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Conversion of cemented revision total knee prostheses to arthrodesis using custom-made arthrodesis modules that preserve the cemented stem anchorage in patients with long-established extensor mechanism insufficiency: A case series

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ABSTRACT

Introduction: Long-established extensor mechanism insufficiency that defies reconstruction is a rare, but devastating, complication after revision total knee arthroplasty (RTKA) that may require arthrodesis. For cemented stem guided knee prostheses with firmly attached stems, prosthesis explantation can lead to significant bone stock loss that may, at worst, make knee arthrodesis significantly more difficult or impossible to achieve. Under these circumstances, conversion of the cemented knee prosthesis with custom-made arthrodesis modules that preserve the existing stem anchorage may be a low-risk alternative. This case series presents this type of conversion to arthrodesis, which was performed for patients with a non-reconstructable, long-established extensor mechanism insufficiency.

Methods: After intraoperatively ascertaining that reconstruction of the extensor mechanism insufficiency was impossible, the inlying revision prosthesis was converted into arthrodesis with custom-made arthrodesis modules, without explanting the cemented stems.

Results: Conversion to arthrodesis was performed in four patients. There was no histopathological or microbiological evidence of a periprosthetic joint infection. Clinical follow-up showed a low level of pain, with a stable knee joint and proper implant position. The Oxford Knee Score increased from 20.5 (95% CI 17–26) to 35.5 (95% CI 30–36) points. The visual analog scale decreased from 5.5 (95% CI 4–7) pre-operatively to 1.5 (95% CI 1–2) points at last follow-up. No implant-specific complications occurred.

Conclusions: Conversion of cemented RTKA with firmly attached cemented stems, without evidence of loosening, to arthrodesis might be a surgical treatment strategy for patients with a long-established extensor mechanism insufficiency that cannot be reconstructed.

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1. Introduction

Extensor mechanism rupture after total knee arthroplasty (TKA) or revision total knee arthroplasty (RTKA) is a rare but serious complication that can be differentiated into patellar tendon and quadriceps tendon ruptures and fractures of the patella [1,2]. Current literature reports an incidence of 0.1–2.5% for this kind of complication [3–5].

Various treatment strategies for extensor mechanism insufficiency have been described in the literature to date [2,5,6]. Conservative treatment should be limited to incomplete ruptures with an active extension deficit of ≪20°. Complete intra-operative or postoperative ruptures of the quadriceps tendon or patellar tendon should, on the other hand, be treated surgically [2]. Today, multiple surgical options are available to reconstruct a failed extensor mechanism, including primary repair (e.g., suture fixation), reconstruction with allograft (e.g., Achilles tendon allograft), autograft (e.g., semitendinosus tendon, gastrocnemius rotational flaps), and the use of synthetic materials [2,5]. However, all published procedures have a low level of evidence for the results (evidence level III, mainly from retrospective case series). There is also currently no treatment strategy to reconstruct a failed extensor mechanism that is associated with a superior outcome, and a reliable reconstruction is hard to achieve. Primary repair results, for example, are often disappointing and, in many cases, an extensor lag may persist [6–9].

Treatment of a long-established extensor mechanism insufficiency after RTKA that is refractory to conservative therapy remains a surgical challenge. Reconstruction can often be hindered by a critical soft tissue situation after multiple revision procedures, such as in cases of two-stage or multi-stage TKA exchanges. In such an event, arthrodesis may be the only remaining treatment option for pain relief and to create a stable situation [1,10]. Moreover, in cases with cemented stem guided knee prostheses with long, firmly attached stems, explantation of the prosthesis may prove difficult and can often lead to a further significant loss of bone stock, which can, at worst, make knee arthrodesis extremely difficult or even impossible to achieve. Under these circumstances, a conversion of the cemented knee prosthesis into an arthrodesis with the help of custom-made arthrodesis modules that do not necessitate explantation of the firmly attached stems may be a low-risk alternative.

2. Material and methods

Four consecutive patients (three (75%) female, one (25%) male) who were unable to extend their knees following RTKA were included in this case series. The inclusion criterion was an extensor mechanism insufficiency after RTKA that was refractory to conservative therapy with lack of reconstruction. In three of the four cases, the indication for RTKA had been aseptic loosening and, in one case it had been a reimplantation as part of a two-stage procedure after a periprosthetic joint infection (PJI). All of the included patients had femoral and tibial long sectional cemented knee prostheses. In one patient (Patient 2), the whole femur had previously been replaced with a modular total femoral prosthesis (Waldemar LINK GmbH, Hamburg, Germany). The exclusion of a PJI was based on standardized procedures defined by the Musculoskeletal Infection Society [11,12].

This study was approved by the local institutional review board (Institutional Ethics Committee, No. 226/13). Radiological imaging and bone scintigraphy were carried out pre-operatively to exclude aseptic loosening or PJI.

The indication for open revision was when patients had extensor mechanism insufficiency that was refractory to conservative therapy. When reconstructing the extensor mechanism was intraoperatively confirmed as unfeasible, the prosthesis was

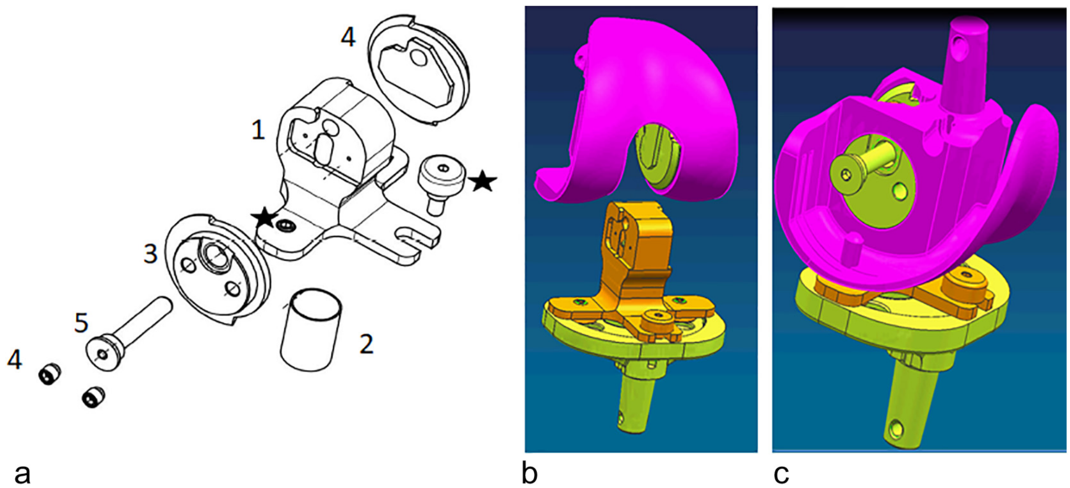

Fig. 1. Pre-operative planning proposal (Patients 2, 3 and 4) for the custom-made implant (a: plan drawing; b: virtual 3D model, ventral view; c: virtual 3D model, lateral view). Note on surgical technique for conversion of a LINK rotation knee prosthesis with cemented stems: first, the femoral coupling component was explanted. Next, an adapter [2] was put on the axis. Then, the custom-made coupling-module [1] was fixed to the tibial component with a screw (★), and the femoral guiding bushings [3 and 4] were replacement with custom-made implants without range of motion. A stable situation was established though two headless screws [4] and a linking screw, which were implanted from the medial side [5].

converted into an arthrodesis, without explanting the cemented stems. In patients without previous attempts at reconstruction, unfeasible reconstruction was defined as: an extremely degenerated tendon structure, with a wide gap between the torn ends, which could not be bridged through allograft or autograft, synthetic material, or reduced by any means. The custom-made components that were required for this procedure had been prepared beforehand to allow great flexibility in the choice of procedure during the operation (Waldemar LINK GmbH, Hamburg, Germany; Implantcast GmbH, Buxtehude, Germany).

In patients with LINK rotation knee prostheses with cemented stems (Patients 2, 3 and 4), the following surgical conversion technique was performed (Figure 1): after explantation of the femoral coupling component, the custom-made coupling module was attached to the tibial component with a screw, and the femoral and tibial components were coupled. A stable situation, without range of motion, was established by using two headless screws and a linking screw, which were implanted from the medial side. In the patient with a MUTARS GenuX knee prosthesis (Patient 1), conversion was achieved by removing the femoral component, after decoupling it from the stem, followed by fixation of the custom-made coupling module on the tibial component and femoral stem, with screws (Figures 2 and 3).

2.1. Pre-operative planning

Pre-operative planning was carried out in cooperation with the manufacturers of the prostheses systems. The median time between a request for pre-operative planning and confirmation was 13 days (95% CI 11–14). The required time from confirmation of the order to completion of the custom-made products was 31.5 days (95% CI 28–35). Figure 1 depicts an exemplary pre-operative planning proposal. Figure 4 shows the manufactured custom-made component before implantation. A further reduction in leg length, to the set goal of two centimeters in total, was taken into consideration during planning, to allow circumduction of the leg without necessitating compensation.

All patients were fully informed about the operation as an individualized treatment strategy, with off-label use of the components and operation-specific risks, especially regarding possible premature loosening of the prosthesis. Due to the off-label use of

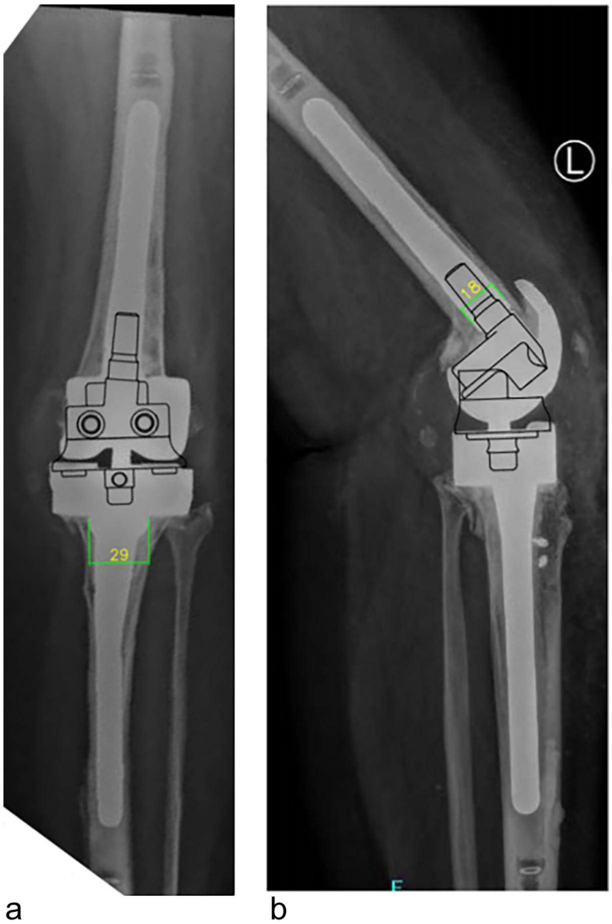

Fig. 2. Pre-operative planning proposal (Patient 1) for the custom-made implant. Conversion was performed by removing the femoral component after decoupling it from the stem, and then fixing the custom-made coupling module to the tibial component and to the femoral stem with screws.

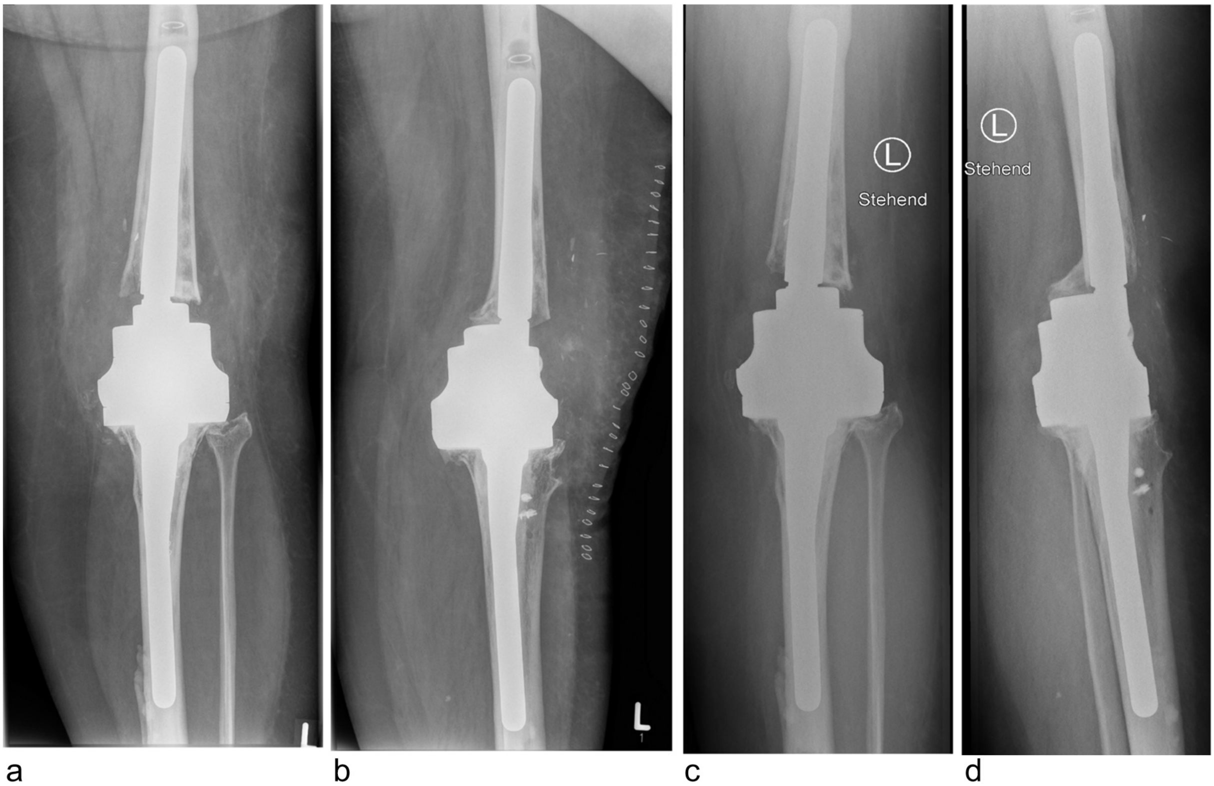

Fig. 3. Radiological follow-up of patient 1 in two planes, directly after the operation (a, b), and 2.7 years postoperatively (c, d).

the custom-made implants as an individualized treatment strategy, the manufacturers did not report any (mechanical) contraindications (e.g., body weight).

Intraoperatively, the joint was extensively debrided and the explanted components were sonicated. During the operation, at least four periprosthetic tissue samples were taken from representative areas for histopathological and microbiological processing. Microbiological processing of the samples followed standard methods, as described elsewhere [13]. Prosthesis stability was tested with the appropriate instruments to exclude any loosening. Afterwards, conversion to arthrodesis was performed. Figure 5 shows exemplary intraoperative placement.

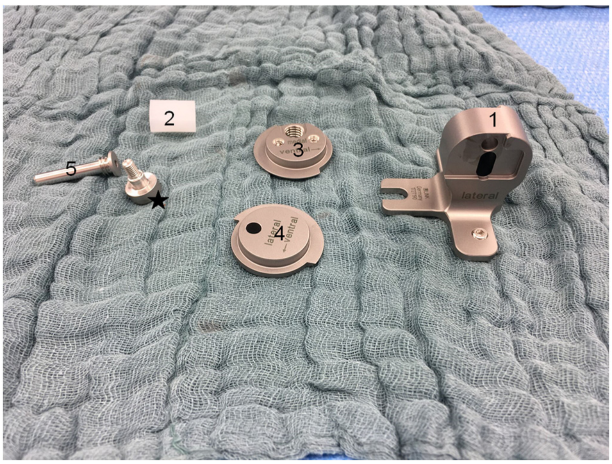

Fig. 4. Manufactured custom-made component before implantation. Custom-made coupling-module [1], adapter [2], femoral guiding bushings [3 and 4], screw (★), and a linking screw [5], which was implanted from the medial side.

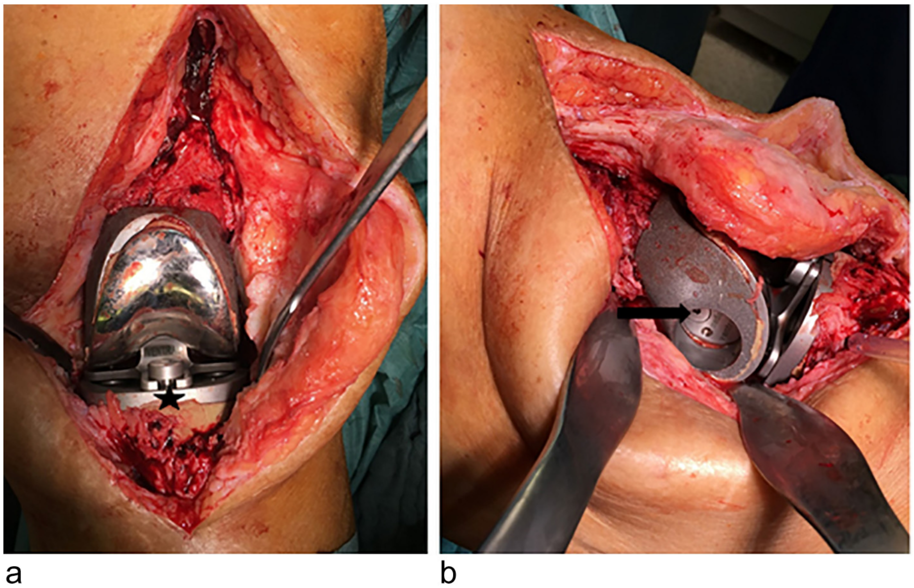

Fig. 5. Intraoperative placement after conversion. View of the left knee from anterior (a) and medial (b). The custom-made coupling module was attached to the tibial component with a screw (★). A linking screw (arrow, implanted from medial) established a stable situation without range of motion.

2.2. Clinical and radiological follow-up

Clinical and radiographic follow-up assessments were performed postoperatively at six weeks, six months and one year, and thereafter at one-year intervals. The Oxford Knee Score (OKS) and Visual Analog Scale (VAS) were assessed pre-operatively and postoperatively at final follow-up, and the limb length discrepancy was recorded [14,15]. Evaluation of the pre-operative and postoperative radiological imaging was carried out by three independent examiners, particularly regarding: new osteolysis; significant or progressive radiolucent lines in comparison with previous images; sintering of the tibial or femoral prosthesis component; and bone substance loss in the sense of stress shielding. The TKA complications work group definitions were used to evaluate postoperative complications [16]. Moreover, a distinction was made between implant-specific and non-implant-specific causes of failure.

2.3. Statistical analysis

Statistical analysis was performed with MS Excel 2016 for Windows (Microsoft Corporation, Richmond, USA). The median and its 95% confidence interval were calculated according to Calmettes et al. [17] Median and the 95% CI were used for comparison.

Table 1
Descriptive summary of patient data after retrospective evaluation.

Patient ID	Age (years)	Sex	BMI (kg/m^2)	Indication for RTKA	Duration of total extensor mechanism insufficiency (days)	Previous reconstruction attempts	Exchanged components	Type of RTKA (manufacture)
1	55.63	F	36.50	One-stage exchange (aseptic)	121	1. Primary repair, 2. Ipsilateral autograft (illiotibial tract)	Femoral joint component/ coupling module	MUTARS GenuX, cemented stems (Implantcast)
2	73.21	F	24.50	Two-stage exchange (PJI)	111	None	Coupling module	LINK total femur Megasystem C/LINK Endo M Tibia, cemented stems (LINK)
3	64.53	F	29.40	One-stage exchange (aseptic)	854	None	Coupling module	Modular Knee prostheses, Endo model M (LINK)
4	61.88	M	27.75	One-stage exchange (aseptic)	60	Primary repair	Coupling module	Modular Knee prostheses, Endo model M (LINK)
Average	63.81		29.78		286.5			

F, female; M, male; BMI, body mass index; RTKA, revision total knee arthroplasty; PJI, periprosthetic joint infection.

Table 2
Descriptive summary of patient data after retrospective evaluation.

Patient ID	Operation time (cutting/suture (minutes))	Leg-length discrepancy (pre-operative/ postoperative)	VAS (pre-operative)	VAS (post-operative)	Length of hospital stay (days)	Follow-up (weeks)	OKS (pre-operative)	OKS (postoperative)
1	86	−1.0/−1.5	7	2	11	129.28	18	36
2	154	−4.5/−4.5	5	2	12	141.43	17	30
3	122	−1.0/−1.5	6	1	21	60.71	26	35
4	98	0.0/−0.5	4	1	9	26.42	23	36
Average	115	−1.63/−2.13	5.5	1.5	13.25	89.46	21	34.25

VAS, Visual Analog Scale for pain; OKS, Oxford Knee Score.

3. Results

All patients in this study underwent a one-stage procedure. As evident from the detailed patient history and review of prior medical records, extensor mechanism insufficiency had been present for an average of 116 days (95% CI 60–854) in the four patients. The median age of the patients was 63.2 years (min.: 55.6; max.: 73.2; 95% CI 55.6–73.2). Median body mass index (BMI) was 28.58 kg/m^2 (min.: 24.5; max.: 36.5; 95% CI 24.5–36.5). In one case (Patient 1), extensor mechanism reconstruction had previously been performed, first with a primary repair and then with an autograft of the iliotibial tractus. In another case (Patient 4), a primary repair had been performed. Reconstruction of the extensor mechanism was not possible in any of the cases, nor was there evident loosening of the prosthesis. Thus, conversion to arthrodesis had to be performed in all four cases.

The median duration of the operation for implantation of the custom-made arthrodesis solution was 110 min (range 86–154). The median length of postoperative hospital stay was 9.5 days (range eight to 10). Microbiological processing of the joint aspirates and microbiological and histopathological processing of the periprosthetic tissue samples showed no evidence of a PJI; the Musculoskeletal Infection Society criteria for defining PJI were negative in all cases. For summary of patient data see Table 1 and 2.

3.1. Clinical and radiological follow-up

The median follow-up time after surgery was 95.0 weeks (min.: 26.3 weeks; max.: 141.3 weeks). One patient (Patient 4) attended one follow-up appointment, about 6 months postoperatively, and later died due to non-orthopedic reasons.

At clinical follow-up, a significant improvement in the Oxford Knee Score from 20.5 (95% CI 17–26) to 35.5 (95% CI 30–36) points was observed compared with the pre-operative evaluation. The VAS score decreased from 5.5 (min.: 4; max.: 7; 95% CI 4–7) to 1.5 (min.: 1; max.: 2; 95% CI 1–2) points. Median additional leg length difference in the postoperative radiological imaging in comparison with the pre-operative imaging was −0.5 cm (95% CI 0 to −0.5). One patient had already needed compensation prior to the operation (Patient 2: orthopedic shoes). In this patient, a further reduction in leg length was avoided. Patients 1, 3, and 4 did not need compensation for leg length discrepancy. None of the patients reported postoperative residual instability. At clinical follow-up, the complaints subsided in all patients.

In all cases, radiological evaluation over time showed no evidence of loosening, stress shielding, or vertical migration (Figure 3). At the time of the last postoperative follow-up examination, the knee joints of Patients 1, 3 and 4 were free of irritation. There were no implant-specific complications.

Patient 2 developed a chronic prosthetic joint infection (PJI) under immunosuppression (rheumatoid arthritis) 2.4 years postoperatively due to an ipsilateral abscess on her foot and refusal of surgical therapy. She declined explantation of the prostheses and a fistula was found after several unsuccessful surgical debridements. This patient is currently under weekly follow-up examination by her general practitioner. This event was considered to be a non-implant-specific complication. Further reasons for revision did not arise for any of the cases. Therefore, all of the operations were considered clinically successful.

4. Discussion

While there are several available surgical options to reconstruct a failed extensor mechanism, no gold standard has been described, to date, for treating long-term extensor mechanism insufficiency after primary TKA and RTKA [2]. The clinical results are usually known from case reports and case series, and do not exceed level III evidence. Guidelines also do not exist [2,6,18]. Especially after several revisions, a critical soft tissue situation can be an aggravating factor in cases of long-established extensor mechanism insufficiency, and hinder reconstruction. Under these circumstances, arthrodesis is considered a reasonable treatment option [1,19]. To date, several arthrodesis options have been described, such as an intramedullary nail; external fixation with a uniplanar, biplanar, or circular fixator; or the implantation of compression plates [20]. The common purpose of all options is to achieve a secure, stable, and pain-free situation, with leg length being maintained [10,21]. All methods have a reported complication rate of five to 40% in the literature [10,22]. This complication rate must be kept in mind if explantation of long cemented stems is necessary before arthrodesis. A significant loss of bone stock must be considered if a transfemoral and/or transtibial approach is required to explant the prosthesis and cement. To make matters worse, all of the currently available surgical options have significant disadvantages. External fixation and compression plates require bone-stock augmentation when there is a severe loss of bone stock, and can lead to a reduction in leg length. Furthermore, low fusion rates have been described for these procedures [20,21]. Although intramedullary systems can avoid the issue of leg length reduction and do not require bone fusion, individualized solutions are still urgently needed, especially in cases of extensor mechanism insufficiency [23].

In this context, modular arthrodesis offers the option of individual customization to the given anatomy and existing bone defects, and allows adjustment of the leg length by selection of suitable implant components. These modular components, however, require secure anchorage in the remaining bone stock. After explantation of the prosthesis, the mostly sclerotic remaining bone stock may complicate renewed anchoring and can have a significantly negative influence on the long-term results of these systems [1]. As described in this case series, conversion of RTKA to arthrodesis without explanting the firmly anchored cemented stems of the prosthesis may be a promising treatment alternative.

In all cases in this study, conversion of RTKA could be achieved by replacing the coupling component (Patients 2–4) or the coupling component and femoral component (Patient 1) of the prosthesis with a custom-made arthrodesis module. Nevertheless, this method requires the ability to firmly attach the custom-made implant to the inlying components. Thus, this treatment strategy can only be used if these requirements can be fulfilled. In this context, a consultation with the manufacturer is essential. As a result, this treatment option might not be available for all TKA designs. The implantation of an arthrodesis in the so-called 'cement in cement technique' offers another option. The prerequisite is that the stems can be removed from the cement coat without inflicting damage during the explantation. If the cement coat is damaged, alternative methods, such as cementless modular arthrodesis systems, should be available. It must be considered pre-operatively that possible damage to the cement mantle during explantation could occur; thus, alternative methods, such as cementless modular arthrodesis systems, must be provided for these cases.

Although arthrodesis is generally considered to be a poor outcome, a stable extremity usually provides pain relief [1,19,23]. In the current case series, the VAS at last follow-up was 1.5 points and the median OKS was 35.5 points. These results can be regarded as acceptable and are consistent with those reported in the current literature [24,25].

With a median leg length discrepancy (pre-operative vs. postoperative) of −0.5 cm, the leg length of the patients in this study did not significantly change through the conversion to arthrodesis. This preservation of leg length could be an advantage of this procedure [10].

This study had several limitations, including the small number of cases and the heterogeneity of the patient group in terms of the preliminarily used extensor mechanism reconstruction techniques. Nevertheless, it is believed that this retrospective case series is the only one of its kind in this thematic field. It remains to be seen in the follow-up whether long-term sustainable fixation could be achieved and whether implant survival of the 'converted' prostheses differs from the implant survival of 96.5% (five years) and 82.9% (10 years) reported in the literature for revision prostheses with cemented stems [26]. Special attention must be paid to phenomena like stress shielding near the joint, premature loosening due to consecutive congestion of the anchoring in the bone, or a failure of the modular conical connection at the anchoring points of the custom-made implants. In this context, the connections of the modular components might be more vulnerable to mechanical stress than the monobloc arthrodesis modules.

5. Conclusion

This case series exemplifies a customized surgical treatment option as an alternative, low-risk treatment strategy with satisfactory results for patients with a failed extensor mechanism after RTKA. In selected cases, this customized treatment option should be considered and discussed with the patient as a salvage procedure to provide pain relief and create a stable situation.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. For this type of study, formal consent is not required.

Declaration of Competing Interest

S Gravius has received speaker honorarium from Waldemar LINK GmbH and Implantcast GmbH and financial support from Waldemar LINK GmbH to participate in a surgery course. TM Randau has received speaker fees and travel expenses from Implantcast GmbH. FS Fröschen, N Gravius, MJ Friedrich declare that they have no conflict of interest. No benefits have been or will be received from a commercial party related directed or indirectly to the subject matter of this article.

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