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Robotic-assisted Conversion of Arthrodesis to Primary Total Knee Arthroplasty

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A B S T R A C T

Conversion of arthrodesis to total knee arthroplasty (TKA) is technically demanding surgical procedure. In the literature, most cases are treated with stemmed semi-constrained or hinged prostheses. We present a case of a robotic-assisted conversion of arthrodesis to primary TKA (rTKA) in a 35-year-old patient using a non-constrained posterior stabilized implant. At follow-up, the patient reported outcomes improved remarkably with the highest increase for function and activities of daily living and a substantial improvement of health-related quality of life. This article is the first report of robotic-assisted conversion of arthrodesis to TKA using a non-constrained implant, thus it may serve as a proof of concept for the use of robotics for desarthrodesis. Future studies are warranted to investigate the long-term outcomes in a larger patient cohort.

Introduction

Knee arthrodesis is a limb salvage procedure and was initially described by Nelson and Evarts as a treatment option for failed total knee arthroplasty (TKA) [1]. The most common indication is a failed, unrevisable TKA due to periprosthetic joint infection (PJI), the presence of severe bone loss, severe ligament instabilities, compromised soft tissue structures and inadequate skin coverage, extensor mechanism deficiencies, or the patient's refusal of a revision arthroplasty [2-4]. Additional indications include septic arthritis or tumor resections.

Arthrodesis is an effective procedure which relieves pain, provides stability, and can improve mobility. Evidence from the current literature indicates that the postoperative functional outcomes of knee fusion are superior to above-the-knee amputations [5-8]. Despite that, knee arthrodesis is associated with major functional limitations, which are associated with compromised patient-reported outcome measures (PROMs) due to severe limitations in activities of daily living and a reduced quality of life [9]. Dissatisfaction with the functional outcome may lead to the desire for an alternative treatment option.

Conversion of knee arthrodesis to TKA is a rare and technically demanding surgical procedure. Current evidence on the indications, surgical procedure, and outcomes is limited to few published case series. In the literature, most cases were treated with stemmed semi-constrained or hinged prostheses to compensate for collateral ligament deficiencies [10-13]. However, especially younger patients have a high lifetime risk of revision [14], which constitutes a challenge for subsequent surgical procedures as implant removal of long cemented stems may result in severe bone loss [15].

In this case report, we report 1 case of robotic-assisted conversion of a fused knee to TKA using a posterior-stabilized (PS), primary total knee system.

Case history

A 35-year-old Caucasian male patient presented to our outpatient clinic with a fusion of his left knee. At the age of 12 years, he fell and suffered a penetrating knee injury classified as type I according to Collins and Temple [16]. A subsequent native knee infection was treated with multiple surgical interventions including debridement and irrigation with antibiotic therapy over 6 months. Ultimately, he underwent tibio-femoral contact arthrodesis.

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Clinical presentation

At the initial presentation, the patient reported major limitations in activities of daily living due to knee and thigh pain, the stiffness, and consecutive gait disorder. He further complained about a lack of participation in social life due to his disability and restrictions in working life.

Despite the knee fusion, there was no history of concomitant illnesses or surgeries, and he had no oral medication.

On physical examination, we saw a normal-weight patient with a body mass index of 32.7 m/kg^2 (height 180 cm, weight 106 kg), who was classified as American Society of Anesthesiologists 1.

His gait examination revealed severe limping; however, no walking aids were needed. The lower extremity showed a mild valgus alignment. Inspection revealed a mild asymmetry of the quadriceps muscle, but no muscle atrophy. Tone, consistency, and static contractility were tested.

Two well-healed surgical scars were evident: 1 medial approach comparable to a midvastus approach and 1 lateral approach. There were no clinical signs of infection and no joint effusion. The knee was fused in 30° of flexion. No pathologies of the extensor mechanism were evident. The patella showed a normal orientation, patellar mobility was normal, and there was no patellofemoral pain during examination. While the patient did not report pain at rest, he experienced considerable pain in his left knee and thigh at exertion, especially walking more than 15-20 minutes and standing more than 30 minutes.

The preoperative Knee Society Scores (KSSs) were 25 (objective knee score), 28 (function), 0 (patient satisfaction), and 13 (patient expectations), which equals a poor functional state [17]. Preoperative PROMs are presented in Table 1.

Radiological imaging modalities included bilateral standing weight bearing long leg view, anteroposterior and lateral radiographs of the knee, merchant view for the patella, and additional computed tomography (CT) and magnetic resonance imaging (MRI) scans.

The preoperative radiographs and CT scan showed the healed knee fusion, but no ankylosis of the patella (Figs. 1-3). In the MRI scans, the collateral ligaments were intact. Furthermore, the lateral femoral condyle and parts of the joint space were still definable (Fig. 4).

Due to the history of native joint infection, the preoperative diagnostic tests included laboratory evaluation of inflammatory markers (serum C-reactive protein and white blood cell count) and preoperative joint aspiration for microbiological culture, which yielded negative results.

Preoperative considerations

In view of the aforementioned clinical and radiological findings, and particularly the young age and the patient's high functional demand, a conversion of the arthrodesis to TKA was planned. Two treatment options were extensively discussed with the patient.

The first option was the implantation of a rotating hinge prosthesis due to the potential collateral ligament insufficiency, potential flexion-extension gap imbalance following osteotomy, and the unknown degree of bone loss and bone quality [18]. However, a major drawback of this implant type is the long stems which are associated with severe bone loss in the case of subsequent revision procedures.

The second option was using a nonconstrained implant with PS design with the option to convert to a constrained condylar design. For the PS implant, the postcam mechanism compensates the absence of the cruciate ligaments but requires intact collateral ligaments for mediolateral stability [19]. The constrained condylar design provides a higher varus and valgus stability and can compensate for medial or lateral collateral ligament insufficiencies.

As the status of the soft tissues, especially the extensor mechanism and collateral ligaments was promising in the preoperative MRI scan, we decided for the second option using a primary PS implant.

Written informed consent was obtained prior surgery. The patient gave his written consent for the publication of the case report.

Surgical technique

The patient is placed in supine position. Positioning devices include a lateral support which is placed at the level of the thigh and a leg stabilizer to position the knee in 90° of flexion. At our institution, a pneumatic thigh tourniquet is applied, which is used during cementation.

A knee with multiple previous incisions requires careful incision planning. Previous incisions should be followed whenever possible, and the most lateral scar should be selected to prevent devascularization of the lateral skin flap [20]. The angle between incisions should be more than 60° to minimize the risk of skin necrosis. As the cutaneous blood supply is based on penetrating vessels that travel through the fascia, subcutaneous fat and ultimately reach the

Table 1
Patient-reported outcome measures.

Variables	Preoperatively	6 weeks	6 months	12 months	Δ preoperatively– 12 months
Knee Society Score					
KSS knee score	25	28	32	32	7
KSS function score	28	63	70	75	47
Patient satisfaction	0	32	32	22	22
Patient expectation	13	9	15	9	−4
Oxford Knee Score (OKS)	24	36	36	32	8
Knee Injury and Osteoarthritis Outcome Score (KOOS)					
KOOS pain	36	83	56	69	33
KOOS symptoms	54	68	54	75	21
KOOS ADL	35	85	69	74	39
KOOS sport	15	25	50	45	30
KOOS QoL	19	80	63	75	56
Forgotten Joint Score (FJS-12)	10	40	58	81	71
EQ-5D-5L					
EQ-5D-5L utility value	0.361	0.778	0.864	0.778	-
EQ VAS	60	75	90	90	30

ADL, activities of daily living; EQ-5D-5L, EuroQol-5 Dimensions-5 Levels; KOOS, Knee Injury and Osteoarthritis Outcome Score; KSS, Knee Society Score; QoL, quality of life; VAS, visual analog scale.

Figure 1. Preoperative radiological imaging. (a) Preoperative long leg standing radiographs of the healthy right leg with a constitutional varus alignment of 1.2° (mPTA 85.4°, lDFA 86.6°, aHKA 1.2° varus), (b) preoperative long leg left knee with knee fusion and secondary valgus deformity, (c, d) preoperative anteroposterior and lateral view of the knee, and (e) patella skyline view.

epidermis, it is crucial to preserve the plane between subcutaneous tissue and fascia [21]. Safely obtaining adequate exposure is an integral step for the success of the surgery. In general, the medial parapatellar incision is an excellent extensile approach to the knee, distal femur, and proximal tibia. A quadriceps snip may be performed if adequate exposure is not achieved with medial parapatellar arthrotomy [21].

In the presented case, the surgery was performed by the senior author (M. E.) using an imageless robotic system (CORI, Smith and Nephew, Memphis, TN, USA). Before incision, the robot was set up including procedure selection, calibration of the robotic handpiece, and burr check-up. The previous midline incision was modified and followed by a standard medial parapatellar arthrotomy.

Figure 2. Preoperative CT scan. (a) Coronal, (b) sagittal, and (c) axial reconstructions of the left knee showing the healed knee fusion in the coronal and sagittal plane, but no ankylosis of the patella. CT, computed tomography.

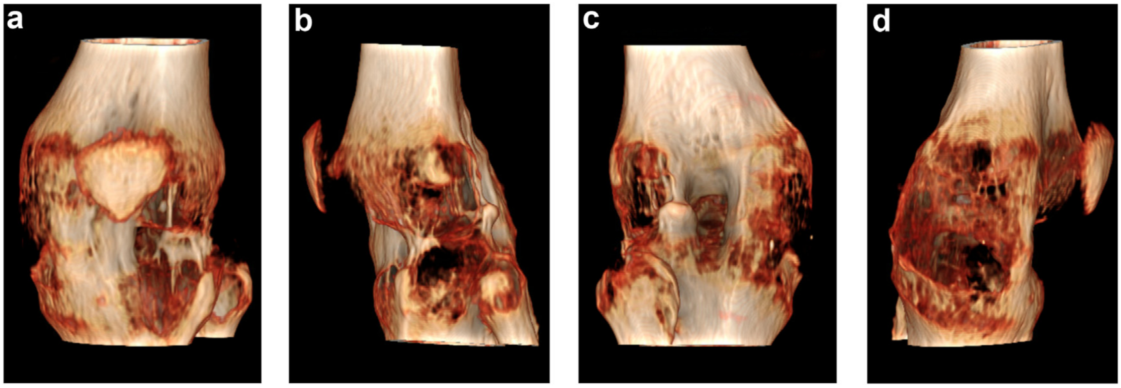

Figure 3. Three-dimensional reconstruction of the preoperative CT scan. The figure provides the (a) ventral, (b) lateral, (c) dorsal, and (d) medial view of the left knee. CT, computed tomography.

First, an extensive synovectomy is performed, removing all fibrous adhesions from the medial and lateral gutters, the suprapatellar pouch, and peripatellar tissue. To improve exposure, a subperiosteal dissection of the medial capsule and the deep layer of the medial collateral ligament are performed. To safely mobilize the extensor mechanism, fibrous adhesions between the patellar tendon and anterolateral tibia are defined and released carefully. A partial excision of the infrapatellar fat pad facilitates the exposure of the tibia.

According to the international clinical practice guidelines for PJI, 5 intraoperative samples were taken for microbiological cultures and histopathological analyses [22].

The level of the osteotomy is crucial for an anatomical restoration of the joint line, and the reconstruction of joint line height is directly linked to the postoperative functional outcome. In revision TKA, the old meniscal scar, the medial epicondyle, the adductor tubercle, and the fibular head serve as anatomical landmarks for the assessment of joint line height. However, in cases with severe deformities, a correct identification of anatomical landmarks may constitute a major challenge. In cases with previous knee fusion, the inferior pole of the patella is not considered a reliable landmark to determine the femorotibial joint line. In this present case, the fibular head and the partially preserved cartilage at the lateral femoral condyle were considered the best references and were therefore chosen to determine the joint line height and the level of the osteotomy.

Osteotomy of the tibiofemoral fusion is performed using an oscillating saw and is completed with an osteotome. At this point, the tibia can be rotated externally to improve exposure and to reduce tension on the extensor mechanism. Lateral subluxation of the patella is preferred over eversion to avoid extensor mechanism injury. Patellar osteophytes were removed, and a patellar denervation was performed. Intraoperative examination of patellar tracking revealed a maltracking with a lateral patellar shift. This was addressed by a lateral facetectomy and lateral retinaculum release.

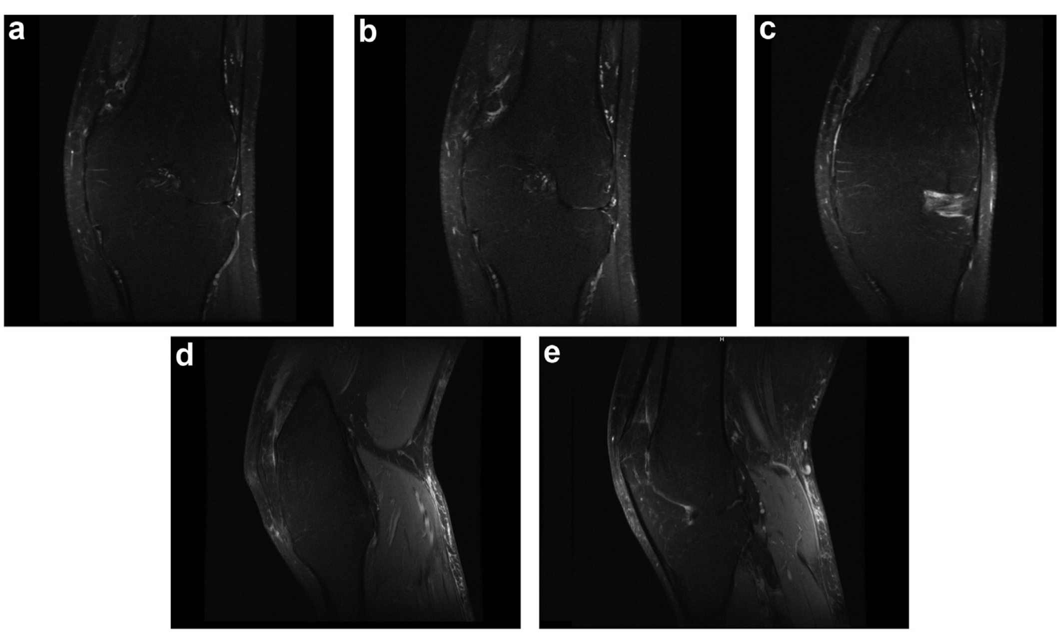

Figure 4. Preoperative MRI scan. (a-c) Representative coronal reconstructions show the healed knee fusion on the medial site, partially preserved cartilage of the lateral femoral condyle and posterior tibial plateau, and intact collateral ligaments. (d, e) Sagittal reconstructions show the preserved quadriceps and patellar tendon. MRI, magnetic resonance imaging.

In the next step, the bone defect should be assessed according to the modified Anderson Orthopaedic Research Institute classification [23]. Large defects may require additive treatment options such as impaction bone grafting, bone cement, modular stems, or metaphyseal filling devices [15]. The bone defect was classified as Anderson Orthopaedic Research Institute Type F1-T1, the collateral ligaments were intact, and there was no mediolateral instability. Based on these intraoperative findings, the implant choice was a primary, bi-cruciate-stabilized prosthesis (Journey II BCS, Smith and Nephew, Memphis, TN, USA).

Next, the femoral and tibial pins and arrays were placed. The calibration of the robotic system was performed which includes the definition of the hip and knee center and the registration of the range of motion according to the developer's standard. As it is an imageless system, the bony surface was registered using the robotic handpiece to generate the 3-dimensional model of the joint and deformity (Fig. 5). In the subsequent steps, the range of motion is registered from full extension to deep flexion and the soft tissue tension is registered using spacer blocks to apply adequate varus and valgus stress. Assessment of the soft tissue balance in full extension (0°) and 90° of flexion is crucial for the planned soft tissue balance when it comes to component positioning.

For implant positioning, the goal was to reconstruct the native joint line height and joint line obliquity. As the lateral femoral condyle was preserved partially, it served as a reference. Additionally, the constitutional varus alignment of the contralateral healthy knee (medial proximal tibial angle (mPTA) 85.4°, lateral distal femoral angle (lDFA) 86.6°, arithmetic hip-knee-ankle angle (aHKA) −1.2° varus alignment) was taken into consideration.

The alignment of the femoral component is planned using the virtual, 3-dimensional planning software of the robotic system following the functional alignment principles [24]. After validation of the surgical plan, the execution was performed in a hybrid technique. The distal cut was conducted with the semi-autonomic burr and the following femoral cuts were performed using the 5-in-1 cutting block. The plane of the planned tibial cut was verified using the robotic system and then conducted using the tibial cutting block. No soft tissue releases were necessary. After testing with the trial components and a 9-mm inlay, the original implants were cemented. The final registration with the robotic system confirmed the precise execution of the surgical plan, balanced extension and flexion gaps, and perfect ligament balance over the full range of motion. Intraoperatively, the range of motion was 0°-150° of flexion.

A closed suction drain was placed and was removed on the first postoperative day.

Postoperative care regimen

Postoperatively, the patient was allowed immediate full weight-bearing according to the standard protocol for primary TKA procedures. During inpatient hospital stay, he received intensive physiotherapy and continuous passive motion treatment. The postoperative X-rays confirmed the correct implant position with a neutral alignment (mPTA 89.4°, lDFA 89.1°, aHKA −0.3°) (Fig. 6). The intraoperative samples were negative for bacterial and fungal pathogens.

The patient was discharged 9 days postoperatively with an active range of motion of 0-0-70°.

Postoperative outcome

Clinical and radiological follow-up visits were scheduled 6 weeks, 6 months, and 12 months postoperatively.

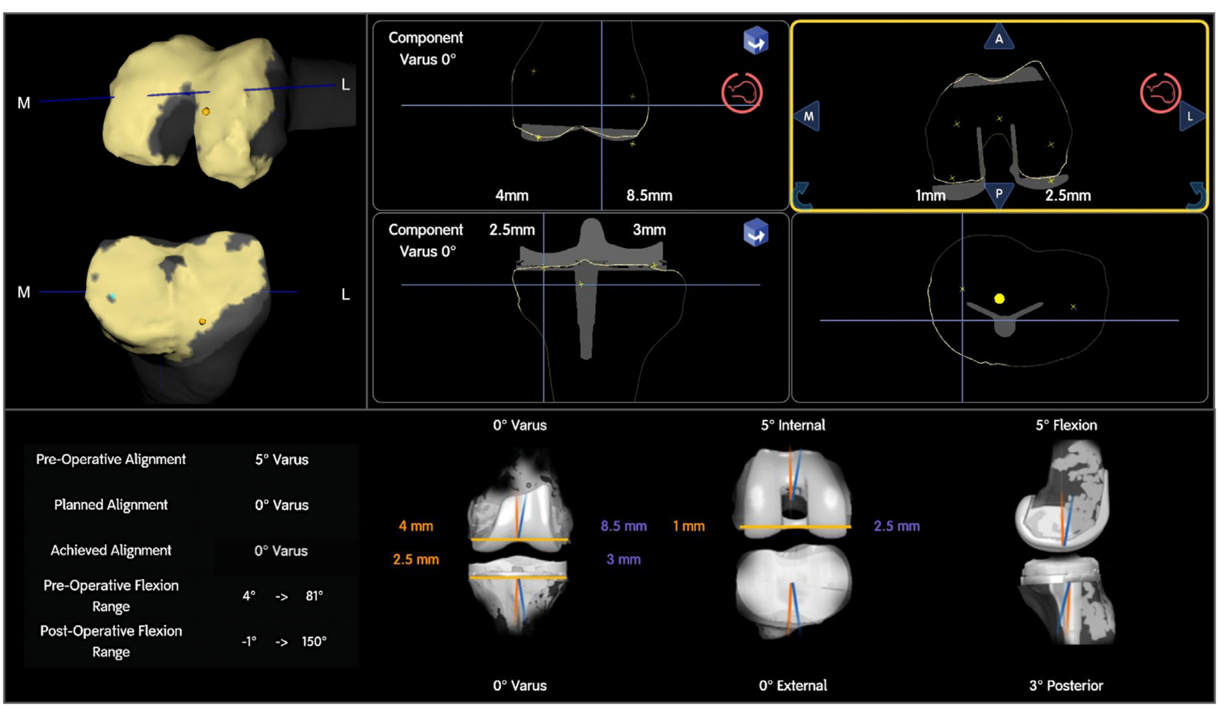

Figure 5. Intraoperative 3-dimensional implant planning using the Cori imageless robotic system. Upper row: 3-dimensional models of femur and tibia following osteotomy of the arthrodesis, planning screen visualizing the position of the femoral and tibial components. Lower row: the postoperative results show the achieved neutral alignment. Intraoperatively, the range of motion was 0°-150° of flexion.

Figure 6. Postoperative radiographs. (a) Postoperative long leg standing radiograph with a neutral alignment (mPTA 89.4°, lDFA 89.1°, aHKA −0.3°), (b, c) postoperative anteroposterior and lateral view of the knee, and (d) patella skyline view.

Clinical examination revealed irritation-free wound and soft tissue conditions, without clinical signs of infection. There was no mediolateral or anteroposterior instability. Postoperative range of motion was 0-10-50° for extension/flexion at 6 weeks, 0-5-65° at 6 months, and 0-10-70° at 12 months postoperatively. Patella tracking was physiological. Straight leg raise was possible and Janda score for muscle strength was 5/5 for knee extension.

PROMs were obtained preoperatively, and 6 weeks, 6 months, and 12 months postoperatively (Table 1, Fig. 7). All KSS subscales revealed a postoperative improvement. The KSS knee score improved from 25 preoperatively to 32 at the latest follow-up. KSS function score showed a substantial improvement from 28 preoperatively to 75 at 12 months postoperatively. The Knee Injury and Osteoarthritis Outcome Score subscales showed substantial improvements regarding pain (Δpreoperatively-12 months: +33), activities of daily living (Δpreoperatively-12 months: +39), and quality of life (Δpreoperatively-12 months: +56). In line with that finding, the EuroQol-5 Dimensions-5 Levels utility values improved from 0.361 preoperatively to 0.778 at 12 months postoperatively. The Forgotten Joint Score-12 improved from 10 preoperatively to 81 at the latest follow-up.

The x-rays obtained at the follow-up visits did not reveal any radiolucent lines, other radiological signs of loosening, or implant failure.

The patient was highly pleased by postoperative outcome with subjective improvement of knee function, participation in daily life, and re-engaging in sports activities.

Discussion

Conversion of knee arthrodesis to TKA is a rare and challenging surgical procedure. The surgical technique is crucial for the success of the surgery. However, the small number of cases which have been published in the literature and the heterogeneity of the patient population and underlying medical conditions make consistent recommendations for the surgical procedure, implant choice, and alignment strategy difficult.

Preoperative planning and surgical technique

Preoperative workup should involve detailed history taking, clinical examination, and radiological imaging including x-rays and additive CT or MRI imaging. Another factor that is of utmost importance is the patient's motivation and expectation. An

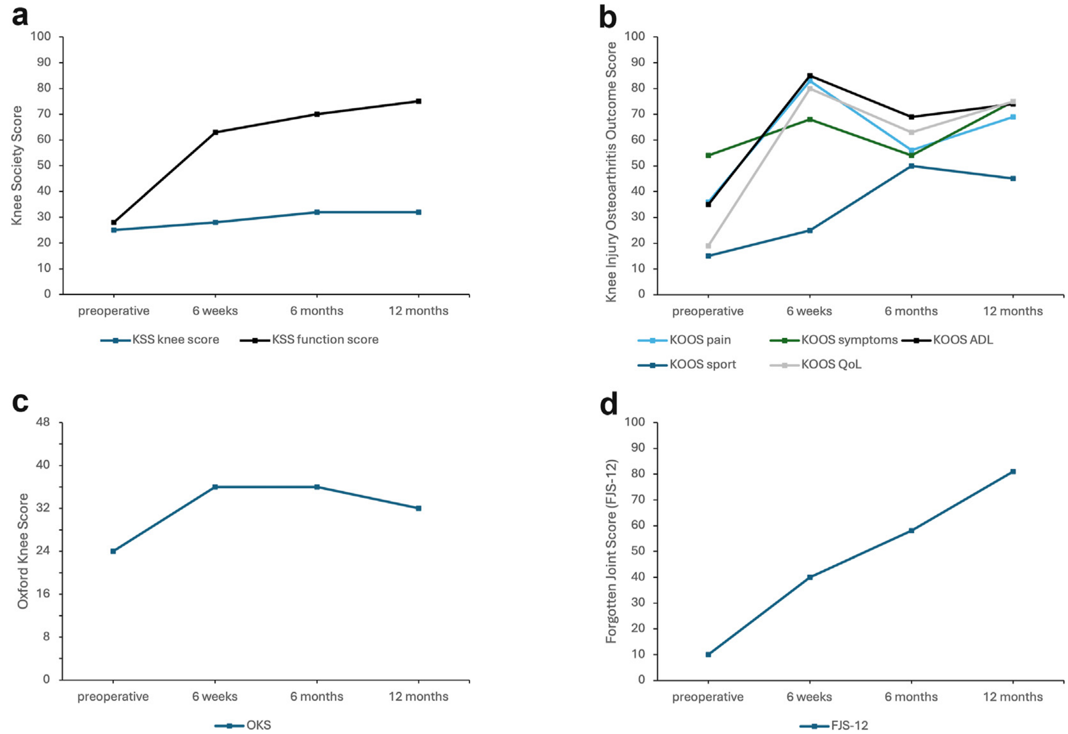

Figure 7. Changes of patient-reported outcome measures plotted over time. (a) Knee Society Score, (b) Knee Injury Osteoarthritis Outcome Score, (c) Oxford Knee Score, and (d) Forgotten Joint Score (FJS-12).

extensive discussion of potential risks and benefits ensures the best possible patient education and realistic expectations [25].

Consensus is that osteotomy should be performed carefully with attention given to preserve as much bone stock as possible and that careful soft-tissue dissection is crucial for the preservation of the medial and lateral collateral ligaments and soft tissue sleeves. Surgical techniques include V-Y quadricepsplasty to address quadriceps contractures [26,27], soft tissue expansion [10,11,28], gastrocnemius flap [10,13], and ligament bracing [11]. For the reconstruction of patellofemoral kinetics, additional surgical steps include patellar osteotomy in cases with patellar fusion with or without subsequent patellar resurfacing [10,11,13,29], patellar thinning [10], lateral patellar release [10], and tibial tubercle osteotomy [10,11,27,29].

In the literature, different implant designs were used including nonconstrained PS implants, semi-constrained or hinged prostheses, and megaprostheses (Table 2). Of note, it has to be mentioned that in some cases declared as nonconstrained PS implants, stemmed femoral and/or tibial components were used [13].

The goal of TKA is the reconstruction of the constitutional lower limb alignment, the restoration of joint line height and joint line obliquity, and the restoration of physiological joint kinematics with a balanced flexion and extension gap. When it comes to TKA in surgically complex cases such as a fused knee, these surgical steps pose major challenges, as the anatomical references are distorted, and soft tissues are compromised. The use of conventional intramedullary rods may be complicated by extra-articular deformities or sclerosis of the femoral canal [36,37]. Moreover, altered anatomic landmarks may compromise intraoperative orientation and can impair correct implant positioning. In the literature, a proximalization of the joint line is reported in up to 50% of the cases in revision TKA [38], which is associated with midflexion instability and impaired clinical outcomes [39]. In addition to that, in conventional manual TKA, the transepicondylar axis serves as an anatomic landmark for the rotation of the femoral component. The altered bony anatomy following knee fusion may lead to malpositioning of the femoral component, which ultimately results in altered patellofemoral kinematics and patellofemoral instability as well as a nonanatomic reconstruction of the posterior condylar offset associated with limited range of motion [40,41].

In the conversion of knee fusion to TKA, ligament balancing represents a severe challenge and often requires extensive soft tissue releases. In these cases, surgeons may choose varus/valgus constrained prostheses. However, 1 major drawback of higher constrained prostheses—especially revision or hinged prostheses with long cemented stems—is the bone loss associated with subsequent revision procedures [15]. This is of high clinical relevance in the subgroup of patients aged 50 years and less, as studies report a lifetime risk of revision of 20% [14].

In the presented case, robotic-assisted conversion of the knee arthrodesis to TKA was performed. The advantages of the robotic system include the 3-dimensional visualization of the bony anatomy, deformity, and objective soft tissue information. The virtual planning software enables for the intraoperative real-time simulation of component placement in all 3 planes. This allows for the simultaneous assessment of the reconstruction of the constitutional limb alignment and joint line orientation, the reconstruction of the patellofemoral joint, and the effect of component placement on ligament balance in extension and flexion. The virtual planning adds value to complex cases, as gap balance is simulated before any additional bone cuts are performed ("precut balancing plan"). In addition to that, the rotation of the femoral component can be adjusted to match the native trochlear groove to prevent patellofemoral instability (Fig. 5).

Table 2
Studies reporting conversion from knee arthrodesis to TKA.

Study	N	Mean age (years)	Gender distribution (female/male)	Indication for knee arthrodesis			Implant design				Mean follow-up (years)	Complication rate	Functional outcome
				PJI	OA	Other	Nonconstrained	Semi-constrained	Rotating hinge	Mega-prosthesis			
Holden et al. (1988) [30]	2	68.5	2/0	0	2	0	2	-	-	-	4.25	n.r.	ROM
Mahomed et al. (1994) [28]	2	55.0	2/0	0	1	1	2	-	-	-	n.r.	n.r.	ROM, HSS
Cameron et al. (1996) [10]	17	59.1	7/10	11	4	1	5	9	2	-	n.r.	53.0%	ROM, HSS
Naranja et al. (1996) [27]	37	53.0	28/7	7	3	17	n.r.				7.5	57.0%	ROM
Kreder et al. (1999) [31]	18	60.9	n.r.		n.r.		n.r.				2.8	n.r.	ROM
Kim et al. (2000) [32]	14	42.3	8/6	0	0	14	-	14	-	-	5.2	87.6%	ROM, HSS
Henkel et al. (2001) [13]	7	58.0	6/1	5	2	0	4	3	-	-	4.7	85.7%	ROM, HSS
Kim et al. (2003) [26]	36	39.2	n.r.	0	0	36	36	-	-	-	7.7	61.1%	ROM, HSS
Clemens et al. (2005) [29]	8	53.0	6/2	0	0	8	-	8	-	-	3.4	87.5%	ROM, KSS, WOMAC, Euroqol
Cho et al. (2008) [11]	2	63.5	1/1	1	0	1	-	-	2	-	3.5	n.r.	ROM, HSS
Cermak et al. (2013) [33]	1	46.0	1/0	0	0	1	-	-	1	-	3.5	-	ROM
Abdelaal et al. (2015) [34]	1	71.0	0/1	0	0	1	-	-	-	1	10.0	-	ROM
Kasseem Abdelazim et al. (2019) [35]	6	50.0	1/5	0	0	6	-	-	6	-	2.0	50.0%	ROM, KSS, KOOS
Frieler et al. (2020) [12]	1	58.0	1/0	1	0	0	-	-	1	-	3.0	-	ROM

HSS, Hospital for Special Surgery rating; KOOS, Knee Injury and Osteoarthritis Outcome Score; KSS, Knee Society Score; n.r., not reported; OA, osteoarthritis; PJI, periprosthetic joint infection; ROM, range of motion; TKA, total knee arthroplasty; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

In the presented case, we were able to achieve optimal ligament balance and physiological joint kinematics with a nonconstrained, PS implant.

Functional outcomes

The PROMs obtained from our patient showed a substantial improvement of knee function scores. Furthermore, the KSS subscale for patient satisfaction and the Knee Injury and Osteoarthritis Outcome Score subscales for activities of daily living and quality of life increased postoperatively. In line with that, the EuroQol-5 Dimensions-5 Levels score, which indicates the self-perceived health status, improved after surgery.

These findings are consistent with evidence from previously published case series and meta-analyses. Compared to TKA, knee arthrodesis—although stable and painless—is associated with substantial functional limitations [9]. Studies evaluating the functional outcomes of desarthrodesis consistently prove a significant improvement of TKA-specific PROMs [25,42]. The conversion from knee arthrodesis to TKA is associated with substantial improvements of knee function, decreased pain scores, and an improvement of overall patient satisfaction.

Although the range of motion not limited intraoperatively with 150° of flexion, the postoperative range of motion recorded during follow-up was restricted with an extension lag of 5°-10° and 70° of flexion. Although the patient met clinical criteria for a mild to moderate early fibrosis of the knee and manipulation under anesthesia was discussed, he was satisfied with the overall functional improvement and outcome and did not wish any further procedures. Of note, the achieved range of motion is in line with the data reported in a recent review by Kernkamp et al. who found an average improvement of 80° flexion and average of 13° extension deficit [42].

It is worth mentioning that the inpatient length of stay was longer than in previously published studies, which is mainly attributable to the fact that in the German healthcare system, patients undergoing total joint arthroplasty are regularly discharged to a rehabilitation facility. Thus, the time of discharge depends on the capacities of rehabilitation facilities and prolonged length of stay is the consequence. Furthermore, an intensified inpatient physiotherapy protocol was followed in this case, as surgical case complexity was higher than in primary TKA procedures.

Complication rates

One year postoperatively, we observed a limitation of postoperative range of motion which corresponds to a mild to moderate postoperative fibrosis of the knee [43]. As the patient was satisfied with the postoperative functional outcome, no subsequent surgery was performed.

Because knee fusion is performed as a limb salvage procedure in highly complex medical cases, the takedown of the arthrodesis is associated with a remarkable risk of postoperative complications. In the literature, complication rates range between 50.0% and 87.5%. In a recent meta-analysis, overall complication rate was 47% with skin edge necrosis (21%-25%), PJI (11%), arthrofibrosis (13%), and ruptures of the extensor mechanism (3%-6%) being the most frequent surgery-related complications [25,42]. Revision rates vary between 0.0% and 86%, and indications for revisions included wound complications, PJI, arthrofibrosis, soft tissue complications, ligament instabilities, and aseptic loosening [25].

Current controversies and future considerations

The ideal surgical management for conversion of knee fusion to TKA remains controversial. Each case represents a complex, highly individual anatomic situation that should be analyzed critically.

This case report highlights some of the advantages of innovative technologies in complex cases. Using an imageless robotic system, the patient's individual bony anatomy and ligament tension can easily be registered intraoperatively once the osteotomy is performed. At the planning stage, robotic technology adds value to the surgical procedure as it enables the surgeon to determine the optimal component orientation in all 3 planes while simultaneously visualizing the effect on medial and lateral gap balance in flexion and extension. The position of the prosthesis is adjusted to achieve symmetrically balanced gaps; therefore, additional soft tissue releases can be minimized or avoided. Despite the reconstruction of coronal plane alignment, intraoperative planning also enables for an anatomical reconstruction of the patellofemoral joint to restore physiological patellar tracking.

After approval of the surgical plan, the bone cuts are conducted with the robotic burr, which allows for a high precision and reproducibility.

This case report adds to the current evidence and supports the use of robotic-assisted TKA systems for procedures with a high surgical case complexity [44,45]. We are convinced that the implementation of innovative technologies will improve TKA surgery in complex cases through increased intraoperative control, precise planning, and accurate surgical execution, which will ultimately contribute to overall patient safety.

In conclusion, the conversion knee fusion to TKA is a challenging procedure that should be performed by experienced arthroplasty surgeons.

In the presented case, the postoperative radiological and clinical outcomes were promising. Although postoperative range of motion was limited, the patient reported a substantial increase of knee function, a major improvement of quality of life, and a high level of patient satisfaction.

To the best of our knowledge, this article is the first report of robotic-assisted conversion of arthrodesis to TKA using a nonconstrained PS implant. It may therefore serve as a proof of concept for the use of robotic-assisted TKA for desarthrodesis. Future studies are warranted to investigate the long-term outcomes in a larger patient cohort.

Summary

Conversion of knee fusion to TKA is a rare and technically demanding surgical procedure. The implementation of robotic technology adds value to complex cases as it provides an accurate 3-dimensional model of the patient's individual anatomy and provides intraoperative real-time simulation of the effects of component positioning on medial and lateral gap balances in extension and in flexion.

Although this report is limited to the findings of 1 patient undergoing takedown of knee fusion and subsequent total knee replacement, the outcome and radiological results are promising. Further studies are warranted to investigate the long-term outcomes of robotic-assisted conversion of arthrodesis to TKA in a larger patient population.

KEY POINTS

- Knee arthrodesis is a limb salvage procedure which is performed in highly complex medical conditions. The most common indications are failed, unrevisable total knee arthroplasty (TKA) with severe bone loss, ligament instabilities, extensor mechanism deficiencies or persistent infection, septic arthritis, and tumors.
- Although knee arthrodesis is an effective procedure which provides stability and relieves pain, it is associated with major functional limitations and compromised patient-reported outcome measures, which lead to severe limitations in activities of daily living and a reduced quality of life.
- Conversion of knee fusion to TKA is a rare and technically demanding surgical procedure. The goal of TKA is the reconstruction of the constitutional alignment of the lower limb, the reconstruction of joint line height and joint line obliquity, and the restoration of physiological joint kinematics with a balanced flexion and extension gap.
- Robotic-assisted TKA allows for the intraoperative registration of the patient's bony anatomy and registration of soft tissue tension. It enables the surgeon to determine the optimal component orientation in all 3 planes while simultaneously visualizing the effect on medial and lateral gap balance in flexion and extension. As a consequence, intraoperative control is increased, and the surgical plan is executed with high precision which is beneficial for overall patient safety.

Conflicts of interest

Dr. Peter Savov received speakers bureau/paid presentations for Smith & Nephew. Prof. Dr. Max Ettinger received speakers bureau/paid presentations for Smith & Nephew and Microport and received research support from Smith & Nephew as a Principal Investigator. All other authors declare no potential conflicts of interest.

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Informed patient consent

The author(s) confirm that written 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 case report (series).

CRediT authorship contribution statement

Ricarda Stauss: Writing – original draft, Visualization, Project administration, Formal analysis, Data curation, Conceptualization. **Peter Savov:** Writing – review & editing, Methodology, Investigation. **Hendrik Pott:** Writing – review & editing, Methodology, Investigation. **Max Ettinger:** Writing – review & editing, Supervision, Methodology, Investigation, Data curation, Conceptualization.

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