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Case report

# Total knee arthroplasty for severe valgus deformity of the knee with extra-articular deformities of the femur and tibia using a 3-dimensional image matching software system

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*Keywords:*
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A B S T R A C T

*Introduction and importance:* Knee osteoarthritis with femoral and/or tibial extra-articular deformities makes total knee arthroplasty (TKA) technically difficult to perform, especially using intramedullary-based instrumentation systems. The Athena Knee 3-dimensional (3-D) image matching software is effective for TKA with an extra-articular deformity, especially in case of using a long-stem prosthesis or not available computer-assisted navigation systems.
*Case presentation:* A 79-year-old woman presented with right knee pain secondary to a progressive valgus deformity and gait disturbance. She had experienced a supracondylar femoral fracture fifteen years ago, and a tibial shaft fracture ten years ago on the same side; both of fractures were treated surgically. She had a severe valgus knee deformity and extra-articular deformity of femur and tibia, and valgus stress test detected medial knee instability. The range of motion was 0° in extension and 75° in flexion. Severe medial knee laxity compelled us to use a constrained and long-stem prosthesis, resulting in the use of an intramedullary guided system. The 3-D software system helped us to determine the amount of bone to cut as well as the appropriate entry points for the intramedullary rods and mechanical axis restoration. At two years after surgery, knee range of motion improved to 90° in flexion, and walking ability had also advanced from the use of two crutches to that of a T cane.
*Conclusion:* The 3-D image matching software system for preoperative planning was useful for TKA with extra-articular deformity, especially in the case of a long-stem prosthesis without using a navigation system.

## 1. Introduction

Total knee arthroplasty (TKA) is an effective surgical treatment for severe osteoarthritis of the knee joints that helps in pain reduction and recovery of functional capacity. The restoration of proper lower limb alignment is essential for successful TKA, but the existence of femoral and/or tibial extra-articular deformities complicates this restoration [1–4]. Therefore, accurate preoperative planning is necessary for TKA involving an extra-articular deformity. 3-dimensional (3-D) image matching software that has been introduced recently is sufficiently accurate to assess lower extremity alignment as well as implant size and positioning [5,6]. In this case report, we reported a successful TKA for a patient who had a severe valgus knee deformity with both, femoral and tibial extra-articular deformities, using Athena Knee 3-D image matching software (SoftCube Co., Ltd., Osaka, Japan) for preoperative planning.

This work has been reported in line with the SCARE 2020 criteria [7].

## 2. Presentation of case

A 79-year-old woman presented with right knee pain secondary to a progressive valgus deformity and gait disturbance. She had experienced a supracondylar femoral fracture fifteen years ago, and a tibial shaft fracture ten years ago on the same side; these were surgically managed with retrograde intramedullary nail and plating, respectively. In addition, total hip arthroplasty was performed on the contralateral side for severe osteoarthritis eight years ago. There was radiographic

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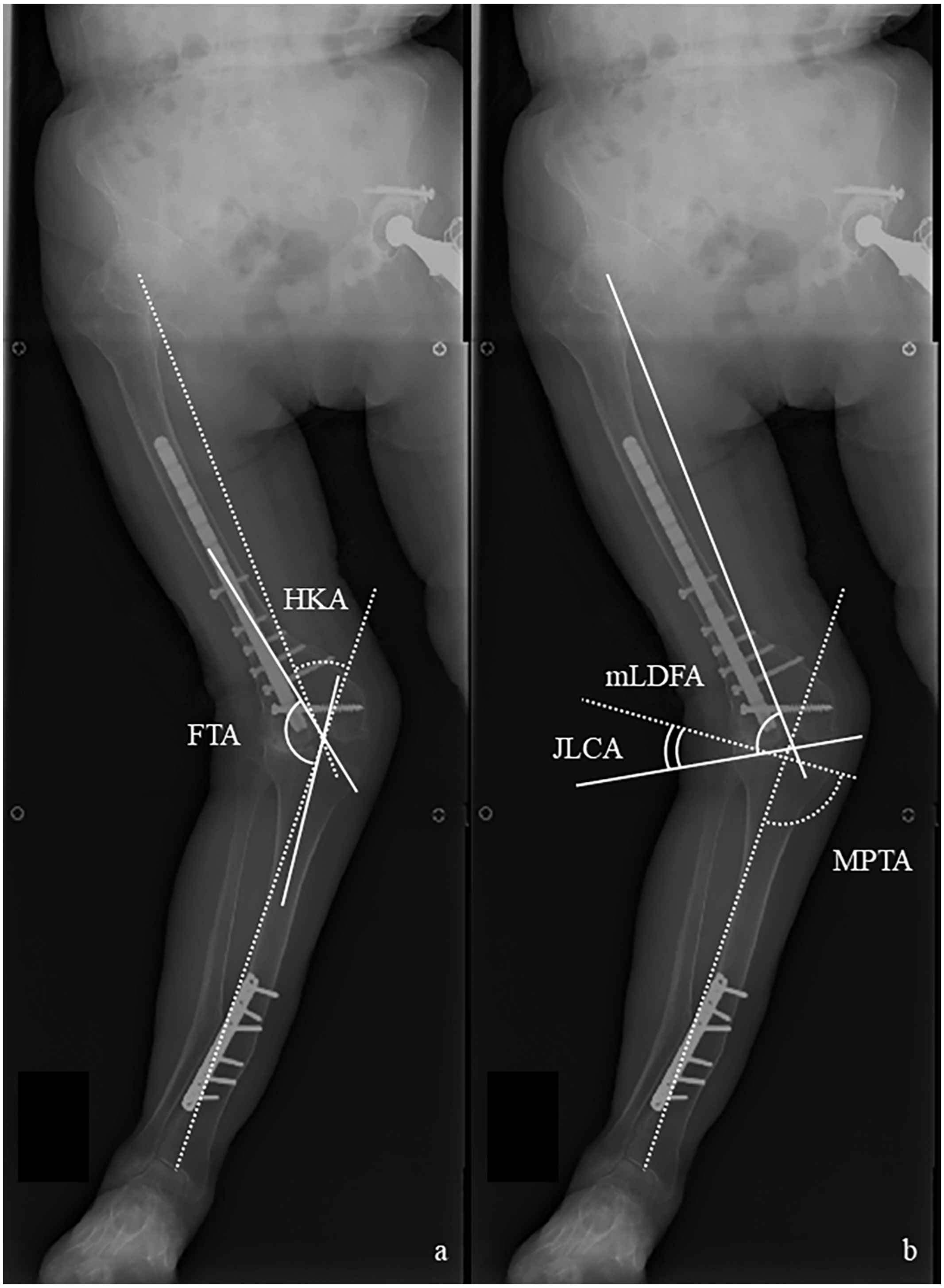


**Fig. 1.** Preoperative long leg standing radiograph.
(a) The HKA angle was 40.5° valgus, and the FTA was 135°.
(b) The mLDFA was 78.0°, the MPTA was 94.6°, and the JLCA was 25.1° valgus.
HKA: the hip-knee-ankle, FTA: femoro-tibial angle, mLDFA: mechanical lateral distal femoral angle, MPTA: medial proximal tibial angle, JLCA: joint line convergence angle.

osteoarthritis of the right hip, but she didn't have hip pain. She had a severe valgus knee deformity, and valgus stress test detected medial knee instability. The range of motion was 0° in extension and 75° in flexion. She required bilateral crutches for walking. She had no allergies. The patient's Knee Society Score (KSS) Knee Score and KSS Function Score were 31 and 27 points, respectively. Preoperative long leg standing radiography revealed the hip-knee-ankle (HKA) angle of 40.5° valgus, the femoro-tibial angle (FTA) of 135°, the mechanical lateral distal femoral angle (mLDFA) of 78.0°, the medial proximal tibial angle (MPTA) of 94.6°, and the joint line convergence angle (JLCA) of 25.1° valgus (Fig. 1). The extra-articular deformity of the femur was 9.6° in lateral bowing and of the tibia was 15.0° in medial bowing in the coronal plane. Considering the severe medial laxity and the large amount of bone expected to be cut, we selected long-stem Zimmer® Rotating Hinge

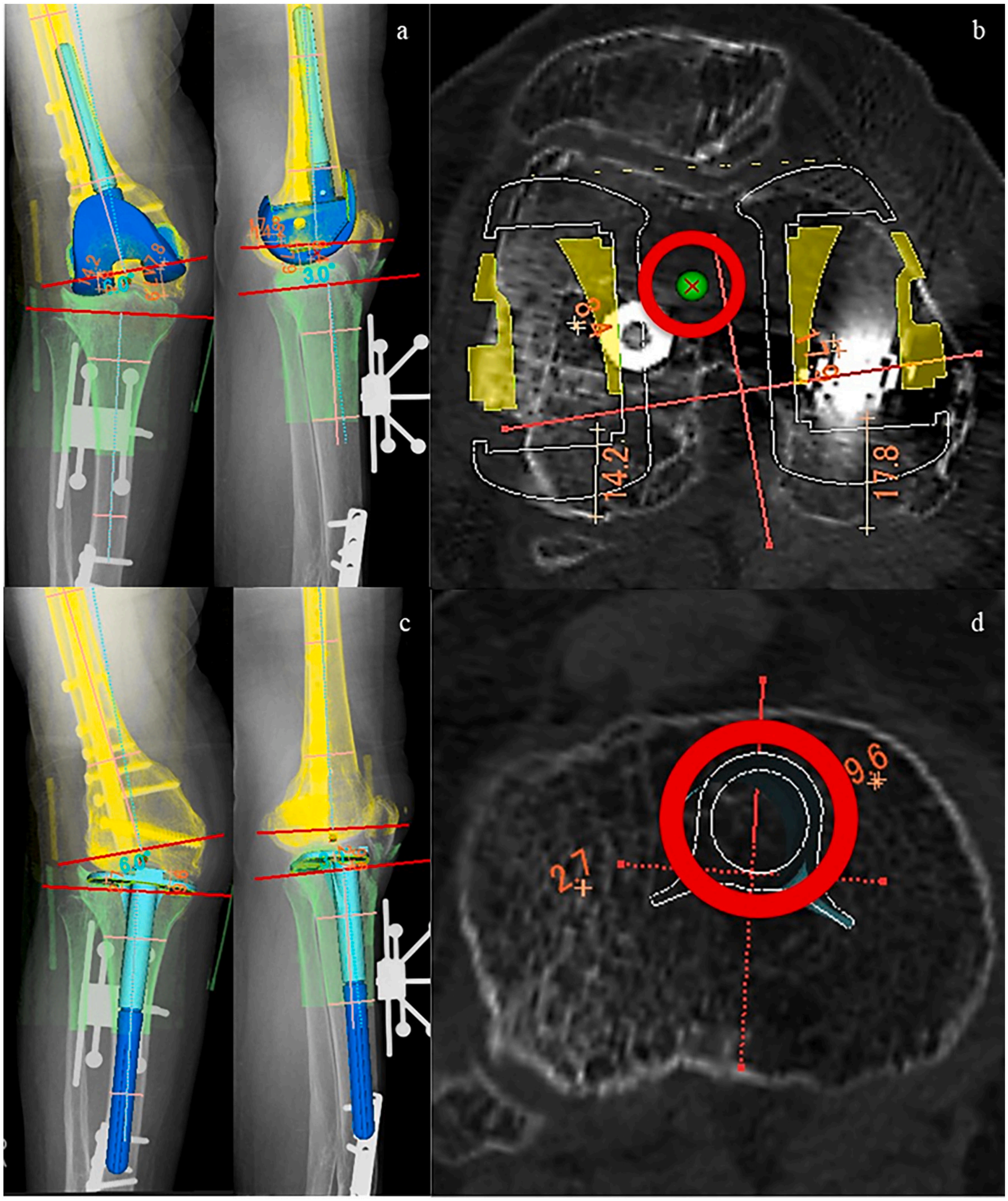


**Fig. 2.** The Athena Knee preoperative planning process.
(a) The femoral preoperative templating, the red line indicating the vertical line to the anatomical axis of the distal femur and the blue line indicating the mechanical axis of the femur.
(b) The intramedullary rod entry point pointed in the red circle area was marked and adjusted as laterally as possible because of the varus deformity of the distal femur.
(c) The tibial preoperative templating, the red line indicating the vertical line to the anatomical axis of the proximal tibia and the blue line indicating the mechanical axis of the tibia.
(d) To correct for the tibial diaphysis valgus deformity, the intramedullary guide entry point in the red circle area was located on the medial side to align the long stem along the mechanical axis. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Knee with an offset stem.

An image-matching software system (Athena Knee) that was developed for 3-D preoperative planning makes it possible to create a 3-D assessment of lower limb alignment for normal and implanted knees [5,8]. First, anteroposterior and lateral plain radiographs were taken of the knee joint with a 3-D marker attached to the surface of the lower leg that is used to create the 3-D image. Next, a computed tomography image and 3-D models of the prosthesis are matched to the radiographs using a computer-aided design program. Finally, the component size and position are adjusted to create a 3-D preoperative planning image [5,9]. In the Athena Knee femoral preoperative planning process, a varus deformity was noted at the distal femur, so we adjusted the location of the entry point for the femoral long stem to be as lateral as possible (Fig. 2a, b). In the tibial preoperative templating process, we planned to

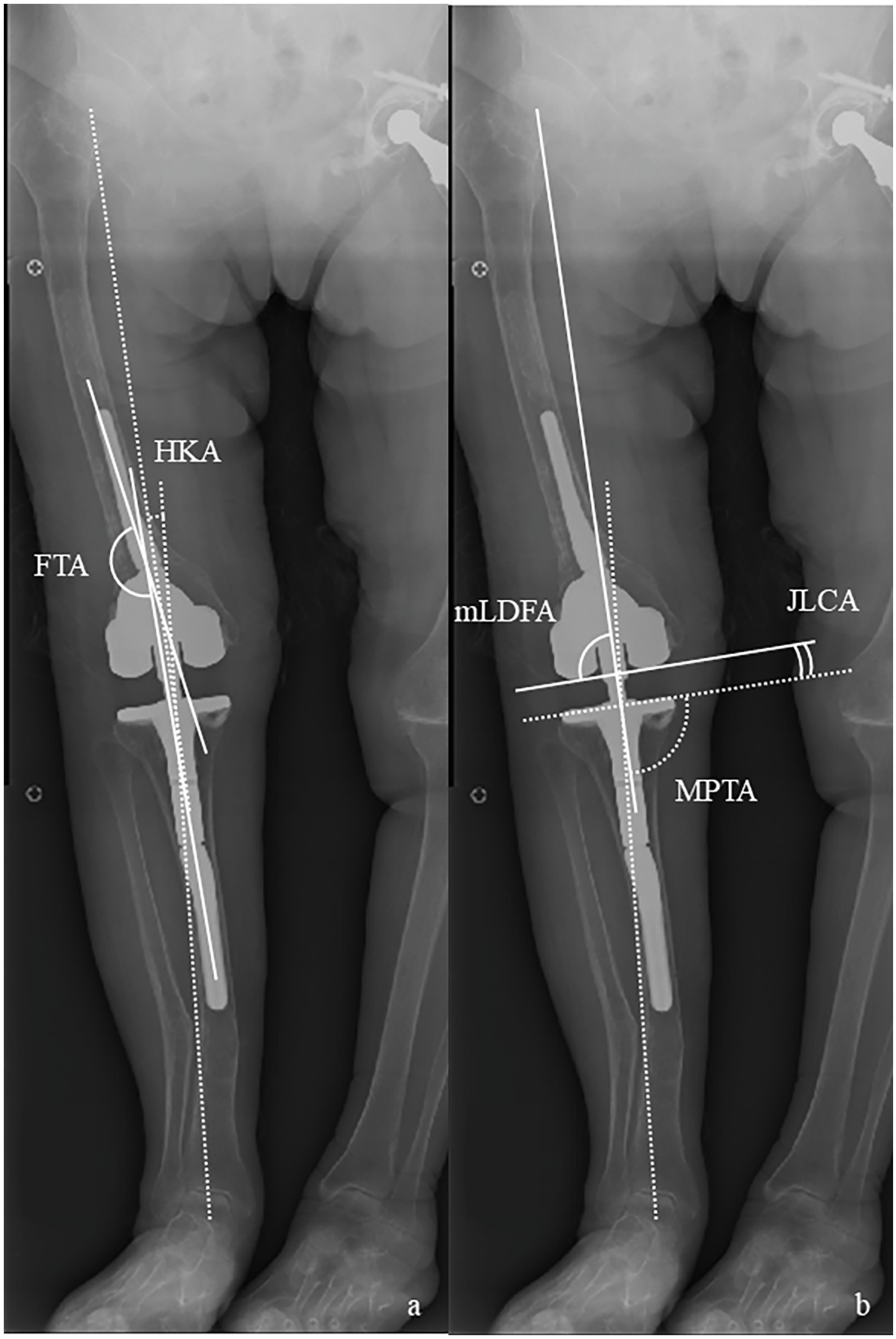


**Fig. 3.** Postoperative long leg standing radiograph.
(a) the HKA angle was 3.7° valgus, and the FTA was 174.5°.
(b) the mLDFA was 91.0°, the MPTA was 93.4°, and the JLCA was 1.7° valgus.
HKA: the hip-knee-ankle, FTA: femoro-tibial angle, mLDFA: mechanical lateral distal femoral angle, MPTA: medial proximal tibial angle, JLCA: joint line convergence angle.

locate the entry point for the tibial component on the medial side and align the long stem along the mechanical axis to correct for the tibial diaphysis valgus deformity (Fig. 2c, d).

During surgery, TKA was performed using the lateral approach after removal of the intramedullary nail of the femur and the plate of the tibia. Each intramedullary rod was inserted into the femoral and tibial canals using the entry point locations from the Athena Knee preoperative planning process as references. The femoral and tibial component sizes were the same as those in the preoperative templating. The distal femoral, posterior femoral, and tibial cuts were achieved with almost nearly preoperative planning. In order to release the tight lateral soft tissue, lateral collateral ligament, popliteus tendon and iliotibial band were released, thereby correcting the valgus deformity to neutral alignment.

At 2 years postoperative assessment, radiograph measurements of the right lower extremity revealed the HKA angle of 3.7° valgus, the FTA of 174.5°, the mLDFA of 91.0°, the MPTA of 93.4°, and the JLCA of 1.7° valgus (Fig. 3). Knee range of motion was 0° in extension and 90° in flexion. KSS Knee Score and KSS Function Score improved from 31 to 83 and from 27 to 73 points, respectively. There were no complications. Walking ability had progressed from using bilateral crutches to using only a T cane.

## 3. Discussion

Extra-articular deformities of the femur and/or tibia distort the anatomical axis and bone canals, and make achieving appropriate bone resection and proper lower limb alignment technically difficult [1,2,4]. Such extra-articular deformities are caused by malunited fractures, previous osteotomies, metabolic bone disease, and excessive femoral bowing [1,2], and the larger the deformity and the closer it is to the knee joint, the greater the impact on the knee joint [10]. Wang et al. reported that TKA in conjunction with intra-articular bone resection is an effective procedure for patients with arthritis of the knee and extra-articular deformity <20° in the femur or <30° in the tibia in the coronal plane [1]. In the present case, the patient had an arthritic knee with extra-articular deformities of the femur with 9.6° in lateral bowing and of the tibia with 15.0° in medial bowing. Therefore, we selected the one-stage TKA with intra-articular correction. It was also better for our elderly patient to undergo a less invasive procedure with fewer potential complications.

Several studies have reported that computer-assisted navigation systems were useful and efficient tools for knee arthritis with extra-articular deformities [3,6,8,11–13]. However, in the present case, there was a risk of fracture on the navigation pin sites after removal of the intramedullary nail of the femur and the plate of the tibia, we selected conventional intramedullary guided knee instrumentation systems. In contrast to navigation systems, intramedullary instruments need to determine the direction of the bone cut in reference to the anatomical axis after the insertion of an intramedullary rod. The distorted anatomical axis and bone canal created by the extra-articular deformity obstruct the accurate insertion of an intramedullary guide and restoration of the mechanical axis, and make TKA with intramedullary instrumentation more difficult [2,14]. Thus, accurate preoperative planning and entry point assessment for the intramedullary guide become important for TKA involving an extra-articular deformity.

Although 2-D assessments using plain anteroposterior and lateral radiographs have been conventionally used for preoperative TKA planning, surgeons had to create 3-D images from 2-D radiographs and were not able to confirm the actual entry points for intramedullary guides three-dimensionally. However, using the image-matching software system, we can estimate component size and bone cut quantity and predict the degree of mechanical axis correction. Besides, in the case of TKA with extra-articular deformities, we can confirm three-dimensionally whether each long stem of the component can pass through the angular deformity and where the entry point for the intramedullary guide was located. In the present case, the entry point of the femur was moved to the lateral side because of the varus deformity, whereas the entry point of the tibia was adjusted to the medial side due to its valgus deformity. The 3-D confirmation of the entry point eased the intramedullary rod insertion and bone resection and provided acceptable results. The findings of this case suggest that use of the Athena Knee 3-D image matching software system is useful and helpful for TKA with an extra-articular deformity when we assess lower limb alignment required bone resection quantity, and intramedullary rod entry point.

## 4. Conclusion

It has been reported that the existence of femoral and/or tibial extra-articular deformities complicates successful TKA in the literature, therefore accurate preoperative planning is necessary for TKA involving an extra-articular deformity. The Athena Knee 3-D image matching software enables accurate preoperative planning and 3-D assessment of the entry point for an intramedullary rod, so it is effective for TKA with an extra-articular deformity, especially in case of using a long-stem prosthesis or not available computer-assisted navigation systems.

## Consent

Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

## Ethical approval

Ethical approval is exempt/waived at our institution.

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## Guarantor

Tomoyuki Matsumoto.

## CRediT authorship contribution statement

Kemmei Ikuta and Shintaro Mukohara drafted the manuscript and collected the data. Tomoyuki Matsumoto finalized the manuscript and performed the surgery. Naoki Nakano, Shinya Hayashi and Ryosuke Kuroda have cooperated in this manuscript.

## Declaration of competing interest

N/A.

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