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Case Report

Failure of the Femoral and Tibial Components Following Anterior Cruciate Ligament Injury After Robotic-Assisted Bicruciate-Retaining Total Knee Arthroplasty

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A B S T R A C T

We report a case of failure of the femoral and tibial components due to anterior cruciate ligament (ACL) injury after robotic-assisted bicruciate-retaining total knee arthroplasty. A 70-year-old woman with osteoarthritis underwent robotic-assisted bicruciate-retaining total knee arthroplasty. At 8 months after surgery, persistent knee pain and swelling of the knee joint were noted after fall in knee. We diagnosed a failure between the femoral and tibial components following an ACL injury. Proximal ACL injury and spin out of ultra-high molecular weight polyethylene were confirmed. We selected a constrained condylar knee prosthesis due to large bone attribution after femoral and tibial component removal. Postoperative three-dimensional computed tomography images suggested that excessive internal rotational alignment of the tibial component caused stress on the ACL.

Introduction

Total knee arthroplasty (TKA) is a common and cost-effective surgical treatment for osteoarthritis of the knee, with proven effectiveness in reducing pain and improving quality of life [1-3]. However, numerous studies suggest that only 82%-89% of patients are satisfied with their postoperative outcomes [4-6].

Bicruciate-retaining (BCR) TKA is gaining attention again because preservation of anterior cruciate ligament (ACL) results in kinematics closer to those of the native knee and potentially improves patients' knee function and satisfaction after TKA when compared with posterior-stabilized TKA [7,8]. However, historically, BCR TKA [9-12] has caused what is called “kinematic conflict,” where ligamentous tension increases at certain flexion angles due to the preservation of all ligaments, resulting in early postoperative revision. Hence, robot-assisted (RA) procedures have been introduced to determine osteotomy volume and component alignment to balance soft tissues to ensure that both cruciate ligaments are functional in each patient.

We report a case of revision surgery in a patient with a failure of the femoral and tibial components due to failure of the ultra-high molecular weight polyethylene (UHMWPE) locking mechanism after ACL injury following RA BCR TKA.

Case history

A 70-year-old female farmer with body mass index of 21.5 kg/m^2 and bicompartmental knee osteoarthritis (Fig. 1) underwent RA TKA (CORI, Robotic Surgical System, Smith & Nephew, Plymouth, MN) with a BCR prosthesis (Journey II XR, Smith & Nephew, Inc., Memphis, TN) (Fig. 1). The patient had no preoperative pain and was able to farm without hindrance. At 8 months after surgery, the patient fell while working in agriculture and sustained injury due to valgus loading of the knee joint, internal rotation, and adduction of the hip joint, that is, knee in.

She presented to the emergency department with complaints of swelling in the right knee and inability to walk due to pain 10

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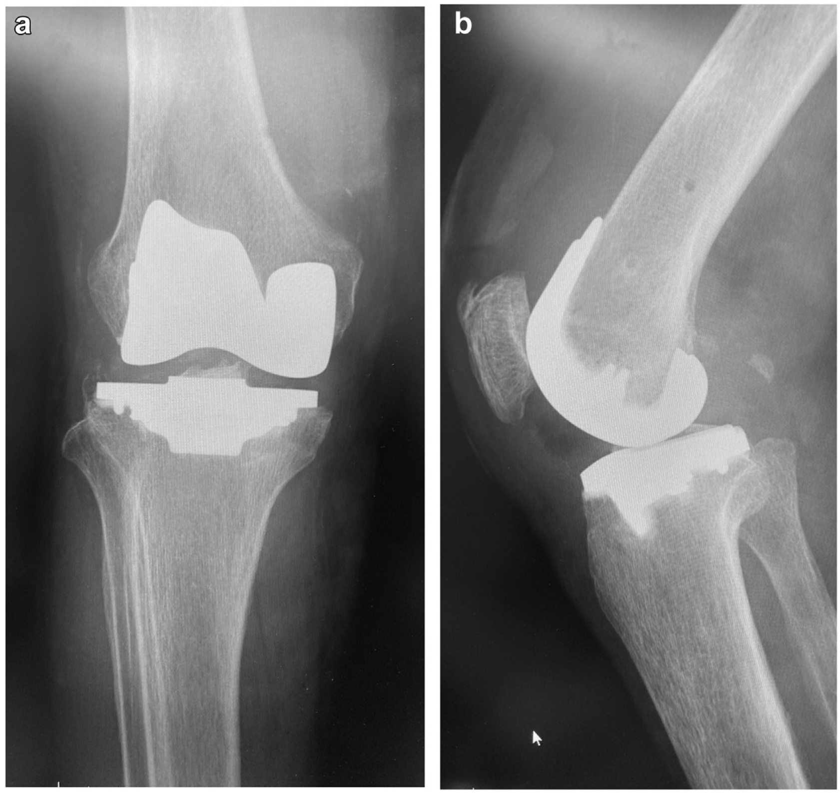


Figure 1. Postoperative plain radiographs after robotic-assisted bicruciate-retaining total knee arthroplasty. (a) Antero-posterior view; (b) lateral view.

months after surgery. Clinical findings included joint effusion with dark brown blood, crepitus with flexion (Fig. 2), positive anterior drawer sign, and anterolateral rotatory instability. Range of motion (ROM) was assessed from 5 to 90 degrees. Plain radiographs of the right knee showed the metal line sign associated with the shapes of the femoral and tibial components and thrust of the femoral component in the medial direction (Fig. 3).

We diagnosed failure between the femoral and tibial components as a result of ACL injury after RA BCR TKA. We selected revision TKA using conventional jig-based technique after removal of the XR prosthesis.

Surgical procedure

Revision TKA using a medial parapatellar approach was performed under general anesthesia. Black deposits associated with metallosis were observed throughout the intra-articular joint (Fig. 4). ACL proximal half injury and spin out of the lateral UHMWPE were confirmed (Fig. 4). Black deposits associated with metallosis were debrided as much as possible. We have identified the cause as being failure of the femoral and tibial components; therefore, prostheses were removed. Constrained condylar knee (Persona CCK: Zimmer-Biomet, Warsaw, Indiana) with stem extension on both the femoral (offset: 6 mm, 12 × 135 mm) and tibial component (offset: 3 mm, 13 × 135 mm) was chosen (Fig. 5).

At 1 year after revision CCK TKA, ROM was assessed from 0 to 125 degrees. The 2011 Knee Society Score symptom (25), patient satisfaction (40), patient expectation (15), and daily activity (100) subscores [13] were 18, 26, 8, and 75 points, respectively. The Western Ontario and McMaster Universities Arthritis Index scores for pain (20), stiffness (8), and physical function (68) [14] were 13, 4, and 6, respectively. The Forgotten Joint Score (100), which consists of 12 questions [15] was 55. The Patella Score subscores for anterior knee pain (15), quadriceps strength (5), ability to rise from a chair (5), and stair-climbing (5) [16] were 10, 5, 3, and 4, respectively.

Discussion

We performed revision CCK TKA due to failure of the femoral and tibial components and spin out of the lateral UHMWPE with failure of lateral UHMWPE and metal locking mechanism in tibial component following ACL injury at 10 months after RA BCR TKA.

A possible factor was proximal ACL injury due to a valgus loading while farming at 8 months after surgery. Thereafter, medial movement of the femoral component (Fig. 6) began causing the femoral component to collide with the tibial component locking

Figure 2. Crepitus on the lateral side of the skin incision with flexion (red arrow).

mechanism, resulting in metal wear (Fig. 7a and c). The UHMWPE locking mechanism on the lateral side of the tibial component was thereby ruptured, causing lateral spin out and wear on the lateral articular surface of the tibial component (Fig. 7b). If lateral UHMWPE spin out occurred irrespective of ACL injury, it was considered that the wear would not occur in only one location in the UHMWPE (Fig. 7d).

We have previously reported that achieving slight laxity in the medial joint gap (MJG) from 0° to 140° of flexion, tightness of the lateral joint gap (LJG) at 90° of flexion, and physiological laxity (MJG < LJG) from 0° to 140° of flexion results in improved postoperative patient ROMs with Journey II XR prosthesis using conventional jig-based technique and a balancer [17]. Therefore, with the RA surgical technique, component alignment and osteotomy volume were determined with consideration of soft tissue balance in reference to these findings. In the present case, intraoperative gap assessments were MJG of 1.0 mm and LJG of 2.0 mm in extension and MJG of 2.2 mm and LJG of 3.7 mm. From extension to 100° of flexion, MJG was smaller than LJG, consistent with physiological laxity. However, from 100 degrees of flexion to deep flexion, MJG was larger than LJG indicating medial laxity (Fig. 8). The preoperative hip and knee angle (HKA) improved from 9 degrees of varus alignment to 6 degrees of varus alignment after surgery (Fig. 8). Determining component alignment based on this patient's soft tissue balance resulted in undercorrection of the postoperative HKA, while the MJG resulted in a concern for medial loosening with deep flexion.

Malalignment in both the coronal and sagittal planes is considered a risk factor for ACL injury. Varus alignment in the coronal plane [18] and increased posterior tibial slope in the sagittal plane [19] are risk factors for ACL injury. Preoperative HKA improved from 9 degrees of varus alignment to 6 degrees of varus alignment after surgery with robotic technology (Fig. 8). Postoperative 3DCT images of the femur and tibia were superimposed onto those of the preoperative 3DCT plan using computer software (ZedView, ZedKnee; LEXI Co., Ltd., Tokyo, Japan) (Fig. 9) [20-22]. Preoperative physiological posterior tibial slope and postoperative posterior angle of the tibial component were equivalent at 6 degrees. In other words, it was not a risk factor for ACL injury. However, postoperative rotational alignment of the tibial component was 15 degrees of internal rotation relative to the Akagi line, a deviation of 12 degrees from the preoperative plan.

With regard to the mechanism of ACL injury, Koga et al. [23] revealed that when a valgus stress is applied to the knee, the resulting tension on the medial collateral ligament produces a compressive force on the lateral compartment. This compression force causes the femoral lateral condyle to deviate posteriorly due to the posterior slope of the lateral tibial plateau, resulting in anterior tibial translation and internal rotation, which leads to ACL rupture (Fig. 10). Fifteen degrees of internal rotation alignment of the tibial component with respect to the Akagi line might have caused a large mechanical stress on the ACL, resulting in ACL injury.

We have previously revealed that coronal alignment classes after RA bicruciate-stabilized TKA is not associated with variation in patient-reported outcome measurements [22]. In RA BCR TKA, on the other hand, a boundary of component alignment is necessary for postoperative function without ACL injury. The surgeon should ensure that the postoperative coronal alignment and tibial posterior tilt angle are equal to or less than those before surgery and there is no excessive internal rotation alignment of the tibial component.

The limitations of this study go beyond the ability to clarify this phenomenon in a single case. However, first, we confirmed that ACL was grossly normal and performed RA BCR TKA. Also, during revision surgery, ACL was clearly damaged. ACL injury was the cause of the failure, as the medial migration of the femur was observed after 8 months postoperatively. The medial migration of femur does not occur unless the ligament is ruptured.

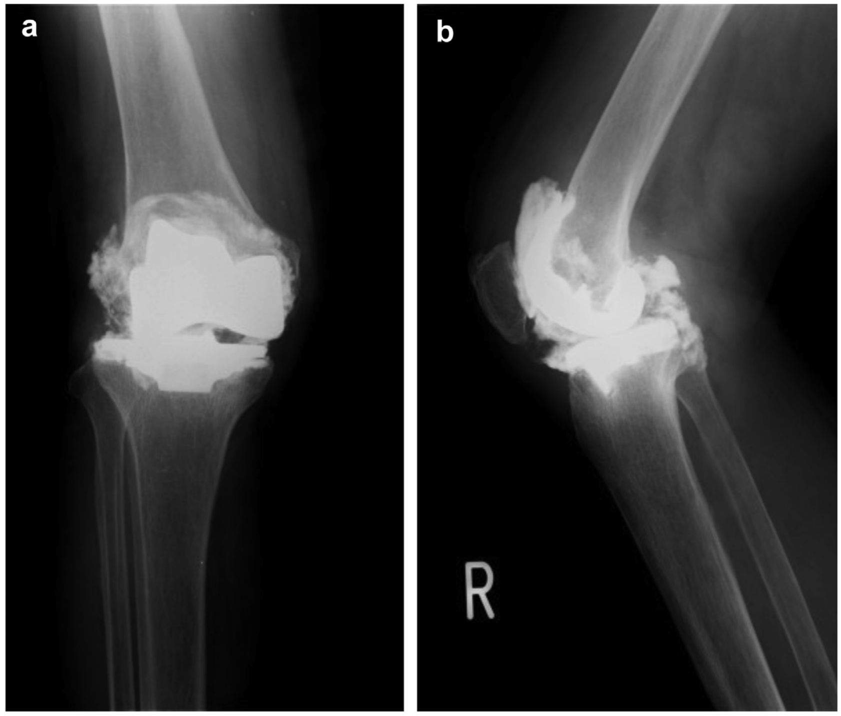


Figure 3. Plain radiographs at 10 months after surgery. (a) Antero-posterior view; (b) lateral view. The metal line signs associated with component shapes and thrust of the femoral component in the medial direction were observed.

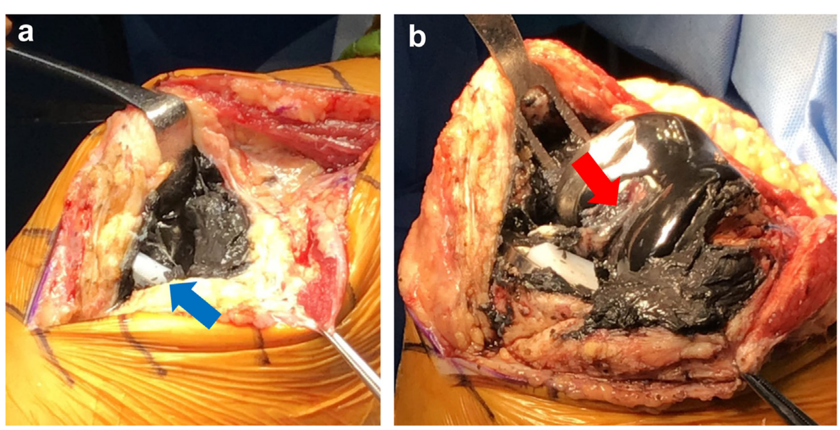


Figure 4. Intraoperative photographs. (a) In extension; (b) in 90 degrees of flexion. Black deposits indicating metallosis were observed in the periarticular area. Proximal ACL injury (red arrow) and spin out in the ultra-high molecular weight polyethylene (blue arrow) were confirmed.

Figure 5. Postoperative plain radiographs after revision total knee arthroplasty. (a) Antero-posterior view; (b) lateral view. A constrained condylar knee prosthesis (Persona CCK: Zimmer-Biomet, Warsaw, Indiana) with stem extension on both the femoral component (offset, 6 mm; 12 × 135) and tibial component (offset, 3 mm; 13 × 135) was chosen.

Summary

We report a case of revision surgery in a patient with a failure of the femoral and tibial components due to failure of the ultra-high molecular weight polyethylene (UHMWPE) locking mechanism after proximal anterior cruciate ligament (ACL) injury at 10 months after RA BCR TKA.

In this patient, 15 degrees of internal rotation alignment of the tibial component with respect to the Akagi line might have caused a large mechanical stress on the ACL, resulting in ACL injury.

The surgeon should ensure that the postoperative coronal alignment and tibial posterior tilt angle are equal to or less than those before surgery and there is no excessive internal rotation alignment of the tibial component.

Conflicts of interest

The authors declare there are no conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2024.101523.

Informed patient consent

The author(s) confirm that informed consent has been obtained from the involved patient(s) or if appropriate from the parent, guardian, power of attorney of the involved patient(s); and, they have given approval for this information to be published in this article.

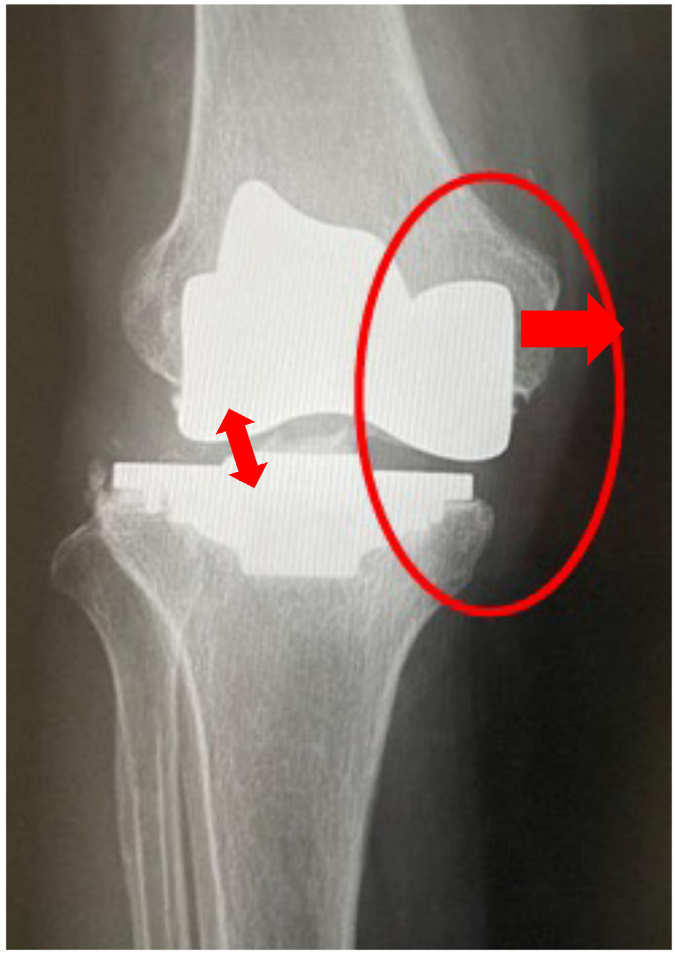


Figure 6. Plain radiographs (antero-posterior view) at 8 months after surgery. Medial migration of the femur and the collision of the lateral articular surface of the femoral component with the UHMWPE locking mechanism of the tibial component (red arrow and circle).

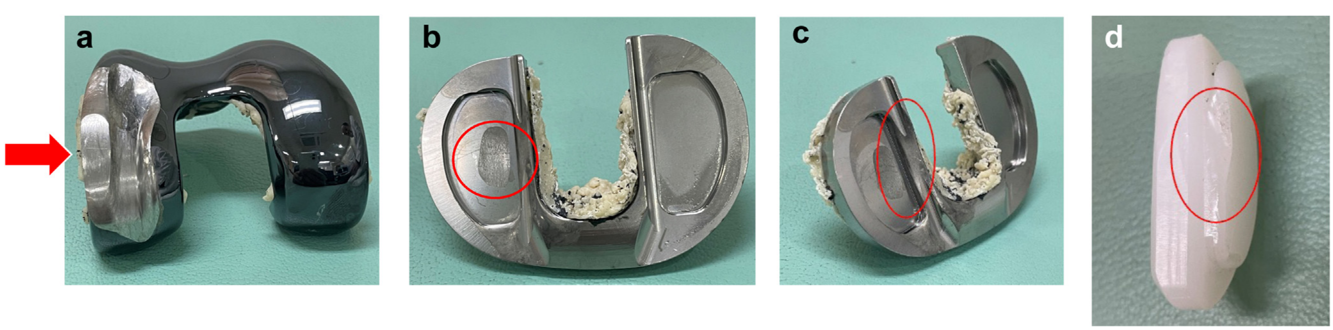
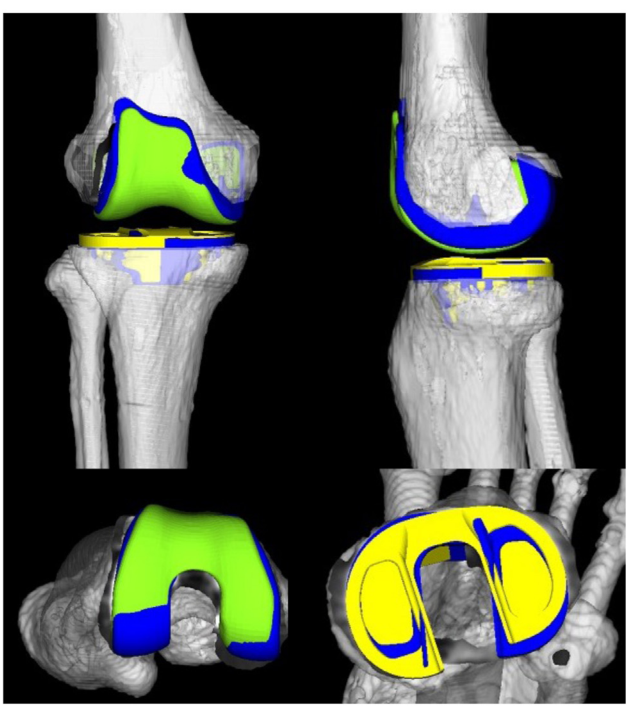


Figure 7. Images of the removed prosthesis. (a) In the femoral component, wear on the lateral side of the sliding surface and breakage consistent with the edge of the tibial baseplate (red arrow). (b) Wear on the lateral surface of the tibial base plates (red circle). (c) Wear on the central lateral edge of the tibial baseplate (red circle). (d) Slight wear on the sliding surfaces and deformation of the distal end of the lateral UHMWPE (red circle).

Figure 8. Intraoperative gap assessment and component alignment. Preoperative HKA angle of 9 degrees varus improved to postoperative HKA angle of 6 degrees varus, corresponding to undercorrection. Gaps were assessed intraoperatively: medial joint gap (MJG) of 1.0 mm and lateral joint gap (LJG) of 2.0 mm in extension, and MJG of 2.2 mm and LJG of 3.7 mm. From extension to 100 degrees of flexion, MJG was smaller than LJG, consistent with physiological laxity. However, from 100 degrees of flexion to deep flexion, MJG was larger than LJG, indicating medial laxity.



Femoral Component

Parameter	Pre	Post	Difference
Varus (3D Mechanical Axis)	Varus 1.00 °	Varus 0.50 °	Valgus 0.50 °
Flexion (3D Mechanical Axis)	0.00 °	Flex 3.49 °	Flex 3.49 °
Varus (Distal Axis)	Valgus 8.94 °	Valgus 9.44 °	Valgus 0.50 °
Flexion (Distal Axis)	Flex 0.12 °	Flex 3.61 °	Flex 3.49 °
Rotation (TEA)	0.00 °	IntRot 3.03 °	IntRot 3.03 °
Rotation (PCA)	ExtRot 5.08 °	ExtRot 2.06 °	IntRot 3.02 °
Distal Resection Thickness(Medial)	9.86 mm	8.74 mm	-1.12 mm
Distal Resection Thickness(Lateral)	9.64 mm	8.72 mm	-0.92 mm
Post. Resection Thickness(Medial)	12.12 mm	14.50 mm	2.38 mm
Post. Resection Thickness(Lateral)	8.13 mm	12.94 mm	4.81 mm
Med-lat position diff			Lat 0.43 mm
Ante-post position diff			Ante 0.50 mm
Dist-prox position diff			Down 1.04 mm

Tibial Component

Parameter	Pre	Post	Difference
Varus (3D Mechanical Axis)	Varus 1.51 °	Varus 1.51 °	0.00 °
Ant/Post Tilt (3D Mech Axis)	PosTilt 6.00 °	PosTilt 6.00 °	0.00 °
Rotation (AP Axis)	IntRot 2.51 °	IntRot 15.56 °	IntRot 13.05 °
Rotation (X-Axis of Tibia)	IntRot 2.33 °	IntRot 15.28 °	IntRot 12.95 °
Prox. Resection Thickness(Medial)	5.83 mm	4.83 mm	-1.00 mm
Prox. Resection Thickness(Lateral)	10.88 mm	9.88 mm	-1.00 mm
Med-lat position diff			Med 0.76 mm
Ante-post position diff			Ante 0.23 mm
Dist-prox position diff			Up 1.01 mm

Figure 9. Preoperative three-dimensional computed tomography (3DCT) plan and postoperative 3DCT images were shown. 3D computer-aided design (CAD) data of femoral and tibial components were fitted to the 3DCT plan and images. Preoperative plan components are shown in blue. Postoperative components are shown in green and yellow [20-22]. Preoperative physiological posterior tibial angle and postoperative posterior tibial slope were equivalent at 6 degrees. Postoperative tibial rotation alignment was 15 degrees of internal rotation relative to the Akagi line, a deviation of 12° from the preoperative plan.

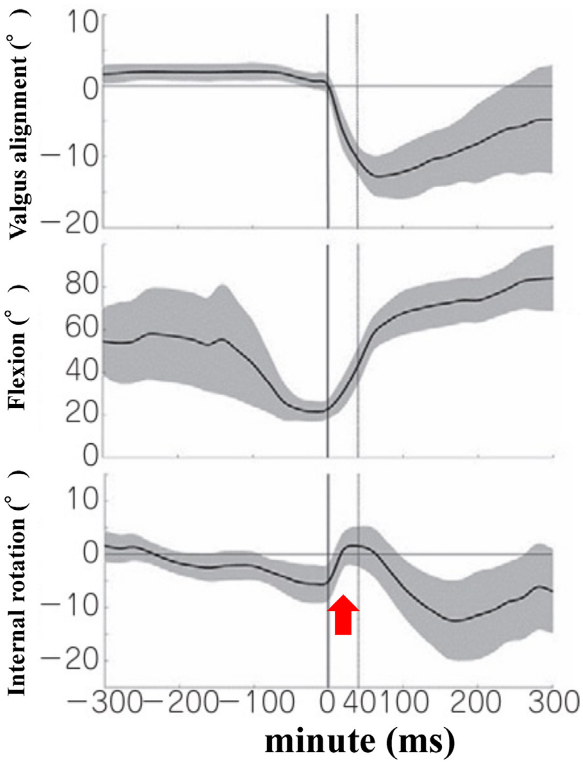


Figure 10. Koga et al. [23] found that the mechanism of anterior cruciate ligament (ACL) injury is rapid valgus stress and internal rotation (red arrow) that occurs by 40 ms after ground contact. Knee in, toe out is the result of a subsequent ACL injury.

CRediT authorship contribution statement

Kosuke Shiga: Investigation, Conceptualization. **Takao Kaneko:** Formal analysis, Data curation. **Ayakane Yamamoto:** Conceptualization. **Kazuki Amemiya:** Data curation. **Masaru Omata:** Data curation.

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