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CASE REPORT Open Access

Bilateral same-day transtrochanteric rotational osteotomy using computed tomography-based navigation: a case report

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Abstract

Background Transtrochanteric rotational osteotomy (TRO) for osteonecrosis of the femoral head (ONFH) is considered technically demanding, with varying results among institutions. This is due to the complex soft tissue exposure and determination of the osteotomy line. We report a case in which the osteotomy line was assessed using the Stryker OrthoMap® three-dimensional (3D) computed tomography (CT)-based navigation system and determined as preoperatively planned.

Case presentation The patient was a 24-year-old male with alcohol-related ONFH. Japanese Investigation Committee Classification Type C2/C2 Stage 3b/3b was confirmed through magnetic resonance imaging, and TRO was performed bilaterally on the same day using the Stryker OrthoMap® 3D CT-based navigation system. The patient was hospitalized for 55 days, and full loading was allowed at 6 months postoperatively. Eight months after surgery, the patient could return to work at his previous job in the restaurant industry relatively quickly. One and a half years postoperatively, the functional score improved from a preoperative visual analog scale of 90 to 12 mm at and the Japanese Hip Society Hip Evaluation Questionnaire improved from 31 points preoperatively to 59 points.

Conclusions This is the first report of a bilateral TRO for bilateral ONFH performed on the same day using CT-based navigation. For osteonecrosis, which is often bilateral, accurate determination of the osteotomy line as planned preoperatively using CT-based navigation contributes to shorter operative time, less intraoperative blood loss, and allows for bilateral same-day surgery. This may improve situations in which patients are hesitant to undergo bone-preserving surgery because of the long period of time required to return to work, thereby facilitating their early reintegration into society.

Keywords Bilateral osteonecrosis of the femoral head, CT-based navigation, Transtrochanteric posterior rotational osteotomy, Bilateral same-day surgery, Return to work, CAS, Joint-preserving surgery

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Background

Transtrochanteric rotational osteotomy (TRO) has been reported to be an effective joint-preserving surgery for the treatment of osteonecrosis of the femoral head (ONFH) in young patients with extensive areas of necrosis to reduce disease progression and pain [1, 2]. However, postoperative outcomes have been questioned in Europe [3–5]. It is now performed in East Asia but is considered a technically demanding procedure. In Japan, however, the number of doctors who recommend osteotomy and the number of adolescent patients who choose osteotomy are on the decline, partly due to the need for long-term hospitalization and the long period of time required to return to work but also due to improved long-term outcomes of total hip arthroplasty (THA) [6]. The factors that make TRO a difficult procedure are exposing the complexity of soft tissues to avoid vascular injury as much as possible and determining the osteotomy line. Femoral anteversion varies greatly from person to person, and the anteversion angle cannot be determined from two-dimensional images [7].

Since 2021, we have been using Stryker OrthoMap® three-dimensional (3D) navigation software to perform accurate osteotomies, thereby improving postoperative outcomes and reducing surgical invasiveness. We report a case in which the patient could return to work 8 months after undergoing bilateral high-degree posterior rotational osteotomy (HDPRO) on the same day. The surgical technique used was based on the principles described previously [8, 9].

Case presentation

The patient was a 24-year-old male with alcohol-related bilateral ONFH. He had bilateral hip pain for 3 months and an X-ray of the pelvis showed bilateral osteonecrosis of the femoral head (Fig. 1a) after a magnetic resonance imaging (MRI) showed Japanese Investigation Committee Classification (JIC) Type C2/C2 Stage 3b/3b [10] (Fig. 1b). Alcohol intake was 120 g/day. He had a history of epilepsy and asthma for which he was taking prednisolone 5 mg for the past 2 years. For asthma attacks he would take a maximum dose of 10 mg; no steroid pulse therapy was used. He smoked 10 cigarettes/day, and his physical information was as follows: height, 176 cm; weight, 62 kg; and body mass index (BMI), 20.02. His occupation was a server in the food service industry.

The preoperative visual analog scale (VAS) scores were 90 mm on both sides [11], and the Japanese Hip Society Hip Evaluation Questionnaire (JHEQ) scores for pain, function, and mental state were 0/0, 3/3, and 28, respectively, for a total of 31/31 out of 84 points [12].

Preoperative plan

Computed tomography (CT) images from the patient's iliac crest to the femoral condyle were taken with a 1.5-mm slice, and the images were imported into the Stryker OrthoMap® 3D navigation system. The necrotic area was identified and painted over using the necrotic area of the MRI image as a reference (Fig. 2a), the neck axis was identified in coronal, transverse and sagittal sections of the hip joint (Fig. 2b), a plane perpendicular to the axis

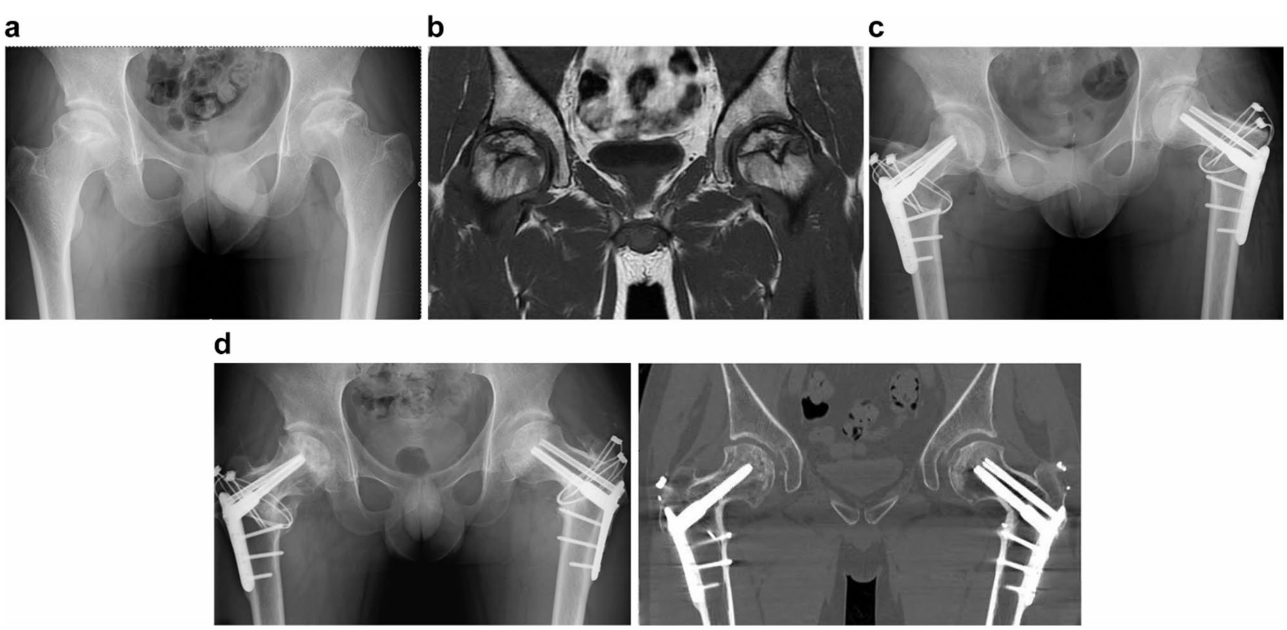

Fig. 1 **a**. Preoperative X-ray. Frontal view of both hip joints Japanese Investigation Committee Classification Type C 2/C2 Stage 3b/3b. **b**. Preoperative magnetic resonance imaging. Central slice of the femoral head. **c**. Immediately after surgery. Surgery time: Total 3 h30 m. Blood loss: 310 ml. **d**. Frontal view and computed tomography coronal section of both hips 1.5 year post-op. Joints preserved. Intact ratio on the right and left improved from 0–51% and 0–47%, respectively

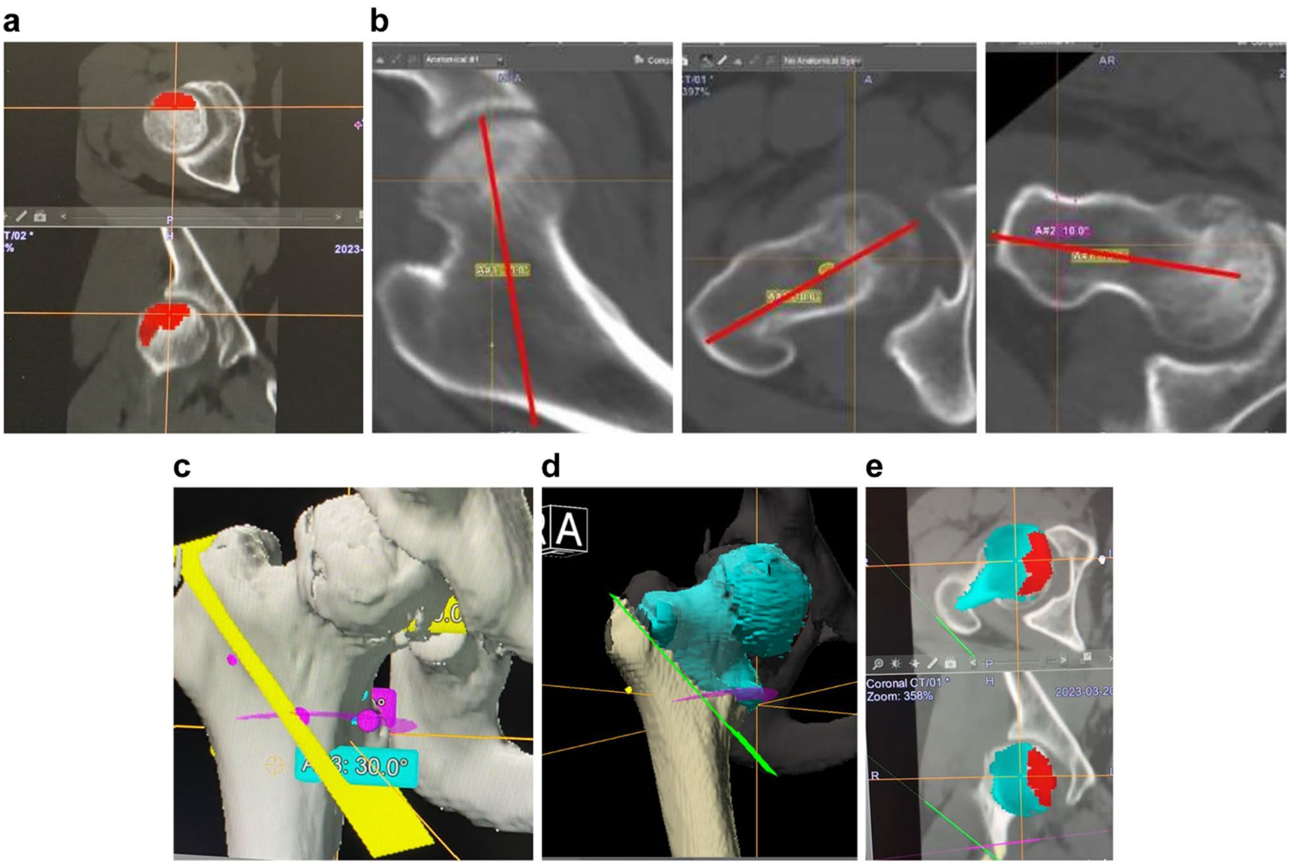

Fig. 2 **a**. Computed tomography image is imported into navi, and the necrotic areas are filled in red with reference to the necrotic areas on the magnetic resonance imaging. **b**. Identifying the cervical axis using coronal, transverse, and sagittal sections of the computed tomography. **c**. Creating a plane perpendicular to the cervical axis. **d**. Scheduled posterior rotation in a plane taking into account the varus component. **e**. The patient was considered eligible for the procedure if at least 40% of sufficient intact area at rest could be achieved in the coronal slice of the femoral head center in the simulation

was created (Fig. 2c), the osteotomy plane was adjusted to prevent the anteversion angle from changing when applying internal rotation using Sugioka's method [13], and the osteotomy plane was then adjusted on the plane, and a high degree of backward rotation was applied (Fig. 2d). About 40% or more intact postoperative load area obtained in the central slice of the simulated bone head (Fig. 2e) was considered as an indication [14].

Surgical procedure

Starting from the right

Under general anesthesia and in the full left lower lateral recumbent position, two NAV Ortholock EXPins were inserted into the distal femur. The Patient Tracker was attached, and it was checked that it was working when the affected limb was rotated in and out (Fig. 3a).

Skin incision (20 cm) with a modified Southern approach

1. The posterior short external rotator muscle group was separated 1 cm from the attachment site of the greater trochanter. The gluteus medius and minimus muscles were detached from the joint capsule, with the affected limb in extension and internal rotaFig. (Fig. 3b).
2. To expose the posteroinferior joint capsule, 1/3 of the quadratus femoris muscle was separated, and the external obturator muscle beneath it was elevated and separated. Hip extension and internal rotation made the procedure eaFig. (Fig. 3c).
3. Registration "Point Matching" seven points were predetermined. We took seven points in the following order: top of the greater trochanter, back of the greater trochanter, middle of the intertrochanter, lesser trochanter, innominate tubercle of the greater trochanter, lateral femoral condyle, and medial femoral condyle. If the average error was 2–3 mm, the process would move on to "surface matchinFig. Fig. 3d. In "surface matching," about 50 points with a deviation within 1 mm were considered acceptFig. (Fig. 3e).
4. To perform the greater trochanter osteotomy, the anterior border of the gluteus medius and vastus

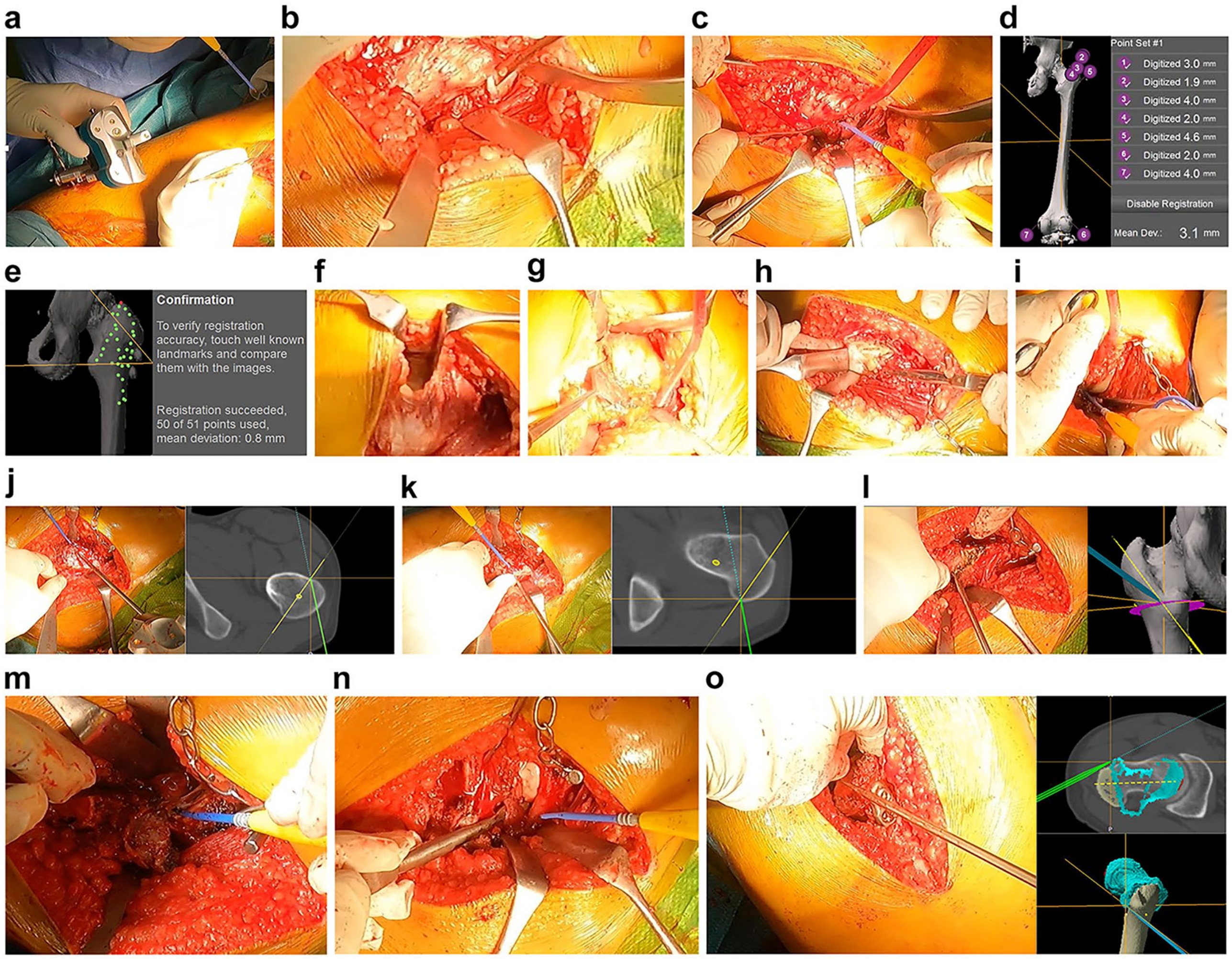

Fig. 3 **a**. Two NAV Ortholock EXPins are inserted into the distal femur and the Patient Tracker is attached. **b**. The piriformis muscle is elevated with the elevatorium, and the short external rotator muscle group is separated from the attachment site of the greater trochanter by 1 cm. **c**. The external obturator muscle is drawn from behind the quadratus femoris and dissected. Expanding below the joint. **d**. Point matching. Seven points are determined in advance and matched by pointer until deviation of about 3 mm. **e**. Surface matching. Aligned to a deviation of less than 1 mm. **f**. The lower leg is externally flexed, separating the gluteus medius and vastus lateralis. **g**. The osteotomy of the greater trochanter, anteriorly thickening the osteotomy to preserve the gluteus medius. **h**. The lower limb is internally rotated and extended, the lesser trochanter is expanded, and the iliopsoas tendon attached anteriorly to the lesser trochanter is drawn and detached by elevating with the elevatorium. **i**. Circumferential incision from the top of the joint capsule to its almost full circumference. **j**. Setting the osteotomy plane. Marking the anterior part of the greater trochanter. **k**. Marking the posterior part of the greater trochanter. **l**. Marking the part of lesser trochanter. **m**. The central bone fragment is rotated posteriorly while the soft tissue and ligaments are dissected to the medial side of the neck. **n**. The central bone fragment is rotated anteriorly, and the residual external obturator muscle is dissected. **o**. The consistency of the simulated central bone fragments is checked by using a pointer to confirm that the rotation and varus are applied as planned

lateralis were exposed, and the lower extremity was held in flexion-external rotaFig. (Fig. 3f).

5. Osteotomy of the greater trochanter. To avoid vascular injury and ensure that the chisel does not penetrate the intertrochanteric crest while also preserving the gluteus medius, a thicker anterior osteotomy was made and externally rotated, starting distally in Fig. 3g. The elevatorium used to expand the anterior joint capsule was expanded between the anteroinferior joint capsule and the iliopsoas muscle. The vastus lateralis muscle was detached from the femur at the point where its anterior osteotomy line entered. The lower limb should be held in a flexed external rotation position.
6. Internal rotation and extension of the lower extremity, adductors extended and elevated with elevatorium, and the iliopsoas tendon were separFig. (Fig. 3h).
7. Circular incisions were made from the joint capsule top. Posteriorly, the posterior descent was performed in the extended internal rotation position and anteriorly in the flexed external rotation posiFig. (Fig. 3i).

8. Establishment of osteotomy plane. Three points were identified with a pointer (anterior to the greater trochanter, (Fig. 3j), posterior to the greater trochanter, (Fig. 3k), and at the lesser trochanter (Fig. 3l)), and the osteotomy line was determined. Osteotomy was performed using a bone saw.
9. A 3-mm K-wire was inserted anteriorly into the central fragment, which was rotated posteriorly to dissect the joint capsule from the medial side of the neck. Once the lower frontal area has been dissected, high-degree posterior rotation is made instantly possFig. (Fig. 3m).
10. Next, a 3.0-mm K-wire was inserted posteriorly into the central fragment and rotated anteriorly, and the remaining external obturator was remFig. (Fig. 3n). It took 40–50 min to reach this point.
11. The central fragment was rotated posteriorly again to check its alignment with the simulated bone fragmFig. (Fig. 3o).
12. Fixed with Compression Hip Screw (F-system: MIZUHO CO). The surgery was completed with additional sutures. The patient was returned to the supine and right lower lateral positions. The same was done for the left side.

Surgery was performed for the right (120° HDPRO 20° Varus, 1 h 50 min of operation time, blood loss 160 ml) and left lip (120° HDPRO 20° Varus, 1 h 40 min of operation time, blood loss 190 ml), followed by postoperative X-ray (Fig. 1c).

Postoperative treatment began with 1/4 partial weight bearing (PWB) at 4 weeks postoperatively, increasing the load every week. The patient was on 2/3 PWB at 7 weeks postoperatively and discharged with bilateral Lofstrand canes at 55 days postoperatively. Six months after surgery, the X-rays and CT showed good bone union, and full weight bearing was allowed. At 8 months postoperatively, he returned to work as a server in the food service industry. There was no evidence of recollapse or osteoarthritis (OA) changes on imaging at 1.5 years postoperatively (Fig. 1d). The femoral anteversion angle was measured using the SYNAPSE VINCENT 3D Image Analysis System. Considering the deformation of the proximal part of the femur due to osteotomy, the angle was measured at four points: two points at the center of the femoral head as proximal as possible to make a circular shape of the femur and two points on the posterior malleolus of the medial and lateral femur as the reference plane. Neither the right nor left sides showed significant changes from 11° preoperatively to 15° postoperatively and from 21° preoperatively to 22° postoperatively, respectively. The postoperative intact ratio was measured using the Miyanishi method [14]. The right and left femurs improved from 0% preoperatively to 51% postoperatively and from 0% preoperatively to 47% postoperatively, respectively. Although the patient had some claudication, he could still work standing up one and a half years after the surgery. At the last postoperative follow-up one and a half years after surgery, the JHEQ score and VAS were 12 mm. His pain, function, and mental scores were 23/23, 8/8, and 28, respectively, for a total of 59/59 points. A perfect score, especially for pain, and other scores also show a trend toward improvement. The preoperative range of motion was 90° in flexion and 120° postoperatively (Table 1).

Table 1 Japanese orthopedic association hip disease evaluation questionnaire and range of motion: preoperative and last observation

	Preoperative (*R*/L)	At 1.5 year post-operative last observation (*R*/L)
Visual analog scale (mm)	90	12
Pain	0/0	23/23
Function	3/3	8/8
Mental	28	28
Total (Total)	31/31 (out of 84 points)	59/59 (out of 84 points)
Flexion (°)	90/90	120/120

Discussion and conclusions

ONFH with extensive necrosis causes early crushing, and 80% are catastrophic within 2 years [15]. It is also said that more than half of ONFH is bilateral, and 70% is steroid-induced [16]. Joint-preserving surgery is desired as much as possible since it frequently affects people in their 20–40 s. Current Joint-preserving procedures include core decompression (CD) [17] and proximal femoral osteotomy, but in CD, the benefits are limited to small areas [18]. For younger patients with extensive necrosis, an osteotomy that moves the necrotic area to a non-weight-bearing area as early as possible is desirable.

Currently, the main osteotomy techniques for ONFH are curved varus osteotomy (CVO) [19] and TRO. Lee et al. compared the two procedures and reported that CVO has a shorter operation time, less bleeding, a lower incidence of osteophyte formation, and a lower rate of secondary collapse [20]. The indications for CVO are relatively narrow, such as for JIC Type B and C1. We developed a surgical navigation technique to perform a spherical varus osteotomy at the intertrochanteric region, which we named spherical varus rotational osteotomy (SVRO), expanding the indication to Type C2 [21]. However, TRO is necessary in cases where necrosis is more extensive, and SVRO cannot secure a healthy load-bearing area of over 40%.

TRO was first published in 1978 [1] and is an excellent technique performed for a wide range of ONFH in young patients, such as JIC Types C1 and C2. In recent years, however, the number of THA conversions has been declining, even in Japan, due to the increased life expectancy of THA, the many complications associated with THA conversion after TRO surgery, and, above all, the long hospital stays and long rehabilitation periods required [6]. Clinical outcomes vary from facility to facility, and it is a technically demanding procedure. The number of cases of TRO and CVO [19] that have been performed in East Asia is decreasing every year [22], which has further reduced the opportunities to learn osteotomy [23]. Clinical outcomes are uncertain due to the complexity of setting the osteotomy angle and soft tissue exposure that minimizes vascular injury. In a systematic review of osteotomies for ONFH, Quaranta et al. found that the conversion rate to THA was 31.5%, and the average bone preservation time from osteotomy to THA was 7.6 years [24]. Surgical techniques need to be disseminated, and the duration of hip preservation needs to be improved. It is not enough for one surgeon to understand this technique for soft tissue exposure; at least two assistants, including a foot holder, need to understand this technique to perform a routine operation, thus decreasing operating time and surgical invasiveness and avoiding vascular injury as much as possible.

Although with the advent of highly cross-linked polyethylene, good long-term results for THA < 55 years of age are now possible [25], the rates of revision surgery, periprosthetic fracture, and periprosthetic joint infection after total hip replacement in ONFH are significantly higher than those in OA [26]. Furthermore, THA outcomes in those < 40 years of age are poor both in the short and long term [27, 28]. Therefore, joint-preserving surgery is preferable for patients in their 20s and 30s.

The preoperative torsion angle is important in determining the osteotomy plane in TRO. In the original method, the osteotomy plane was determined with respect to the malleolar axis through intraoperative radiographs. Sonoda et al. approximated the postoperative cervical body angle and anteversion angle by the vertically-inclined degree of anteroposterior (AP)-view line, the posteriorly-tilted degree of lateral-view line, and the preoperative femoral anteversion, and the postoperative femoral anteversion using vertically-inclined degree of AP-view line and posteriorly-tilted degree of lateral-view line [29]. PRO has also made approximations to determine the postoperative cervical body angle and anteversion angle for each angle of posterior rotation, but it is difficult to control the osteotomy line with the same accuracy as the intraoperative simulation software [30]. Atsumi et al. thought that osteotomy based on the malleolar axis was impossible and used intraoperative fluoroscopy to determine the osteotomy plane centered on the cervical axis. However, intraoperative assessment of the anteversion angle with X-rays is considered inappropriate because the X-ray image is only a projection image; there are limitations in detecting the cervical axis using single plane radiography, lack of reproducibility, and landmark mismatch [7]. Since the 3D hip joint is evaluated in two dimensions, errors are made, and even if accurate preoperative simulations are performed, errors are made in the anteversion and internal rotation angles, which require correction and additional osteotomies, resulting in an increase in operating time and surgical invasiveness. From 2021 to the present, about 30 TROs have been performed using navigation, none of which to date have required additional osteotomies.

The application of computer-assisted surgery (CAS) to orthopedic surgery has been remarkable in recent years, and many papers have demonstrated its effectiveness in acetabular osteotomy [31–33]. It has also been reported on the femoral side, although in smaller numbers [34–36]. Takao et al. describe precise proximal femoral osteotomies using CT-based navigation, with angular osteotomy error within 5° and position error within 4 mm [34]. In a systematic review of osteotomies for developmental dysplasia of the hip, Liu et al. found that navigation-assisted techniques in pediatric hip osteotomies enhance surgical precision, reduce operation times, and minimize radiation exposure, thereby improving overall surgical outcomes, suggesting that clinical outcomes of hip osteotomies can be improved through 3D navigation [37].

In this study, we used CAS to reduce the invasiveness of the surgery, enabling bilateral same-day surgery, reducing the hospital stay from 6 months to 2 months, and allowing the patient to return to work on his feet in 8 months. For patients of working age, the use of CAS and our surgical teams should work together to reduce as much leave from work as possible for the surgery. Currently, patients in office work can return to work 3 months after surgery.

TRO is not a difficult procedure if the osteotomy plane is determined as per the preoperative plan using a 3D navigation system, and routine soft tissue exposure is possible. As a future issue, tracing osteotomized central bone fragments is currently impossible, and improvements in this area are desired.

The use of a 3D navigation system significantly enhances the precision of TRO, potentially transforming this technically demanding procedure into a more standardized and minimally invasive operation. By entrusting the determination of the osteotomy lines to the navigation system, surgeons can fully concentrate on soft tissue management. This technological advancement streamlines the surgical process and reinforces the importance of maintaining essential surgical skills. Looking ahead, further advancements in navigation technology promise to improve outcomes in complex orthopedic surgeries.

Abbreviations

TRO	Transtrochanteric Rotational Osteotomy
JIC	Japanese Investigation Committee Classification
CAS	Computer-Assisted Surgery
ONFH	Osteonecrosis of the Femoral Head
OA	Osteoarthritis
ARO	Anterior Rotational Osteotomy
HDPRO	High-degree posterior rotational osteotomy
JHEQ	Japanese Hip Society Hip Evaluation Questionnaire
HXLPE	Highly Cross-Linked Polyethylene
CD	Core Decompression
CT	Computed Tomography
MRI	Magnetic Resonance imaging
THA	Total Hip Arthroplasty
CVO	Curved Varus Osteotomy
COC	Ceramic-on-Ceramic
COP	Ceramic-on-Polyethylene
PWB	Partial Weight Bearing
VAS	Visual Analog Scale
SVRO	Spherical Varus Rotational Osteotomy

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Author contributions
M.W. conceived and designed the analysis; I.K. and S.K. collected the data; D.K. contributed data/analysis tools; T.I. and K.K performed the analysis; and M. Watanabe wrote the paper. All authors have read and approved the final version of the manuscript.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Ethical approval was not required for this study. Informed consent for publication of this case report was obtained verbally from the patient prior to submission.

Consent for publication
Written informed consent was obtained from a participant for the publication of this study.

Competing interests
The authors declare no competing interests.

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