in-vivo kinematics changes after insert replacement for posterior cruciate ligament deficiency: a case report

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Abstract. In cruciate-retaining (CR) total knee arthroplasty (TKA) the preservation of the posterior cruciate ligament (PCL) provides joint stability and drives knee kinematics. No previous studies described in-vivo knee kinematics of PCL-deficient CR TKA. In the present case report it's described the in-vivo kinematic pattern change in a patient with post-operative PCL failure before and after insert replacement to a cruciate substituting (CS) design. In-vivo fluoroscopic analysis showed that PCL-deficient TKA showed more anterior translation of the lateral femoral condyle with respect to a cohort of patients operated of CR-TKA with intact PCL, undergoing fluoroscopic analysis. The replacement to a CS design provided more external rotation of the femoral component and less anterior motion of the lateral condyle. The antero-posterior translation of the medial condyle was similar in PCL-deficient knee, CS TKA and controls. TKA with PCL deficiency showed more antero-posterior motion compared to TKAs with intact PCL and this can be source the of instability and a potential factor for patient's dissatisfaction. For this reason surgeons should attentively verify PCL integrity when performing a cruciate-sparing TKA. (www.actabiomedica.it)

Key words: posterior cruciate ligament, kinematic, fluoroscopy, cruciate-retaining, cruciate-substituting, TKA

Introduction

Video-fluoroscopy analysis represents one of the best investigations for the assessment of in-vivo three-dimentional (3D) kinematics of the normal and prosthesized knee. The kinematic study of the knee implanted with total knee arthroplasty (TKA) has a fundamental importance for the development of new prosthetic implants designed to reproduce as close as possible the kinematics of the native knee. Studies describing the distal anatomy of the femur reported that the knee flexes and extends on a single radius of curvature: from this assumption, came the postulation of a single radius of femoral condyles curvature (1). Following these biomechanical principles, TKAs with a single-radius femoral component design were introduced to more accurately reproduce kinematics of the normal knee joint. With software and 3D models it is possible to obtain a 3D pose of the femoral and tibial prosthetic components of the prosthesis into the space throughout the whole range of motion of three motor tasks used in the evaluation of knee kinematics (2,3).

Conditt et al. reported better functional outcomes of cruciate retaining (CR) implants over posterior-stabilized (PS) designs, in particular in high-demand patients, performing those activities involving deep flexion (4). In CR designs, the posterior cruciate ligament (PCL) is responsible for maintaining the femur posterior on the tibia in flexion, providing joint stability and enhancing knee proprioception. As reported

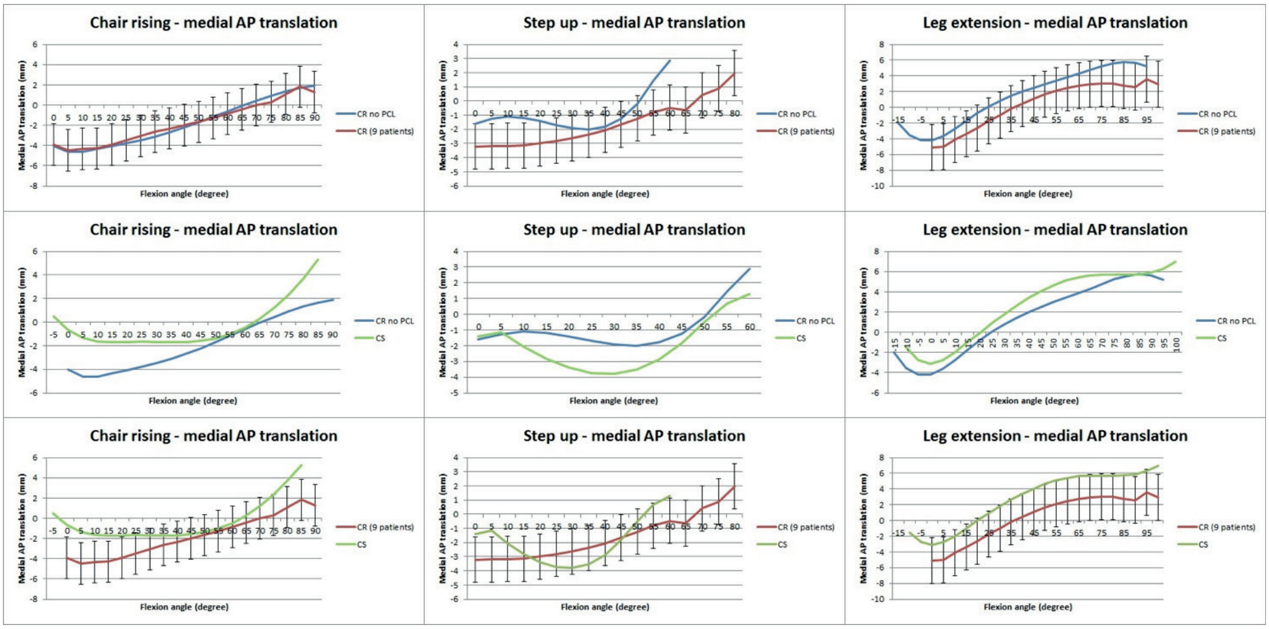

Figure 1. Comparison of axial rotation between patients treated with TKR with different tibial insert in three motor tasks.

by Rodriguez-Merchan, post-operative failure of the PCL represents a frequent cause of CR TKA failure and subsequent revision: if the PCL is incompetent or lost post-operatively, there is a potential risk for TKA instability and loss of weight bearing range of motion (5). To the best of our knowledge, no studies reported quantitative data showing kinematic patterns of PCL deficiency in a CR TKA. In the present video-fluoroscopy study it's reported the in vivo kinematic pattern before and after polyethylene replacement of a posterior cruciate retaining single-radius-femoral component TKA with a deep-dish, cruciate substituting (CS) polyethylene insert: it has been hypothesized that postoperative PCL loosening has an effect on knee kinematics and that polyethylene liner exchange to a CS insert restores CR TKA kinematics close to cases with intact PCL.

Case Report

A 56-years old man presented to the senior author (FC) with severe knee osteoarthritis. He reported disabling pain and difficulties with activities of daily living. His active range of motion was 0°-140°. After signing informed consent, he underwent CR TKA (Triathlon, Stryker, Mahwah, NJ, USA) using patient-specific technology (OtisMed, Alameda, CA, USA).

The patient was asked to take part to video-fluoroscopy assessment as part of a standard post-operative study protocol. He was asked to perform three motor tasks: chair rising/sitting, stair climbing and leg extension against gravity. For stair climbing, three 21-cm-high steps were used; to assess stepping up and down, only the first step was used, and four up/down cycles were performed in a single repetition. For the rising and sitting exercise, chair height was set specifically for the patient in order for him or her to begin with the knee flexed at about 80°. Data collection and analysis procedures were previously described and included the use of a standard fluoroscope (1). Three-dimensional prostheses component positions and orientations were obtained from each fluoroscopic image by an iterative procedure using a CAD-model-based shape-matching technique (2). Previous validation showed that 3D position and orientation of the metal prosthetic component, respectively, have an accuracy >0.5 mm and 1° (2). Condylar contact was assumed on the medial and lateral compartments, as the two sets of points at minimum distance between the femoral condyles and the tibial base plate. The positions of these contact points (CP) were expressed in the tibial base-plate reference frame in terms of percentage locations over the anteroposterior (AP) length; 0 % and 100 % corresponded to the most posterior and most anterior location, respectively. Patterns of AP motion of the CP were therefore obtained independently for the medial and lateral condyles. Contact-line rotation, defined as rotation of the line connecting the medial and lateral CP with respect to the mediolateral axis on the tibial transverse plane, was calculated for each flexion angle. During clinical assessment prior to fluoroscopic analysis the patient reported knee AP instability and lateral pain. Clinical examination showed evidences of PCL deficiency. To correct PCL deficiency, it was decided to replace the CR polyethylene insert with a CS polyethylene insert. Five months after surgery, fluoroscopic analysis was repeated following the same principles described above. Data from the two fluoroscopic analyses were eventually compared with each other and matched with those of 9 patients undergoing the same investigation at 6 months of follow-up after CR TKA implanted with the same patient-specific technology.

Data analysis showed that the kinematic pattern of axial rotation resulted to be similar for all motor tasks. The PCL-deficient TKA reported an average axial rotation in the three motor tasks of approximately 13°. The CS TKA resulted in an average axial rotation of 12° in the three motor tasks. Control CR TKA reported an average axial rotation in the three motor tasks of 11°. Moreover, the femoral component of PCL-deficient CR TKA always reached positions of greater internal rotation of the femur at full knee extension than CS design and controls (Figure 1).

The kinematic pattern of medial antero-posterior (AP) translation of the femur reported similar results in all three motor tasks: an average anterior translation of 7 mm for PCL-deficient CR TKA, CS design and controls was reported. The curves describing the kinematic pattern of the implanted knee maintained a constant offset, which was more evident during the last degrees of knee extension, recording a constant more anterior position for PCL-deficient TKA and CS design than control CR TKAs (Figure 2).

As for lateral AP translation, an average posterior translation of the femur of 4 and 6 mm for PCL-deficient knee and CS TKA, respectively, was reported, while an average posterior translation of the femur of 4 mm was described in control TKAs. Furthermore, a constantly more anterior position of the lateral femoral condyle throughout the range of motion and in all three motor tasks was noticed for PCL-deficient knee and

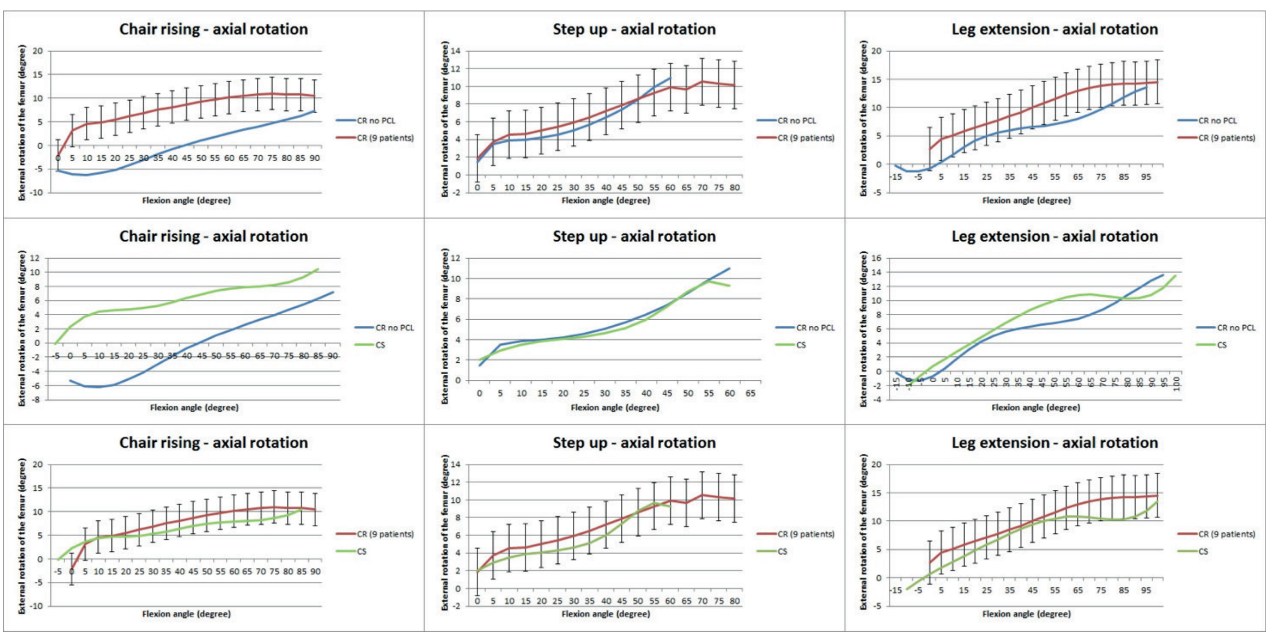

Figure 2. Comparison of medial antero-posterior translation between patients treated with TKR with different tibial insert in three motor tasks.

CS design than controls (Figure 3). In closed-chain motor tasks the CS design significantly changed the kinematic pattern of the lateral femoral condyle, with closer positions to those achieved by normal controls.

Discussion

Many investigators have studied in-vivo knee kinematics after CR TKA, reporting in-vivo motion data (3–7): the kinematic pattern of this design is usually characterized by progressive external rotation of the femur as knee flexion increases, anterior translation of the medial femoral condyle and posterior translation of the lateral femoral condyle. The analysis of the 9 CR TKAs implanted with patient-specific technology showed kinematic patterns closer to those of normal knees, if compared to previous studies on CR TKAs (8–10). Examinated CR TKAs resulted to have higher values of femoral external rotation and posterior translation of the lateral femoral condyle and reduced anterior translation of the medial femoral condyle. Different kinematic patterns are often described for patients receiving a CR TKA. These differences are likely to be explained by PCL deficiency (11): without a functional PCL the femoral component has no constraint on the antero-posterior translation, inducing the femur to move anteriorly more prominently on the lateral than on the medial side. This report is confirmed by the findings of the present study: at equal knee flexion degrees, the patient with PCL failure reported a relatively more anterior translation of the lateral femoral condyle and reduced values femoral external rotation, if compared to controls. These kinematic behaviors were well described for the motor tasks of chair rising/sitting and leg extension against gravity and less for step up/down. With a PCL deficiency the implanted knee does not have any functional cruciate ligament, so the tibial insert, the patello-femoral joint and the medial collateral ligament represent the kinematic constraint.

After polyethylene replacement to a CS insert for PCL deficiency, video-fluoroscopy was repeated: CS insert, aiming to provide more anterior stability to the femoral component translation with flexion(12), is characterized by a raised front lip that offers greater anterior constraint replacing the action of the PCL, especially for what concern the translation of the lateral femoral condyle. This was verified by the findings of the present study: for equal knee flexion degrees,

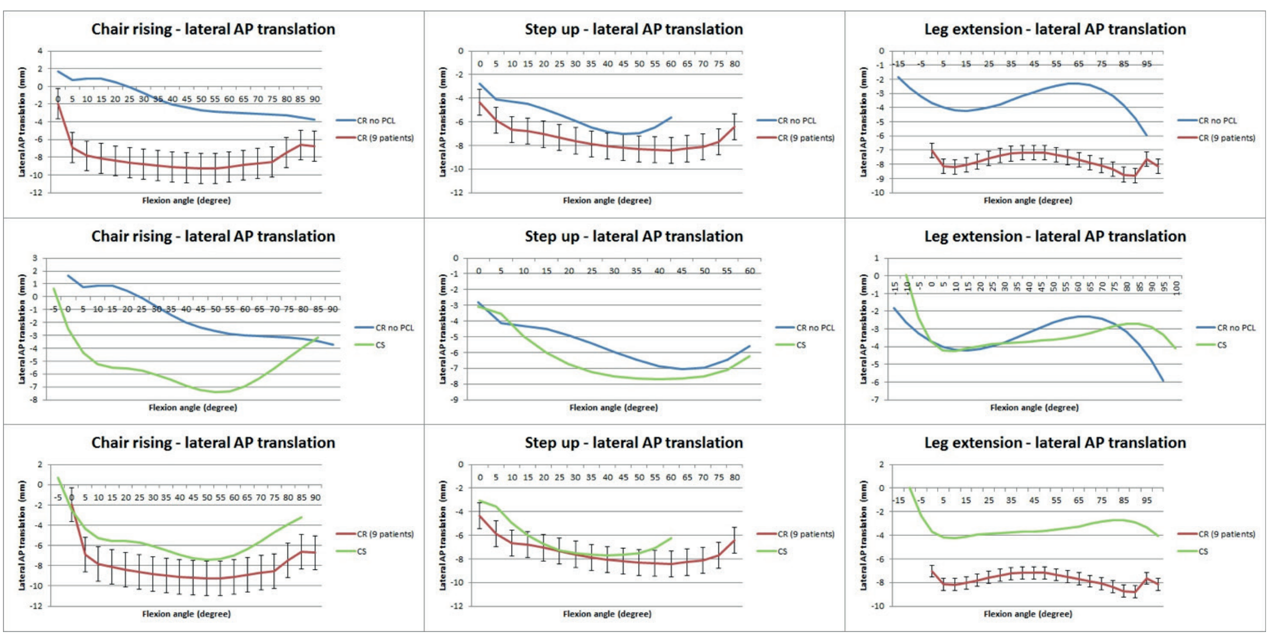

Figure 3. Comparison of lateral antero-posterior translation between patients treated with TKR with different tibial insert in three motor tasks.

values of femoral external rotation increased if compared to PCL deficient TKA. These results are comparable to those of CR controls. For translation of the lateral femoral condyle, the CS design pattern showed a relatively posteriorized motion, closer to controls, compared to PCL deficient TKA. This was noted for chair rising/sitting and step up/down motor tasks, and less for leg extension. For the AP translation of the medial femoral condyle, no overall differences were reported for PCL deficient CR knee, CS TKA and controls.

In conclusion, PCL deficiency represents a common cause of CR TKA failure: when performing cruciate sparing implants the surgeon should attentively verify the integrity of the ligament. The present report demonstrated that post-operative PCL deficiency can significantly modify the kinematics of the implanted knee. Moreover it was verified that CS inserts provide to restore knee function and more closely reproduces the kinematic pattern of PCL functioning CR designs.

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Ethic Committee: Study name: "Studio prospettico randomizzato multicentrico del sistema di protesi totale di ginocchio Triathlon a conservazione del crociato usando le guide di taglio shape-matched." Protocol number: K-S-045. Approved by: Modena Ethical Commitee on 12th July 2011, transmitted with protocol n. 2765 on 5th August 2011.

Conflict of Interest: The authors Valerio Daffara, Francesco Zambianchi, Tania Gualandris, Stefano Seracchioli and Andrea Marcovigi or any member of their immediate family, have no funding or commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article. The author Fabio Catani reports consultancy and speaking fees, royalties, and fees for participation in review activities from Stryker.

Authors Contribution: V.D. – Wrote the manuscript, analyzed and critically interpreted the data. F.Z. – Contributed in data analysis and was a major contributor in writing the manuscript. T.G. – Collected data and performed early analyses. S.S. – Drafted the manuscript. A.M. – Helped in generating the hypothesis and interpreting the data. F.C. – Generated the study hypothesis and critically appraised the manuscript.

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