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Case Report

Planned Realignment Osteotomies Ahead of Knee Arthroplasty for Pronounced Joint Malalignment: A Case Report in Hereditary Multiple Exostoses Disease

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ABSTRACT

Various approaches have been reported to achieve correctly aligned total knee arthroplasty in cases of knee arthritis with pronounced extra-articular bone malalignment. Revision instrumentation and implants have enabled bone correction coincident with knee arthroplasty in notable tibial and/or femoral deviation, however increasing operative complexity and inherent risks. In the presented patient with hereditary multiple exostoses disease and progressing knee arthritis for extra-articular malalignment, elected treatment strategy was to primarily correct joint plane deformity through femoral and tibial osteotomies, ahead of and preparing for later knee arthroplasty. Staged osteotomies prior to total knee arthroplasty are effective for managing severe extra-articular malalignment, improving surgical outcome and prosthetic longevity.

Introduction

Total knee arthroplasty (TKA) is a well-established procedure in patients with primary knee osteoarthritis with usual arthritic deviations, with a proven track record for restoration of function and good longevity of implants. In case of knee arthritis with pronounced bony malalignment (post-traumatic malunions, bone diseases, after osteotomies), TKA represents a more challenging procedure [1-4]. Various approaches to achieve correctly aligned TKA under these conditions have been reported, yet without conclusive recommendations concerning extra-articular correction procedures in relation to the knee arthroplasty procedure.

Restoring alignment in pronounced extra-articular deformity exclusively by articular bone cuts using radiographic templates was earlier shown to create potentially significant and complex ligamentous instability patterns [5]. However, this was propagated in later reports [6,7]. The development of knee revision instrumentation and implants enabled bone correction coincident with knee arthroplasty, including in notable tibial deviation [3,8-11], in femoral deviation [2,12-14], or in cases requiring simultaneous femoral and tibial osteotomy [15,16]. The scope was further widened with the advent of navigational support and patient-specific instrumentation, allowing simultaneous axial correction along with knee arthroplasty [9,17-20]. However, particularly intra-articular bone resections and extensive soft tissue releases [3,6,7,21] increased the need for implants with higher degrees of tibiofemoral constraint [1,2,4].

The strategy of simultaneous bone correction and knee arthroplasty inevitably increases operative complexity and inherent risks [1,13,14,22]. Same-stage knee arthroplasty and osteotomy for osteoarthritis with extra-articular deformity required stem extensions in all and increased prosthetic constraint in femoral and tibial deformities [10,12]. In contrast, staged extra-articular deformity correction was reported as a safe and effective approach, avoiding complex stemmed revision components at later knee arthroplasty in the vast majority of cases [23].

Knee arthritis proves the most frequent consequence of early joint degeneration in hereditary multiple exostoses (HME) disease, resulting from distortion of the tibiofemoral joint plane due to the metaphyseal exostoses in proximity of the epiphyseal growth plates. In contrast to predominantly valgus malalignments in HME [19,24-26], our patient presented pronounced overall varus

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alignment and distal femoral varus deformity as sequelae of medial hemiepiphysiodesis of the distal medial femur during pubertal growth.

In the sparse case reports of knee arthroplasty in HME disease with concomitant deformities, simultaneous corrections requiring arthroplasty systems with long-stemmed components or increased prosthetic constraint were performed in all patients [11,19,21,25].

In the presented clinical situation with a relatively young patient age demanding a high level of activity and with a stemmed ipsilateral hip arthroplasty, the chosen treatment strategy was to primarily strive for a near normal joint plane through femoral and tibial osteotomies, ahead of and preparing for later knee arthroplasty, according to following principles:

- Achievement of restored static alignment through correction osteotomies
- Use of a condylar resurfacing knee prosthesis in primary TKA
- Preservation of ligament structures, lowest level of arthroplastic constraint

Case history

Preoperative evaluation

A 54-year-old man with muscular posture (body mass index 30.4 kg/m^2) and family history of HME disease presented medial-side left knee pain, with predominant load-dependent pain characteristics (Fig. 1). At the age of 14 years, epiphysiodesis at the medial epiphyseal plate of the distal left femur was performed. Further orthopaedic manifestations associated with HME disease and corresponding therapies of the lower extremities included surgical resection of an intertrochanteric osteochondroma of left proximal femur and corrective osteotomy of the distal right tibia for symptomatic valgus deformity with consecutive tibiofibular synostosis.

In gait analysis, left knee varus malalignment was shown, with limitations in range of motion to extension/flexion 0°-10°-105°. Unremarkable scar conditions following epiphysiodesis at the left distal medial femur were recorded. Besides tenderness over the

Figure 1. Initial condition of 54-year-old man with HME, left knee medial compartment arthritis and severe varus malignment of joint plane. (a) Long leg view lower extremities, (b) left knee frontal view, and (c) left knee lateral view.

medial joint space, the collateral and cruciate ligaments were clinically stable.

Conventional calibrated radiographs showed osteoarthritis in the medial compartment with narrowing of the medial joint space. On full-length view of the lower extremities, pronounced femoral varus angulation of 22° [mechanical lateral distal femoral angle (mLDFA) 108°] and tibial valgus deformity of 19° [mechanical medial proximal tibial angle (mMPTA) 106°] were measured. Additionally, leg length discrepancies with relative left-sided femoral shortening of 5.3 mm and relative left-sided tibial overlength of 8 mm were noted. Native magnetic resonance imaging showed pronounced cartilage thinning in the medial compartment with preserved lateral and patellofemoral cartilage, and no damage to the collateral and cruciate ligaments. With clinically equal rotational alignment, no additional rotational computed tomography was required.

Based on the given angular deformities and length discrepancies, and according to the chosen strategy potentially delaying and preparing for later knee arthroplasty, the radiographic planning aimed at restoring regular angulation and level of the knee joint plane.

Isolated tibial or femoral osteotomy might have possibly corrected the overall HKA axis, but would have left the noncorrected counterpart and in particular the joint plane in malalignment, still posing problems at later knee arthroplasty. Therefore, combined femoral and tibial osteotomies seemed inevitable to correct the joint plane.

On the tibial side, medial closing-wedge osteotomy at the proximal-metaphyseal level with varus correction of the tibial plane and relative shortening of tibial length seemed appropriate. On the femoral side, medial opening-wedge osteotomy of the distal-metaphyseal level with valgus correction of the femoral plane and relative lengthening of femoral bone length were planned (Fig. 2). With the intended bone length corrections, alternative osteotomy techniques such as dome type osteotomies not altering bone length were obviously not considered.

Surgical technique

Correction osteotomies

A transcondylar 2-plane medial closing-wedge osteotomy of the proximal tibia metaphysis was performed, with planned correction angle of 19° and removal of a 23 mm osteotomy wedge. The osteotomy was stabilized using an angular-stable 4-hole tibial-head TomoFix plate (DePuy Synthes, Oberdorf, Switzerland). Femoral access was achieved through a medial subvastus approach to the

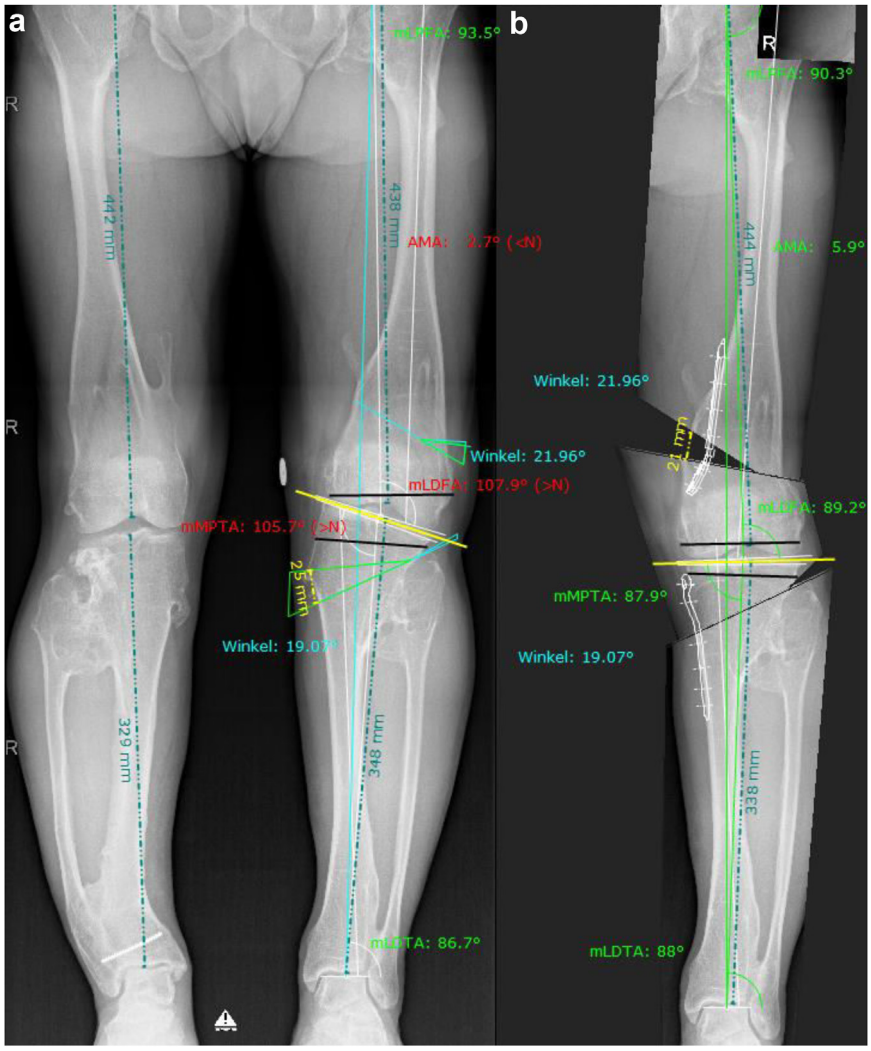

Figure 2. Preoperative radiographic double osteotomy planning. (a) Frontal deformity angles and planned correction angles. (b) Tibial medial closing wedge and femoral medial open wedge osteotomies.

distal femur, incorporating the existing anteromedial scar. Following resection of a posteromedially originating metaphyseal osteochondroma formation, the medial supracondylar opening-wedge osteotomy of the distal femur metaphysis was performed with planned angular correction of 22°. The femoral osteotomy gap was filled with the harvested tibial bone wedge and the osteotomy was stabilized using an angular-stable 4-hole medial femoral TomoFix plate (DePuy Synthes, Oberdorf, Switzerland).

After uneventful wound healing, partial weight-bearing with 2 forearm crutches was accomplished for 3 months until osteointegration of the interposed bone wedge and stable osseous conditions of the osteotomies were radiographically confirmed. Over the following 2 years, knee pain gradually decreased to a well-tolerable level.

Because of progressive left-sided hip pain due to advanced dysplastic coxarthrosis, 13 months after the corrective osteotomies, left total hip arthroplasty with cementless acetabular and long-stem femoral components was performed. The postoperative course was uneventful.

After removal of the osteotomy plates 2 years postoperatively, slowly progressive medial-compartment knee pain with increasing arthritic characteristics developed. With residual femoral malalignment (mLDFA 100°) on full-length radiographs, additional supracondylar lateral closing-wedge osteotomy with 19° angular correction was performed, stabilized with an angular-stable 5-hole LISS plate (DePuy Synthes, Oberdorf, Switzerland). No complications were documented postoperatively, and the patient reached full weight-bearing after 2.5 months with proven bony consolidation. Radiographically resulting femoral and tibial joint planes and overall mechanical tibiofemoral alignment were within regular ranges of primary knee arthritis (mLDFA 91°, mMPTA 88°).

Knee arthroplasty

Based on favorable joint alignment and imaging approved (magnetic resonance imaging) intact collateral ligaments, non-constrained tricompartmental knee arthroplasty was planned (Fig. 3). Using the previous medial osteotomy accesses, an anteromedial approach was performed, including tibial tuberosity osteotomy due to quadriceps shortening. Panarticular chondromalacia was confirmed intraoperatively. Computer navigation–assisted (Kick, BrainLab, Munich, Germany) correction and osteotomies of the remaining arthritic varus deformity (9.5°)

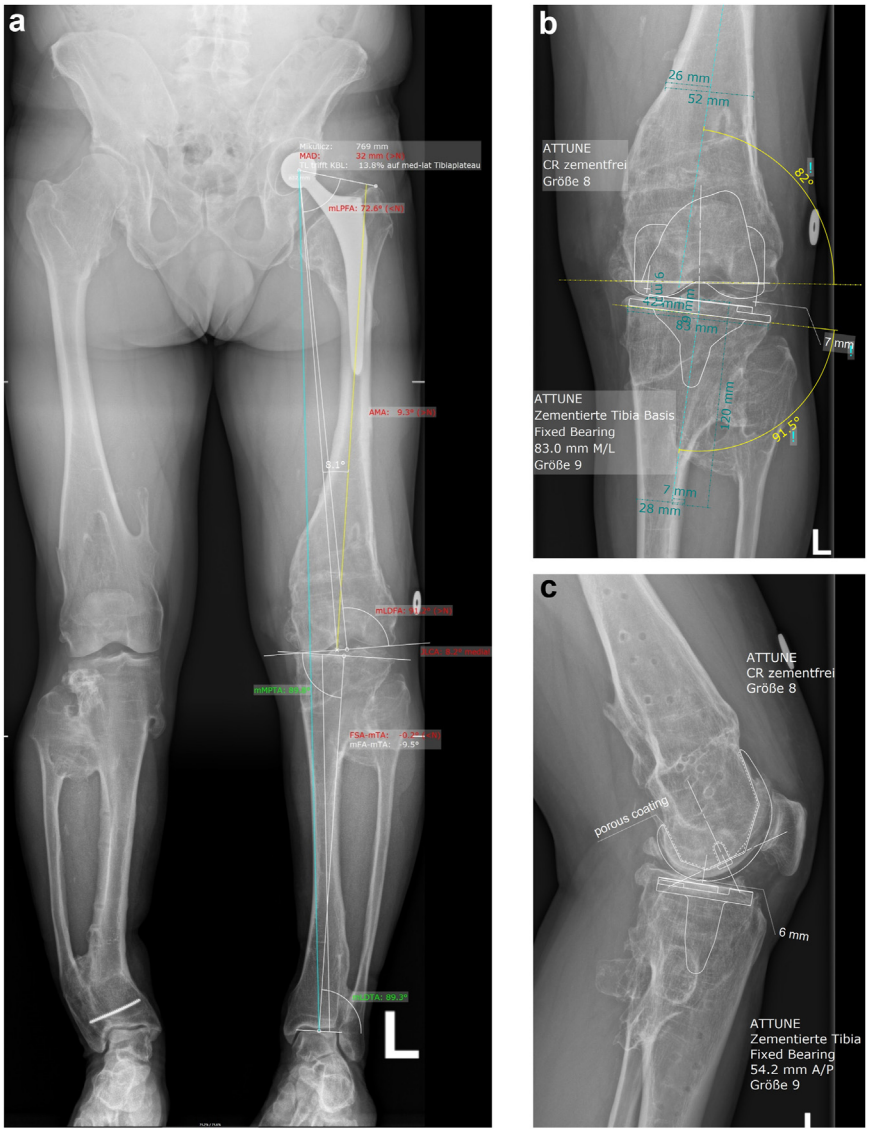

Figure 3. Preoperative total knee arthroplasty planning. (a) Long leg view left lower extremity, (b) left knee close-up frontal view, and (c) left knee close-up lateral view.

was performed. Symmetric flexion and extension gaps were achieved without need for additional soft tissue releases. Standard knee arthroplasty components (Attune, DePuy Synthes, Cork, Ireland) were implanted, with cruciate-retaining porous-coated femoral component, fixed bearing tibial insert and cemented metal-backed tibial component, and cemented medial dome patellar component. Finally, the tibial tuberosity osteotomy was fixed with 2 small-fragment (3.5 mm) cortical screws.

Postoperative evaluation

Following tuberosity osteotomy and until osseous integration, straight leg raise was avoided with partial weight-bearing of 20 kg for 8 weeks. One year postoperatively, the patient is completely pain-free, with excellent subjective proprioception and stability of his TKA, unrestricted for professional and leisure activities including alpine skiing. Clinically passive range of motion with extension/flexion of 0°-3°-105° and stable collateral ligaments over the entire motion range were shown. According to full-length radiography, the targeted alignment of the prosthetic components and overall tibiofemoral alignment have been achieved (mLDFA 91°, mMPTA 90°) (Fig. 4).

The patient provided the authors with written informed consent to report this case in the literature.

Discussion

In knee arthroplasty for degenerative knee arthritis with regular alignment conditions, there is continuing consensus to achieve optimal overall static alignment within a balanced soft tissue envelope to avoid early implant failure [5,11,13,27-30]. The management of notable extra-articular deformity in knee arthritis needing arthroplasty remains a matter of continual debate, depending on various factors including age and activity level of the patient, underlying diagnosis and concomitant ipsilateral joint diseases, location and extent of the deformity, and functional parameters of the arthritic knee [1-3,6,13].

The well-founded analysis of Wolff et al. [5] highlighted the impact of degree extent and proximity of an extra-articular deformity on the knee joint. By means of overlay templates and graphical

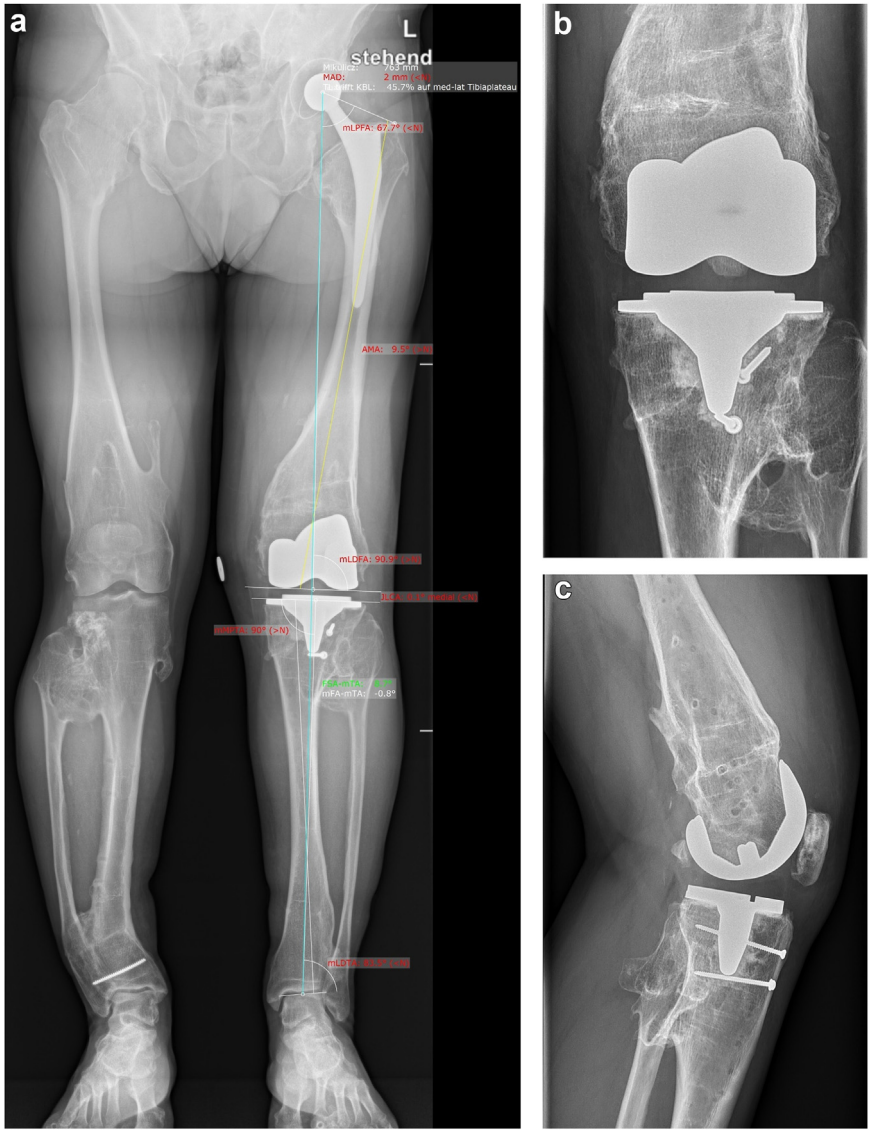

Figure 4. Postoperative 1-year results with achieved realignment. (a) Long leg view lower extremities, (b) left knee image intensifier targeted frontal view, and (c) left knee image intensifier targeted lateral view.

analysis, the boundaries of intra-articular correction of extra-articular deformities were outlined, suggesting corrective osteotomies to preserve the collateral ligamentous structures. Consensus is given on the need for preservation of the collateral ligaments, avoiding excessive release of the concave-sided ligament structures and destabilization of the insertion areas of the contralateral ligaments by the intra-articular osteotomies requiring knee arthroplasty systems with increased constraint [3,8,14,18].

In contrast, Wang et al. [6] reported on TKAs in knee arthritis with extra-articular deformities, propagating feasibility of intra-articular corrections of up to 20° of femoral and up to 30° of tibial coronal deformities. These findings were supported by other authors [4,7,20].

Based on extent and location of femoral and tibial angular deformities and respective radiographic planning of the presented patient, corrective osteotomies ahead of or concomitant to knee arthroplasty were considered necessary. Moreover, relative femoral and tibial length discrepancies with consecutive inequality of the knee joint levels suggested corresponding bone length corrections. This was achieved on the tibial side by means of shortening closed wedge osteotomy and on the femoral side by means of lengthening open wedge osteotomy.

Simultaneous correction osteotomy and knee arthroplasty have been recommended [6,9,10,12,17,19], claiming advantages of reduced operative interventions and shortened treatment duration [13-15]. This approach however requires stemmed components to stabilize the osteotomies in proximity to knee arthroplasty implants and increases the need of constraint articulations [1,2,4,11,12,16]. Besides favorable functional results, increased complication rates of 18.2%-46.7% have been reported [13,14], including increased hematoma and infection rates due to prolonged operative time, and ligament instability as well as non-unions as a consequence of increased technical complexity.

In contrast, with given criteria and thresholds concerning extent and location of angular deformities, staged osteotomies followed by subsequent knee arthroplasty were recommended [23,27], claiming a safe approach to bone alignment correction while maintaining articular soft tissue tension. Apart from potential postponement of knee replacement, preserving capsuloligamentous structures enables later knee arthroplasty using a standard knee arthroplasty system with nonconstrained articulation and epiphyseal anchorage of the arthroplasty components, reducing technical complexity and consequently perioperative complications, potentially increasing implant survival.

In the presented case, the need for combined angular and length corrections at both femoral and tibial sections adjacent to the knee joint had to be achieved by separated correction osteotomies. From our point of view, reducing operative complexity by means of preceding osteotomies and improvement of later knee arthroplasty outweighed the argument of intervention numbers.

Apart from high accuracy of bone cuts and consequently reliable mechanical alignment [9,17,18], computer navigation in TKA overcomes potential conflicts with intramedullary hardware such as stems of ipsilateral hip arthroplasties [3,27]. Using navigation support for the presented case provided the most accurate technique for correction of the residual arthritic joint deformity. Weight-bearing radiographic control approved final achievement of the aimed alignment.

In the sparse reports of knee arthroplasty in HME disease, frequently lacking comparable information concerning preoperative extent and location of the deformities, various operative techniques have been applied, predominantly using arthroplasty systems with higher constrained or hinged articulations and long-stemmed components [11,19,21,25]. Staged approaches in knee arthritis for pronounced extra-articular deformity with alignment correction separated from later knee arthroplasty have not been reported to date.

The presented clinical situation of a relatively young patient age with demanding activity level and stemmed ipsilateral hip arthroplasty in place demonstrates how the chosen treatment strategy of preceding femoral and tibial osteotomies prepared the arthritic knee joint for a primary knee arthroplasty system precluding the necessity of stemmed revision implants and increased arthroplastic constraint.

Summary

- For arthroplastic treatment of knee arthritis with notable extra-articular deformities, both extended preoperative planning and operative experience are required.
- The aim of preceding axial realignment by means of correction osteotomies close to the knee joint enabling consecutive implantation of a primary nonconstrained TKA was achieved.
- Based on general experience in knee arthroplasty and given the favorable clinical and radiographic results, the presented treatment strategy may be recommended for patients with knee arthritis in HME disease or other sequelae with severe leg malalignment or bone length inequalities requiring knee arthroplasty.
- This may in turn result in optimal functional results and longest possible survival of the arthroplastic knee joint.

Conflicts of interest

The authors declare no competing financial interests or personal relationships interfering with the presented case report. The authors received no financial support for the research, authorship, and publication of this article. The research did not receive any specific grant.

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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).

Ethical approval

Due to the retrospective character of the study and according to the Swiss law, no consultation of an independent local/national medical ethics committee was required (Ethikkommission Nordwest- und Zentralschweiz EKNZ).

The protocol of this study is in accordance with the 64th WMA Declaration of Helsinki—Ethical Principles for Medical Research Involving Human Subjects, Fortaleza, Brazil, October 2013.

CRediT authorship contribution statement

Tim Schmid: Writing – review & editing, Writing – original draft, Visualization, Data curation. **Marietta Schmid:** Writing – review & editing, Writing – original draft, Visualization, Data curation. **Pascal A. Schai:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Formal analysis, Data curation, Conceptualization.

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