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KNEE REVISION SURGERY

Modular knee arthrodesis secures limb, mobility, improves quality of life, and leads to high infection control in periprosthetic knee infection, when revision knee arthroplasty is not an option

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Abstract

Introduction This study compared the outcome of knee arthrodesis versus hinged total knee arthroplasty (TKA) in patients suffering from periprosthetic joint infection (PJI).

Methods 104 patients with PJI were treated using a two-stage exchange of failed TKA. In case of non reconstructable bone loss or loss of extension mechanism, a modular intramedullary arthrodesis nail was used for reimplantation [Knee Arthrodesis Module (KAM); $n=52$]. The control group was retrospectively matched treated using a hinged revision TKA [Rotating Hinge Knee (RHK); $n=52$]. PJI remission rates, functional outcome (WOMAC; KSS) and quality of life (SF-12), as well as comorbidities and pain were evaluated.

Results Mean age was 72.5 years. Charlson Comorbidity Index was higher in the KAM group (3.3 vs. 2.8). PJI remission rate was 89.4% (88.5% vs. 90.4%, respectively). In case of reinfection, implant retention was mostly possible in the RHK group (7.7%), whereas amputations were mostly performed in the KAM group (9.6%). Significant pain reduction (VAS 7.9–2.8) was achieved in both groups. Walking distance was significantly reduced in the KAM groups versus the RHK group (504 vs. 1064 m). WOMAC and KSS function scores were significantly reduced in the KAM group (25 vs. 40 and 35 vs. 64). Only moderate reduction in quality of life in the KAM group was observed (SF-12 physical: 34 vs. 40; SF-12 mental: 51 vs. 56) respectively.

Conclusions Arthrodesis using a modular intramedullary nail is an alternative for limb salvage, pain reduction, and preservation of quality of life and everyday mobility, when revision TKA is not an option. This study presents the largest number of case, comparing the outcome after performing an arthrodesis versus hinged TKA after septic failed TKA.

Keywords Periprosthetic joint infection · PJI · Failed total knee arthroplasty · Knee arthrodesis · Revision total knee arthroplasty

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Introduction

Two-stage exchange is considered most appropriate for chronic and difficult-to-treat cases. Complex interdisciplinary treatment strategies with modular implants and treatment-resistant pathogens represent a professional and financial challenge. However, in difficult-to-treat and difficult late-onset cases, the two-stage or multistage exchange remains the benchmark, owing to the observed high remission rates [1]. The time from resection arthroplasty to reimplantation varies significantly from 2 weeks to several months, and the use of antibiotic-impregnated cement spacers is common [2]. Whereas the short-term mortality rate is 0.045% in primary TKA and 0.205% in revision TKA [3], existing data shows that mortality rates

for two-stage revision in elderly patients aged > 80 years can be ≤ 36.7% [4]. Radical debridement is essential, since infected membranes and tissue sections remaining in situ represent potential sites of reinfection postoperatively [5]. Owing to this radical debridement, in cases of new prosthesis reimplantation, significant bone loss, loss of extension mechanism (quadriceps tendon, patella, patella tendon), and compromised soft tissue can impair the outcome of revision TKA or even render implantation impossible. Kheir et al. reported a remission rate of only 61.6% after a failed two-stage exchange and a reimplantation rate of only 65% following repeat debridement [6]. Revision TKA often requires a more constrained prosthesis due to ligamentous instability and bony defects [7]. Frequent complications are reinfection, wound-healing difficulties, and increased pain levels. The functional outcome and pain-free walking distance is markedly lower than those recorded after primary surgery [8, 9]. Most problems in complex revision TKA can be managed with a wide range of implant systems currently available (e.g., modular metaphyseal sleeves, metal augments, or cones). In case of significant ligamentous deficiencies, a rotating hinge prosthesis can be successfully used. However, especially in revision TKA due to recurrence of infection, extreme bone defects with instability and destroyed extensor mechanism can be present, precluding successful reconstruction with the currently available revision TKA systems [10]. In these situations, arthrodesis remains a limb-preserving treatment alternative. Several procedures of arthrodesis have been introduced and the situation of each patient must be considered in treatment planning. In recent series, septic complications following TKA were the most common indication for knee arthrodesis [10–13]. A compromised extension mechanism leads to a failing TKA. Fröschen et al. proposed to stiffen the knees of patients with cemented revision implants when the extensor is destroyed using an arthrodesis module, and concluded that arthrodesis improves both leg function and pain compared with revision prostheses [14]. In case of extensive bone loss, there is no possibility for contact arthrodesis, such as external fixation or screw-based arthrodesis. Therefore, distance arthrodesis using intramedullary stems, coupled with an arthrodesis module are options for solving complicated situations in long-distance bone stock loss [10, 14]. The knee arthrodesis module can be implanted using cemented and uncemented stems. In case of stem reimplantation, the type of fixation (cemented vs. uncemented) remains controversial. Although fixation of the femoral and tibial joint component of TKA is widely common, cementless fixation of intramedullary stems is possible. However, data for septic revision cases are lacking. The advantages of cementation are a lower perioperative fracture rate in osteoporosis and osteopenia, and better postoperative pain control; however, severe perioperative incidents occur in ≤ 45% of revisions [15]. There are some specific characteristics for revision surgery. A > 80% reduction was observed in cement–bone interface shear strength between primary and revision arthroplasty [16], explaining the higher loosening and revision rates of cemented implants reported in these cases. In case of new revision, there are more stringent prerequisites for cemented prostheses. Despite prior findings, there is no established standard regarding multistage exchange, including the use of spacers and anchorage principles of the revision implant [15].

Failed TKA with significant bone loss and compromised soft-tissues is challenging. The target of treatment after remission of infection is to preserve the limb, restore mobility, and minimize pain. The objective of this study was to compare the outcome of hinged TKA versus knee arthrodesis using a stem-guided knee arthrodesis module in patients with failed infected TKA treated with two-stage revision TKA. The primary outcome measures were PJI remission rates, as well as comparison of patient quality of life and score-based outcome measures. It is hypothesized that arthrodesis patients suffering from low mobility, quality of life and minor pain reduction.

Methods

Patient characteristics

All patients with PJI of failed TKA meeting the inclusion criteria (treatment with two-stage exchange) were retrospectively selected. In total, there were 104 eligible patients (2010–2017). The Study took place in an EndoCert® certificated primary academic referral centre for arthroplasty, in a special department for PJI and fracture related infections. Included patients were operated in a team of four experienced senior surgeons. The groups were retrospectively matched, analysed, prospectively investigated, and allocated into two groups: the Rotating Hinge Knee (RHK) group was treated using a revision TKA (NexGen® RHK; Zimmer, Winterthur, Switzerland), while the Knee Arthrodesis Module (KAM) group was treated using a modular intramedullary arthrodesis nail (KAM-TITAN®; Peter Brehm GmbH, Weisendorf, Germany).

The study was approved by the institutional review board (IRB Approval: LAEKH-FF-03-17). Informed consent was provided by the patients.

This study included patients with chronic recurrent periprosthetic infection of the knee joint. None of these patients fulfilled the criteria for a single-step exchange according to the guidelines of the Infectious Diseases Society of America [17] or the recommendations of the International Consensus Meeting (2013 and 2018) [18, 19]. All patients fulfilled the criteria for late-onset chronic infection. Early guidelines reported that the risk of failure of

prostheses retention increases after 4 weeks from the index arthroplasty or if the duration of symptoms exceeds 4 weeks [20]. The present collective had received index arthroplasty ≥ 3 months earlier and were negative for predictive host factors.

Diagnostics

The diagnosis of PJI was based on published diagnostic criteria [21–23]. All patients met the guidelines of the Infectious Diseases Society of America [2] and the criteria set out by the International Consensus Meeting on PJI (2013) [22, 23] with regard to the presence of a periprosthetic infection.

Surgical procedure

A two-stage exchange was performed as previously described [24, 25] and modified as a multistage procedure as follows (this strategy involves at least two procedures). In the first step, the TKA implant was removed, cultures were obtained, all infected tissue was debrided, and the components and poly-methyl-methacrylate were removed [26]. A calculated systemic antibiotic therapy was initiated after intraoperatively collecting microbiological samples during the first intervention. This therapy was performed using a broad-range antibiotic that provided good soft-tissue penetration (Mostly: Ampicillin/Sulbactam). The antibiotics were changed 3 days following the procedure in accordance with the results of the actual antibiogram. Systemic antibiotic therapy was administered for 6 weeks. An initial intravenous 2 week therapy was followed by a minimum of 4 weeks of pathogen-specific highly bioavailable oral antimicrobial treatment until reimplantation of the revision implant [27, 28]. Static antibiotic loaded spacers were used as standard procedure in both groups. Antibiotic load in PMMA-spacers was chosen individually according to antibiogram and bacterial spectre, taking into account actual ICM recommendations, respecting a maximum amount of 10% antibiotic per PMMA (e.g. 4 g antibiotic per 40 g PMMA). In the prostheses-free periods, biofilm-targeting antibiotics were not used (e.g., rifampin). In the presence of signs of ongoing acute PJI after removal of prostheses in the prostheses-free interval, an additional debridement step was necessary. Multiple stages of revision surgeries were performed until clinical presentation showed no acute signs of ongoing infection. After the last revision step, 6 weeks of highly efficient antimicrobial therapy was administered, followed by an antimicrobial-free interval of 2 weeks. During this time, patients were evaluated for any signs of ongoing infection using inflammatory markers and clinical assessment, like C-reactive protein and leukocyte count in blood as well as procalcitonin (in case of sepsis) [2, 25, 26]. No joint aspiration was performed prior to re-implantation, as well as no alpha-defensin was used, as the use for the timing of the re-implantation is not proofed [29, 30]. In patients with evidence of ongoing infection, a repeat radical debridement procedure was performed, including tissue sample testing, followed by further antimicrobial therapy prior to attempted reimplantation. A new implant was implanted in the absence of evidence of ongoing PJI. The decision to perform revision TKA or knee arthrodesis was based on the quality of the extensor mechanism and the status of the soft tissue. Indications for arthrodesis were extensor apparatus deficiencies or extended non reconstructable bone loss in combination with poor soft-tissue coverage. Extensive tibial defects in combination with extensor mechanism loss are particularly indications for KAM, nevertheless the overall indication for an arthrodesis has to be set individually in the background of patients overall condition, mobility, bone and soft-tissue status. No bone grafts were used. Only KAM and RHK treated patients were eligible for this study. The above-mentioned modular arthrodesis system (KAM-TITAN®) of surface-sanded titanium and consisting of two separate modular femoral and tibial components was used. The system can be implanted either through a cementless or cemented technique [10]. Figure 1 shows the surgical procedure using KAM. In cases of reimplantation of a revision TKA and significant ligamentous deficiencies, rotating hinge design prostheses were used. Therefore, in this study, only one kind of revision TKA (NexGen® RHK; Zimmer) was included to reach the highest possible homogeneity in study design. Figure 2 shows the surgical procedure using RHK.

After reimplantation, mobilization was promptly initiated with the assistance of physiotherapists. Most of our patients used forearm crutches or a rollator. Both groups were treated with increasing weight bearing over 6 weeks, reaching full-weight bearing after that period. Early mobilisation after surgery was performed. After 6 weeks, we performed a radiographic assessment, and allowed mobilization with full-weight bearing.

Patient monitoring

General patient monitoring was performed in accordance with published guidelines [2, 31]. Each patient was evaluated physically and with respect to wound healing, current clinical symptoms, drug allergies and intolerances, comorbid conditions, prior and current microbiology results from aspirations and surgeries, and antimicrobial therapy for PJI (including local antimicrobial therapy). Each patient was tested for C-reactive protein, along with a complete blood count and electrophoresis. A plain radiograph was performed for all patients prior to and after surgery. If fever was evident, we checked the procalcitonin levels and prepared blood cultures for aerobic and anaerobic organisms.

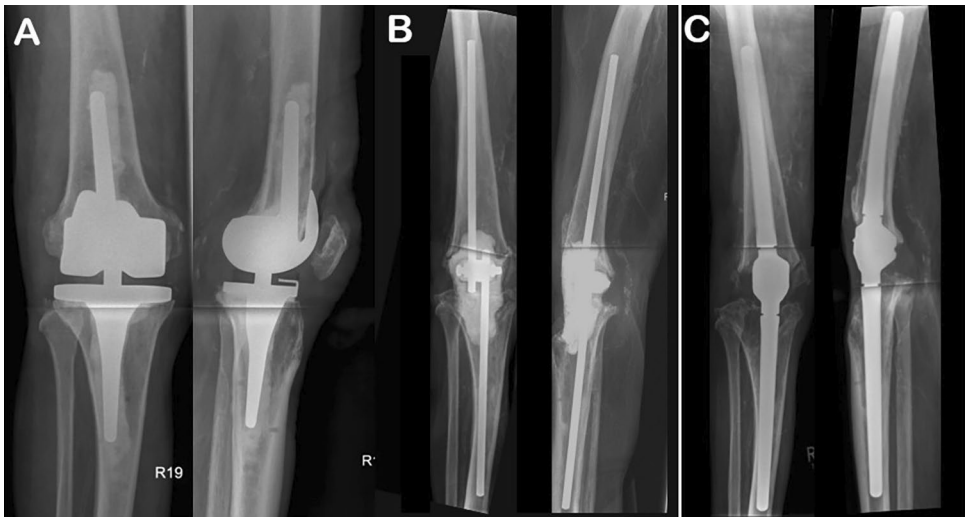


Fig. 1 Patient suffering from periprosthetic infection of hinged total knee arthroplasty (TKA) (**a**). TKA was removed and several revision and debridement steps were performed with significant bone loss and insufficiency of extension mechanism; patellectomy was also performed. A fixed spacer was implanted (**b**). After remission of infection, a cementless stem-guided knee arthrodesis module (KAM) was implanted (**c**)

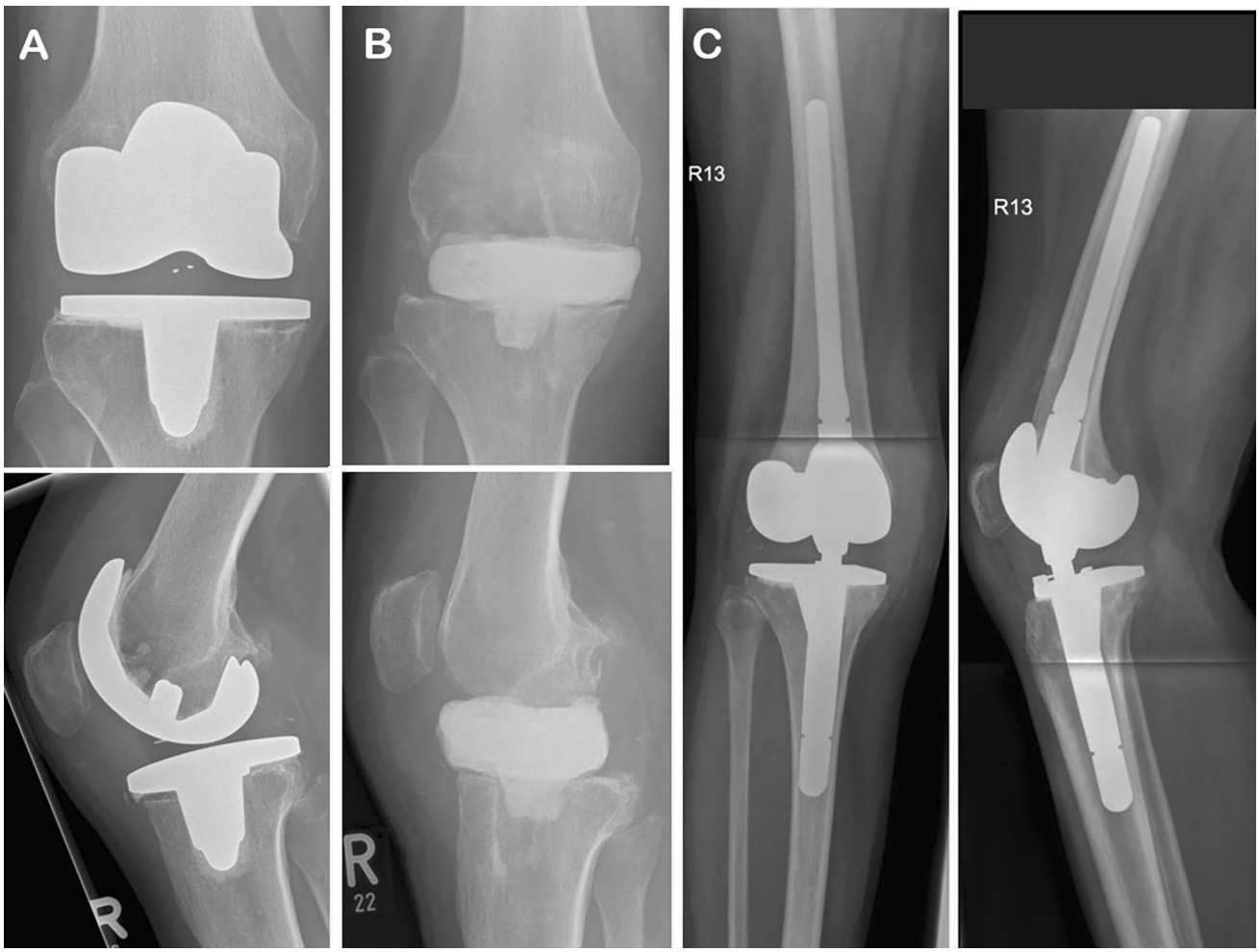


Fig. 2 Patient suffering from periprosthetic infection of total knee arthroplasty (TKA) (**a**). TKA was removed and two-stage exchange was performed. A fixed spacer was implanted (**b**). After remission of infection, a rotating hinge knee arthroplasty (RHK) was implanted, using cementless stems (**c**)

Outcome measures and sample size calculation

Success and remission were defined as the absence of clinical, radiological, and biological (i.e., increased inflammatory markers) signs of infection [2]. In contrast, an endpoint was defined as the detection of reinfection or need for surgical intervention. Clinical outcome was assessed after a minimum follow-up of 16 months (mean follow-up 38 months).

Both groups were prospectively assessed for function and quality of life. The scores used to compare the illness of the patients between the two groups included the Knee Society Score (KSS), the Western Ontario McMasters Universities Osteoarthritis Index (WOMAC), the Short Form Health Survey 12 (SF-12), and the Charlson Comorbidity Index. The scores can be subdivided to compare partial aspects. In addition, we assessed the KSS function score, SF-12 body and psych scores, and WOMAC pain and activity scores, to determine whether the patient suffered from mental or physical restriction, or obtain more precise information regarding the outcome of RHK versus KAM, with scores which do not prominently evaluate the range of motion (ROM). By definition, the ROM in patients with arthrodesis is zero due to stiffened knee, and could falsify the comparison in the scores. Thus, we did no survey the whole KSS score in arthrodesis group, as the ROM is one of the major points there, but did compare the KSS function subscore instead. In addition, we assessed the preoperative and postoperative level of pain using the visual analogue scale [(VAS): minimum: 0; maximum: 10], as well as analgesics used by the patients after follow-up, using the "World Health Organization (WHO) Pain Ladder". Walking distance was assessed in metres. Patient-related factors and comorbidities were assessed. An average of the groups is named "ALL" in the tables and figures.

Statistical analysis

The D'Agostino–Pearson test was used to evaluate raw data for normality. We subsequently used the Wilcoxon signed-rank test and Student's *t* test to evaluate differences between the two groups for non-parametric and parametric data, respectively. Results are presented as the mean and range. The chi-squared test was used for analysis for homogeneity and comparability between the two groups. All tests were two-sided. SPSS version 22.0 (IBM Inc., Armonk, NY, USA) was used for all statistical analyses. We used the statistical programme "G*Power 3.1" to determine the sample size [32]. We used the SF-12 as our primary outcome variable, which has a minimal clinically important difference of 4.8 for the knee, to determine the adequate sample size for group comparisons (KAM vs. RHK) [33]. Based on these findings and the results of a previous study conducted by Hungerer et al. [34], a two-sided unpaired *t* test with an alpha-level of 0.05, a power of 80%, requires 52 patients in each group to detect an effect size of 0.80. The overall sample size was 104 patients, divided in two groups, to obtain valid outcome measures.

Results

Patient characteristics

The mean age was 72.5 years (range 45–97 years) without significant differences between the groups ($p = 0.17$). Similarly, there was no significant difference between the two groups with regard to the body mass index, comorbidities (e.g., hypertension or diabetes) (Table 1). The Charlson Comorbidity Index showed that the arthrodesis group had on average a more severe comorbidity index (KAM 3.3 vs. RHK 2.8), but with slightly non-significant difference ($p = 0.059$). Patient characteristics and data of surgical procedures, including the number of debridement steps between explantation and implantation, are shown in Table 1. Overall 88 (84.6%) patients received additional debridement steps between the stages due to ongoing signs of infection, without significant differences between groups ($p = 0.279$). Mean count was 4.51 surgeries per patient, therefore beside explantation and re-implantation overall 2.51 (Min.:0 Max.:10) debridement steps were carried out in between.

The bacterial spectrum was composed of *Staphylococcus epidermidis* (26%), *Staphylococcus aureus* (19%), and *Enterococcus faecalis* (6%) (Fig. 3). In 37% of cases, more than one form of bacteria were detected, without significant differences between groups ($p = 0.357$). No specific bacterial spectre was present in patients which received additional debridement steps between stages.

Systemic antimicrobial therapy was administered in accordance with antibiograms, most frequently using sultamicillin or amoxicillin/clavulanic acid (34.6%). In 15.1% of cases, a combination with rifampin was performed after reimplantation. Clindamycin (10.1%) and ciprofloxacin (8.9%) were also used. The remaining 31.3% of cases received different antibiotics which were selected in accordance with the antibiogram and taking into account the management of antibiotic stewardship.

Remission rate

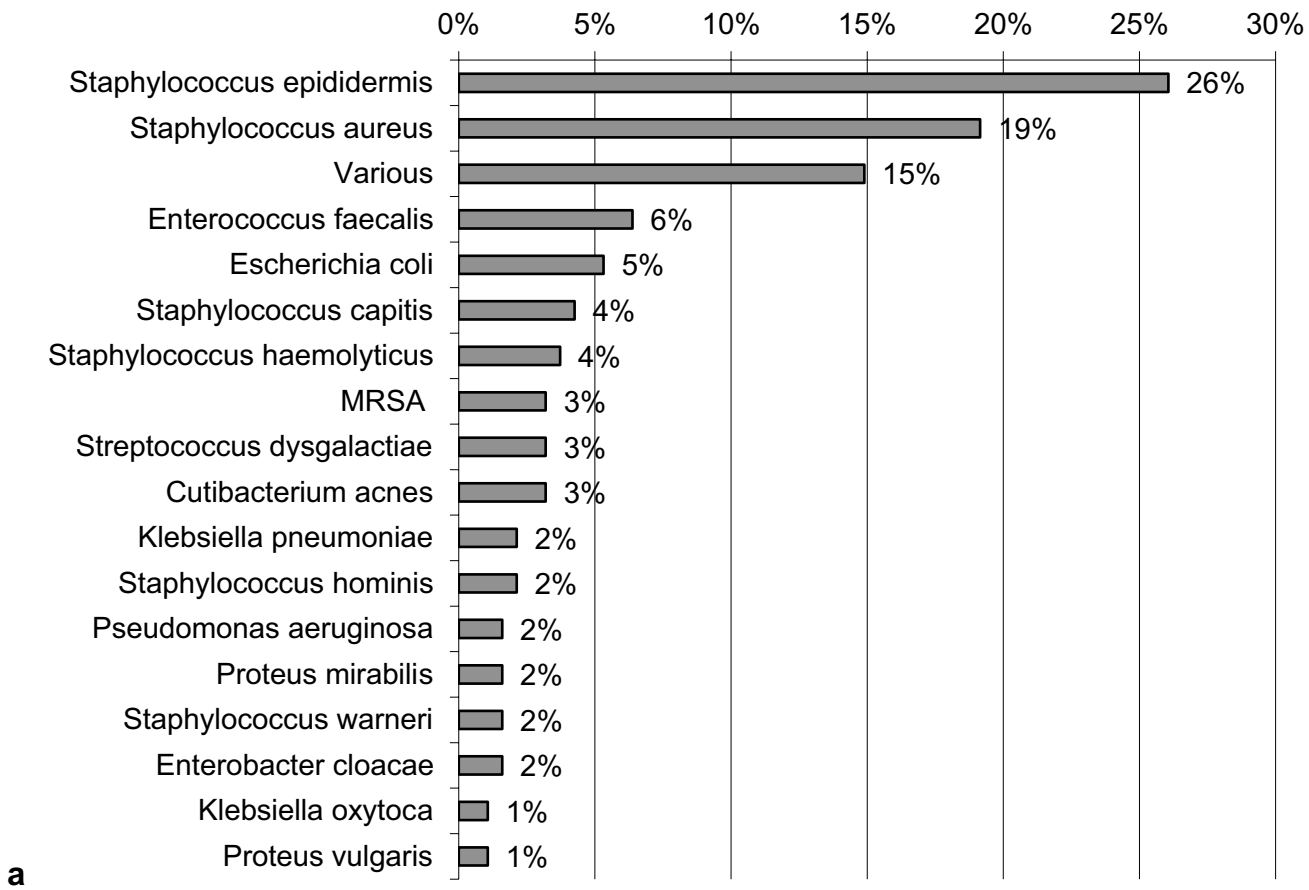
Overall remission rate was 89.4% without difference between groups (KAM 88.5% vs. RHK 90.4%). The remaining 10.6% showed reinfection or ongoing infection (11.5% vs. 9.6%, respectively). These patients received a classical DAIR procedure with a maximum of two debridement steps [35, 36]. Otherwise implant was changed or amputation carried out. In these cases, treatment showed differences (Table 1). In the

Table 1 Comparison of patient characteristics, numbers of surgeries, outcome according to the remission of infection rate, and pain between groups

Variables	Value	All				KAM group				RHK group				*p* value
		n/mean	SEM	Min	Max	*n*/mean	SEM	Min	Max	*n* or mean	SEM	Min	Max	
n	*n*	104				52				52				
Gender	Male	50 (48%)				23 (44%)				27 (48%)				0.435
	Female	54 (52%)				29 (56%)				25 (52%)				
Age	Mean	72.47	1.10	45.00	97.00	73.98	1.66	49.00	97.00	70.96	1.42	45.00	88.00	0.17
BMI	Mean	30.23	0.67	20.00	54.00	30.97	1.15	20.00	54.00	29.59	0.75	22.00	44.00	0.31
Previous surgical revision procedures	Mean	1.10	0.03	1.00	2.00	1.08	0.04	1.00	2.00	1.12	0.04	1.00	2.00	0.51
Previous revision surgery in other hospitals	Yes	94 (90.4%)				48 (92%)				46 (88.5%)				0.371
	No	10 (9.6%)				4 (8%)				6 (11.5%)				
Follow-up	Mean	38.24	1.92	16.00	90.00	37.87	1.82	17.00	75.00	38.62	3.40	16.00	90.00	0.85
In-house surgery including explantation, re-implantation, debridement steps	Mean	4.51	0.24	2.00	12.00	4.92	0.39	2.00	12.00	4.12	0.27	2.00	12.00	0.09
Patients receiving additional debridement, between stage 1 and 2	*n*	88 (84.6%)				46 (88.5%)				42 (80.8%)				0.279
Duration of treatment	Mean (days)	133.32	12.98	42.00	801.00	134.43	21.10	42.00	801.00	132.22	15.33	42.00	699.00	0.93
Charlson Comorbidity Index	CCI	3.10	0.17	1.00	5.00	3.31	0.19	1.00	5.00	2.84	0.15	1.00	5.00	0.059
Diabetes	Yes	21 (20%)				13 (25%)				8 (15%)				0.378
	No	71 (68%)				39 (75%)				32 (62%)				
	N/A	12 (12%)				0 (0%)				12 (23%)				
Hypertension	Yes	74 (71%)				39 (75%)				35 (67%)				0.501
	No	24 (23%)				12 (23%)				12 (23%)				
	N/A	6 (6%)				1 (2%)				5 (10%)				
Therapy outcome	Success	93 (89.4%)				46 (88.5%)				47 (90.4%)				0.776
	Reinfection with implant retention	5 (4.8%)				1 (1.9%)				4 (7.7%)				
	Amputation	5 (4.8%)				5 (9.6%)				0 (0.0%)				
	Conversation to arthrodesis	1 (0.96%)				0 (0.0%)				1 (1.9%)				
Pain before surgery*	Mean VAS [0–10]	8	0.3	0	10	8	0.4	0	10	8	0	0	10	0.844
Pain after surgery*	Mean VAS [0–10]	3	0.4	0	10	3	0.6	0	10	3	0	0	10	0.735
Medication acc. WHO pain ladder	Mean [1–4]	1	0.1	0	3	1	0.2	0	3	1	0	0	2	0.467

KAM Knee Arthrodesis Module, *RHK* Rotating Hinge Knee, *SEM* standard error of the mean, *Min.* minimum, *Max.*, maximum, *BMI* body mass index, *WHO* World Health Organization, *ALL* Average of KAM and RHK

*Significant reduction in pain level in both groups after surgery: $p < 0.001$



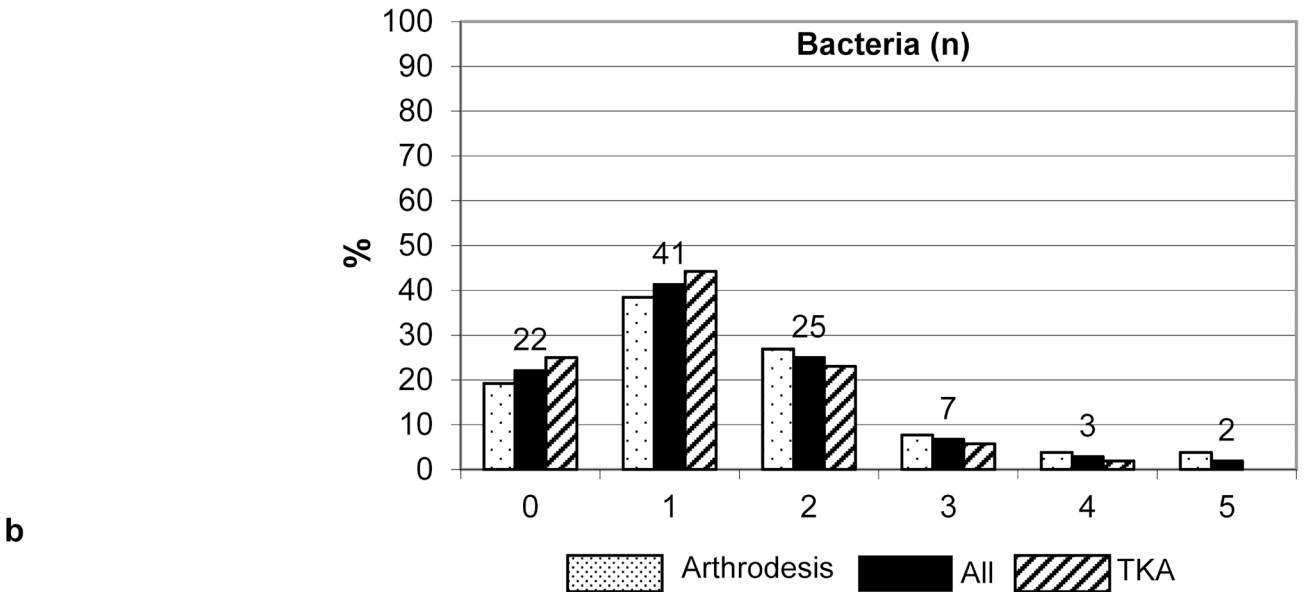


Fig. 3 Bacterial spectrum in all patients (**a**). In 37% of cases, more than one form of bacteria were detected, without significant differences between groups (**b**). MRSA, methicillin-resistant *Staphylococcus aureus*; *TKA* total knee arthroplasty, *All* Average of KAM and RHK group

RHK TKA group, patients with reinfection could be treated mostly with implant retention (7.7% of all RHK). In the KAM arthrodesis group, patients with reinfection had mostly to undergo amputation (9.6% of all KAM). Only 1.9% of patients with RHK TKA had to switch to arthrodesis. Similarly, only 1.9% of patients with KAM had undergone an

implant retention procedure due to reinfection. Patients who underwent amputation after arthrodesis had mostly been treated using arthrodesis as last option and ultima ratio to prevent amputation. In case of reinfection in these patients, there were no more options apart from amputation. There was no case of instable arthrodesis as indication, all cases of amputation were due to ongoing uncontrolled infection.

Pain, functional outcome, and quality of life

There was a highly significant reduction between the preoperative to postoperative pain levels (7.9 vs. 2.8, respectively) ($p < 0.001$). However, there were no difference between groups ($p = 0.844$). The postoperatively need for pain-reliever medication after follow-up according to the WHO pain ladder, was without difference between groups ($p = 0.467$). Of the patients, 45% did not need analgesics, whereas 36%, 13%, and 6% required medication according to levels 1, 2, and 3 of the WHO pain ladder, respectively. Figure 4 shows the outcome scores. Owing to the pain reduction in both groups, the WOMAC pain subscore did not show difference between groups, whereas the WOMAC sum-score showed a highly significant worse outcome in patients with arthrodesis versus those with RHK arthroplasty ($p < 0.001$). In Fig. 4, higher scores on the WOMAC indicate severe pain, stiffness, and functional limitations. Therefore, the most important restriction of patients with arthrodesis is the walking distance, which was significantly reduced in the KAM group versus the RHK group (504 vs. 1064 m, respectively, $p < 0.001$). This aspect in combination with the full reduction of ROM leads to the reduced values in all common outcome scores. The KSS could not be collected in the KAM group due to the necessity of a ROM; therefore, there is no survey presented in Fig. 4. The KSS function score showed significant reduction in the KAM group versus the RHK group ($p < 0.001$). These reduced results in common outcome scores do not affect the quality of life measured by the SF-12 score. There were only moderate differences in the "physical health SF-12 score" ($p = 0.027$) and "mental health SF-12 score" ($p = 0.046$). For comparison, the official SF-12 values of healthy individuals in the investigating country are as follows: physical health 44; mental health 53 [37]. These values for patients with extremity disability were SF-12 physical health 35 and SF-12 mental health 49 [37]. Patients were asked the following question, to proof their satisfaction in combination with their initial expectation:

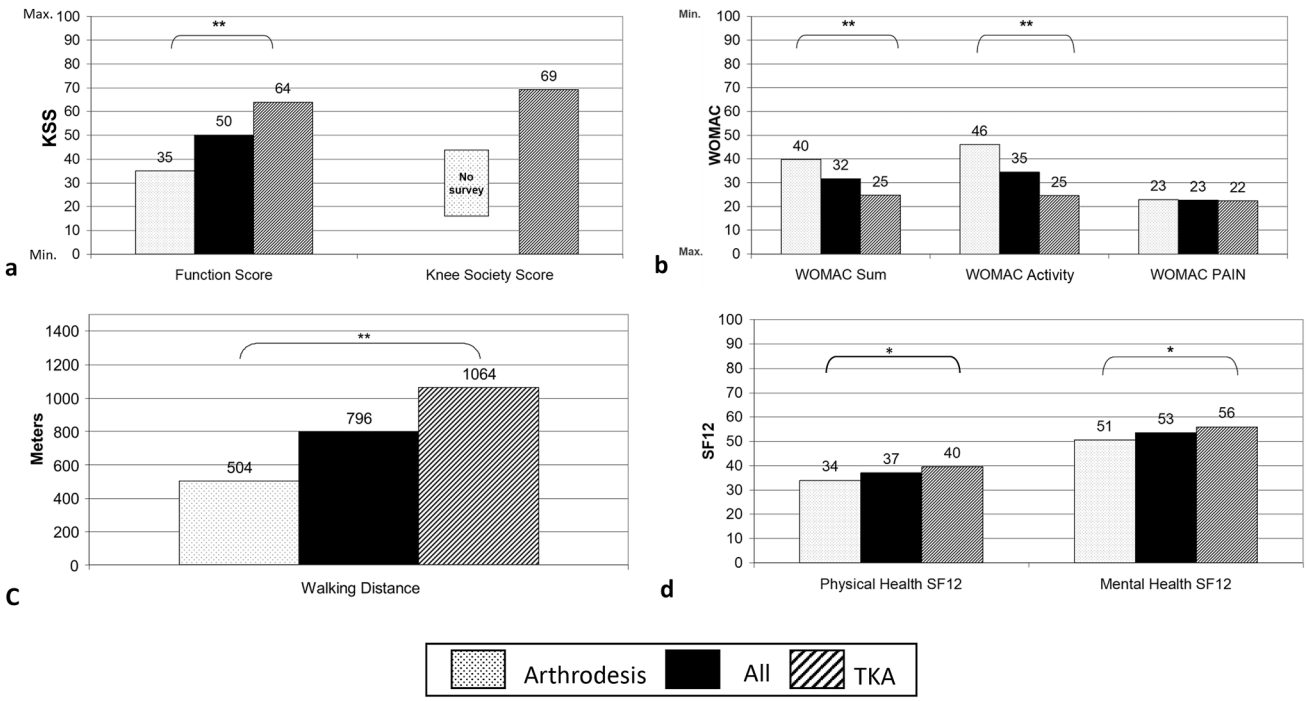


Fig. 4 Outcome scores. Knee Society Score (KSS) cannot be collected in patients with arthrodesis due to the necessity of a range of motion; hence, there was no survey performed. Therefore, the KSS function-subscore was combined to evaluate the functional outcome (**a**). Higher scores on the Western Ontario McMasters Universities Osteoarthritis Index (WOMAC) indicate severe pain, stiffness, and functional limitations (**b**). Maximum walking distance possible was measured in metres (**b**).Quality of life was measured using the Short Form Health Survey 12 (SF-12) questionnaire (**d**). For comparison, the official SF-12 values of healthy individuals in the investigating country are as follows: physical health norm scale 44; mental health norm scale 53. These values for patients with extremity disability were SF-12 physical health 35 and SF-12 mental health 49. *TKA* total knee arthroplasty, *All* Average of Arthrodesis and RHK group; *indicates $p < 0.05$; **indicates $p < 0.001$

"Are you satisfied with the result?". The answer was "yes" in 88% and 81% of patients in the KAM and RHK groups, respectively. The KAM group showed high satisfaction, as the target of therapy was limb salvage and pain reduction, which was achieved in 88.5% of cases (success rate). Moreover, the walking distance was reduced in patients with arthrodesis. However, in general, mobility was secured in the KAM group, and the rehabilitation time to reach a steady state was significantly lower versus that recorded in the RHK group (1.1 vs. 2.4 months, respectively). The KAM group tended to be more sick, as the comorbidity index was higher; fast rehabilitation could be an advantage in this population.

Discussion

Management of failed TKA due to PJI remains challenging, as bone loss and compromised soft tissue determine the selection of revision implant. The target of therapy is to restore a pain-free limb, secure mobility and improve quality of life. A study of > 18,000 patients demonstrated that 38% of cases do not undergo reimplantation within 1 year of prosthesis removal and spacer placement, which underlines the complexity of failed TKA [38]. Although a gold standard for the treatment of PJI is still lacking [2], two-stage revision surgery is described as the benchmark, given that it is associated with the highest remission rates (65–100%) [1, 39, 40].

To the best of our knowledge, this study presents the largest number of case, comparing the outcome after performing an arthrodesis versus hinged TKA after septic failed TKA [41]. Both groups included the same number of patients ($n = 52$), fitted to the sample size calculation, and did not present significant differences in patient characteristics (Table 1). The study compared the clinical and functional outcome, as well the quality of life after reimplantation. The arthrodesis group had a higher comorbidity index and more complicated bone stock and soft-tissue situation; hence, TKA implantation was not possible and arthrodesis was performed. Knee arthrodesis with intramedullary nail or external fixator is the most reliable therapeutic option to achieve definitive infection control in patients with septic failure of TKA [41, 42]. Deficient bone stock, impaired quality of bony surfaces, and shortened limbs may compromise the success of the procedure and lead to poor functional results [41].

In our study, arthrodesis and TKA led to significant pain reduction after reimplantation, as well as only a moderate need for analgesic medication (WHO level 1). Therefore, WOMAC pain score and pain levels on the VAS did not exhibit differences between groups. In contrast, other studies showed that revision TKA can lead to chronic postoperative pain [8]. Besides pain reduction, the target of therapy is limb salvage and preservation of mobility. Although patients with arthrodesis had the most complicated initial situation, it was possible to restore limb function and mobility. Nevertheless, the overall walking distance in the KAM group was approximately 500 m, which was only half of the distance observed in the RHK group. This leads to a significant reduction in all other outcome scores (i.e., WOMAC or KSS function subscore). On the other hand, 88% in the KAM group versus 81% in the RHK group were satisfied with the overall outcome. This suggests that these patients have different expectations in terms of treatment outcome. The KAM group showed high satisfaction, as the target of therapy was limb salvage and pain reduction, which was achieved in 88.5% of cases (success rate). In addition, the rehabilitation time to reach a steady state was significantly lower versus that recorded in the RHK group (1.1 vs. 2.4 months, respectively). Greidanus et al. measured the clinical treatment outcome after primary implant installation and revision prosthesis installation using the SF-12 and WOMAC scores. The outcome after primary endoprosthetic arthroplasty yielded SF-12 values of 49.1 and 31.6 on the mental and body subscales, respectively.

Patients had a worse outcome after revision treatment. Their overall values were 44.0 and 29.8, respectively. Thus, the SF-12 global value was reduced by 18.2 points from primary care to revision care. In parallel, the WOMAC score after primary care was 50.5 and worsened by 7.2 points after revision treatment (43.3) [43]. Similarly, Stevens et al. reported that, after revision treatment and 5-year follow-up, the SF-12 body and mental subscales were 40.6 and 48.3, respectively [44]. Patil et al. collected the congruent SF-36 score after treatment of septic revision prosthesis. They reported postoperative SF-36 scores of 40.4 and 55.5 on the body and mental subscales, respectively [45]. These findings are consistent with those observed in our study population, showing overall scores of 37 and 53 on the body and mental subscales, respectively, along with a moderate significant reduction in patients with arthrodesis versus those with revision TKA. The arthrodesis group in our study tended to be sicker, as the comorbidity index was higher; fast rehabilitation may be an advantage in this population. In addition Gathen et al. reported that arthrodesis was associated with significantly lower revision rate than TKA, which could be advantageous in this collective too [46]. Quality of life was measured using the SF-12 questionnaire. Only moderate reduction in the KAM group versus the RHK group was observed. In comparison with the official norm sample of healthy individuals [37], our patients did not have significant differences in the mental health subscale (SF-12 mental health norm scale: 53 vs. study population: 53). In contrast, the physical health SF-12 value (37 points) was reduced in comparison to that of healthy individuals (44 points). Comparison of the average scores of the "norm sample of patients with extremity disability" [37], and our study population

showed higher values for the latter (SF-12 physical health: 35 vs. 37, respectively; SF-12 mental health: 49 vs. 53, respectively). In conclusion, the quality of life of patients with arthrodesis is moderately lower than that of patients with RHK; however, there was no significant reduction observed compared to the norm sample. Therefore, arthrodesis leads to restrictions in activity versus TKA without overall reduction in quality of life, and faster rehabilitation.

In contrast, Röhner et al. reported "unsatisfactory outcome of arthrodesis performed after septic failure of revision total knee arthroplasty" [47]. Nevertheless, in our study, these patients had a low infection control rate (~ 50% reinfections) and high levels of postoperative pain. The WOMAC score was comparable to that recorded in our population. However, the quality of life measured by the comparable SF-36 [48] survey was only 8% in the previous study versus 38% in our arthrodesis group. Quality of life may be associated with the functional result (WOMAC score comparable in both studies), but is dependent on the level of pain after surgery and high rate of infection control; both factors were better in our population.

Limitations

This study addresses a specific subgroup of patients suffering of recurrent PJI and who had undergone various surgeries, performing finally a knee arthrodesis. These patients were matched and compared to the outcome of revision TKA patients. Limitations occur to the restricted available sample size and therefore the associated statistical assessability. Additionally, it is impossible to do a randomized clinical trial because the decision to do a KAM procedure versus RHK is really dependent on the extensor mechanism, bone loss, bone stock, bone quality and patient decision. These are technical factors to which blinding or randomization cannot be done.

Conclusion

The results showed comparable high PJI remission rates in the two groups. Despite significant bone loss and impaired soft tissue in the arthrodesis group, limb salvage was in line with comparable pain reduction in the RHK group, as well as improvement in overall quality of life. Walking distance, as well as activity and function scores were significantly reduced in the arthrodesis versus revision TKA groups. Therefore, arthrodesis using an intramedullary nail is an option for limb salvage, pain reduction, and preservation of quality of life and everyday life mobility, when revision TKA is not an option.

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Declarations

Conflict of interest All authors declare that they have no conflict of interest. Study is based on institutional review board (IRB) approval (ID FF-03–2017). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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