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## V 1—Tumor-associated segmental bone defects

### V1.02

#### Double barrel vascularised fibula grafts and subsequent intramedullary lengthening for reconstruction of the distal femur following resection of Osteosarcoma

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**Question:** The use of free vascularised fibula grafts is a common technique for the biologic reconstruction of the distal femur after resection of malignant bone tumours. One major problem, however, is the mismatch between the cross-sectional area of the transplanted fibula graft and the local bone as well as resulting leg length discrepancies.

Aim of this study was the evaluation of a staged surgical approach for reconstructing the distal femur—the use of a folded free vascularised fibula graft in A-frame configuration with intramedullary nail fixation and subsequent leg lengthening.

**Methods:** In total 10 patients (mean age 10 years) with an osteosarcoma of the distal femur who were treated with this unique technique—(1) tumour resection with immediate defect reconstruction using a folded free vascularised fibular graft with nail fixation and (2) subsequent intramedullary leg lengthening—were included in this retrospective study. We evaluated all patients with regards to hypertrophy/consolidation of the graft-host junctions, leg length discrepancies, complications as well as the functional/oncologic outcome.

**Results:** The mean defect size was 15 cm, the mean length of the harvested fibula graft (before folding) 22 cm on average. Consolidation was achieved in all cases, whereas bone grafting had to be performed in 4 patients. We recorded hypertrophy in 75% of all graft-host junctions. At the latest follow up, a successful intramedullary leg lengthening procedure had been performed in 7 patients. Obstacles, problems and/or complications were recorded in 40% of our patients (overall—stage 1 and 2), the mean follow-up averaged 6.3 years.

**Conclusion:** The shown technique adds a valuable alternative option for reconstructing the distal femur after resection of malignant bone tumours. Fixating the A-frame construct with a solid rod facilitates a subsequent nail exchange and intramedullary leg lengthening procedures.

### V1.04

#### Fibula-assisted segmental bone transport using intramedullary lengthening nails after Adamantinoma resection

A. Rachbauer, R. Rödl, G. Gosheger, N. Bröking, A. Frommer, A. Laufer, G. Toporowski, B. Vogt

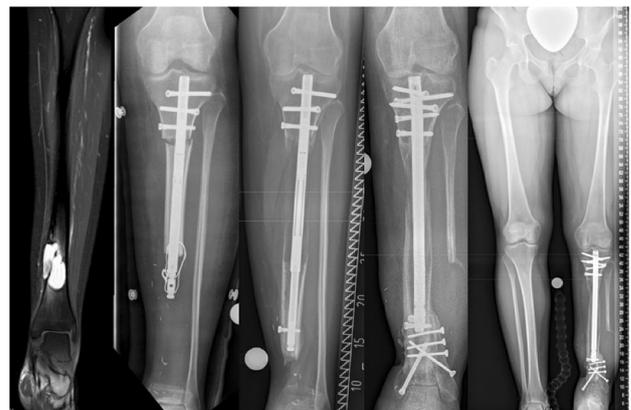
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**Question:** Adamantinomas are rare bone tumors, usually affecting the tibia without infiltration of the soft tissues. Therapy consists a wide tumor resection, chemotherapy or radiotherapy are not needed because metastases and local recurrence occur seldomly. Various opportunities are there to reconstruct the resected tibia. In most cases vascularized fibula transfer is used.

Segmental bone transport is often used to treat bone defects (e.g. trauma, tumour, infection, congenital). A new technique, PABS—plate assisted segmental bone transport, uses a magnetic limb lengthening system and a plate, which maintains the position of the fragments, for segment transport.

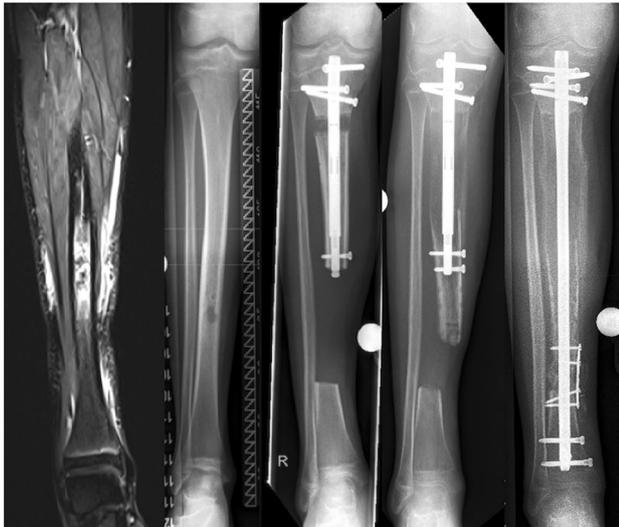
**Methods:** We report on the results of a segmental bone transport in two patients, suffering from adamantinoma of the tibia using ipsilateral fibula as a biological bone plate.

**Results:** Patient OL, female 24 years, was treated by resecting 15 cm of distal tibia in 08/16, followed by osteotomy of the proximal tibia and antegrade insertion of a PRECICE nail (NuVasive). Lengthening started at the 10th postoperative day. Docking was done following the second nail change. Another change of the nail to lengthen for 4 cm is planned.



Patient OL

Patient CF, male 15 years, received the resection of 11 cm of the right tibia in 08/18, followed by proximal osteotomy and antegrade implantation of a PRECICE nail. After distraction of 5 cm (maximum of distraction length) a surgery was performed to restrict the nail to the primary length so another distraction could be performed using the same nail. When leg length equality was achieved, docking was done using a plate an autologous bone graft from the pelvis.



Patient CF

External stabilization during bone transport was provided by a cast, followed by orthosis.

**Conclusion:** Using the fibula as plate for guidance is an elegant and good option to bridge bone defects where the fibula can be spared thus reestablishing leg length. In addition, the perioperative hazards attributed to fibula transfer from contralateral side might be avoided.

## V 2—Infection-associated segmental bone defects and regenerate insufficiency

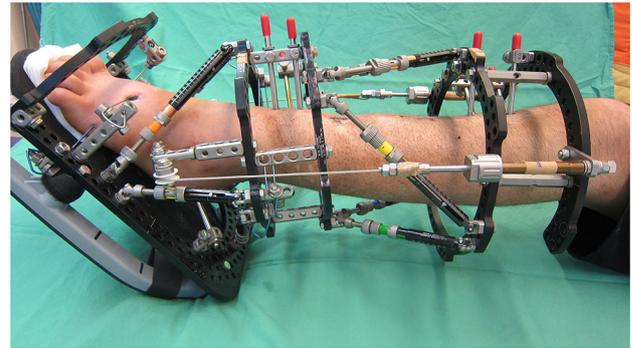
### V2.02

#### Bridging of a large tibial bone defect with the Taylor frame and segment transport with cable technique (Case report)

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**Question:** The bridging of long bone defects presents a special challenge to the growing skeleton. The main focus concentrates on different causalities that favor pseudarthrosis of the tibia. Acquired forms are currently also war injuries. In our case, an infectious tibial pseudarthrosis is presented after a shell splinter injury. The 13-year-old Syrian boy had a grenade splinter injury that was stabilized with a unilateral fixator. Unfortunately, it came to infection and long-range pseudarthrosis.



Proximal frame system: TSF in combination with cable technique transport system. Distal frame system: equinus correction by TSF using the “rocker foot” method.

**Methods:** During a brace treatment, the infection could be cured, so that there were now three corrections after malalignment test needed: 1st defect of about 8–10 cm, 2nd varus deformity with shortening, 3rd equinus position of about 60°. The aim was to correct all 3 misalignments at the same time. With an additional cable technique system, large gaps can be bridged at a distraction speed of max. 1 mm/day. The fibula was not fixated on TSF-System. The same principle applies to the foot correction. The correction of 60° equinus with simultaneous varus correction and extension over the cable system of 10 cm callus distraction could be carried out on schedule within 100 days.

**Results:** After docking operation, the tibia healed to an axis-aligned bone with continuity. The consolidation period is to be determined individually.

**Conclusion:** If the fibular length is normal, the presented method is quite a rare alternative to heal long bone defects of the tibia.

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### V2.03

#### Bone-defect-reconstruction with the Masquelet-technique after treatment of osteomyelitis

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**Question:** Aim: For which patients is bone defect reconstruction with the Masquelet-technique after the treatment of osteomyelitis suitable and which results did we have.

**Methods:** From 11/2011 to 7/2018 we treated 120 Patients (36 f, 84 m) with bone defects up 150 mm after septic complications with the Masquelet-technique. We had infected-non-unions of upper and lower extremity, chronic osteomyelitis, infected knee-arthrodesis and knee- and ankle-joint-empyema. On average the patients were 51 (10–82) years old. The mean bone defect size was 49 mm (15–150). Most of our patients came from other hospitals, where they had up to 20 (mean 5.1) operations caused by the infection. Time before transfer in our hospital was on average 6.6 months (0.5–48). 92 patients received free (25) or local (67) flaps because of soft tissue-defects. 58 patients suffered a polytrauma. In 26 cases femur, in 4 cases a knee arthrodesis, in 74 cases tibia, in 2 cases foot, 6 times ankle-joint arthrodesis, in 6 cases humerus, in 4 cases forearm were infected resulting in bone defects,

In most cases the indication for the Masquelet-technique was low-/incompliance due to higher grade of brain injury and polytrauma followed by difficult soft tissue conditions and problems with segment transport.

In 2/3 positive microbial detection succeeded at the first operation. Mainly we found difficult to treat bacteria. After treating the infection with radical sequestrectomy, removal of foreign bodies and filling the defect with antibiotic loaded cement spacer and external fixation we removed the spacer in common 6–8 weeks later and filled the defect with autologous bone graft. Most of the patients needed an internal fixation after removing of the fixes.

All patients were examined clinically and radiologically every 4–6 weeks in our outpatient department until full weight bearing, later every 3 months.

**Results:** In 102 of 120 cases the infection was clinically treated successful. 63 patients are allowed full weight bearing (45 with secondary internal plates). There were 18 recurrences of infection, 3 patients underwent lower limb amputation.

**Conclusion:** Conclusions: For patients with low-/incompliance for various reasons and for those with difficult soft tissue conditions following flaps the Masquelet technique is a valuable alternative to normal bone graft or segment transport. The stiffness of the new Masquelet-bone as a rod seems a problem and internal fixation is necessary.

## V2.04

### Salvage procedure for periimplant infections after HTO with the Taylor spatial frame: a case series

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**Question:** Periimplant infection after high tibial osteotomy (HTO) with necessary implant removal is rare. The incidence for deep wound infection following Tomofix fixation ranges between < 1 and 3.6%. It is a severe complication, requires further surgeries and can lead to a total knee arthroplasty or even knee arthrodesis.

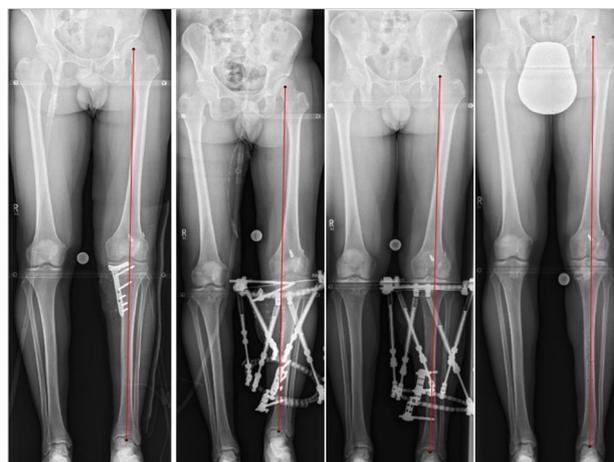
The main objective of this study was to describe the salvage procedure of periimplant infection after HTO of a level-1 trauma center.

**Methods:** These case series consist of seven patients treated between 2016 and 2019 in the septic department of a level-1 trauma centre. All patients had infections following HTO treatment. Infections occurred within 83 days (range 24–191) days following HTO

**Results:** In most cases, an emergency surgery was necessary within 6 h following patient's appearance in our emergency department. The

first surgery contained hardware removal, debridement of infected tissue and application of local antibiotics. In case of insufficient bone consolidation of the osteotomy, an external fixator or an orthosis was applied. Following surgeries may contain a second debridement and soft tissue replacement with free flaps.

After radical debridement, negative pressure wound therapy, successful local and systemic infection therapy, in some cases autologous bone marrowing and wound closure with flaps, a Taylor Spatial Frame was applied in varus alignment. Full weight bearing was allowed. After 14 days, the TSF was used to dynamically correct the varus malalignment to the initially intended limb alignment of the HTO. We had minor complications such as PIN irritation and pain. One patient had thrombosis and pulmonary embolism caused by self-reliant stop taking the recommended thrombosis prophylaxis. The mean duration of bone healing or removal of the TSF was 24 weeks (range 11–35 weeks). In all cases, the initially intended limb alignment of the HTO procedure was restored.



Documented x-rays of one case

**Conclusion:** The TSF is an excellent hardware for a salvage procedure with full weight bearing in early postoperative HTO infection with necessary implant removal and an unstable bone. With TSF treatment, the bone can heal and additionally the limb alignment can be restored.

However, TSF treatment is a demanding procedure and should only be performed by skilled surgeons with high experience in external fixators.

## V2.05

### Callus distraction procedures by osteogenesis imperfecta patients

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**Question:** Most commonly due to multiple fractures in childhood patients with osteogenesis imperfecta may acquire limb length discrepancies as well as secondary deformities in the shortened limb. Refracture rate in these patients is increased, especially in bones that are not protected by an intramedullary nail, in addition the overall consolidation time tends to be longer. The aim was to find a reliable and safe method for limb lengthening in this population.

**Methods:** In this retrospective study we compared five patients with osteogenesis imperfecta that had an average shortening of the lower limb of 3.8 cm. One group of two patients was treated by tibial lengthening with an external fixator followed by intramedullary rodding. This group were patients with Sillence type 3 that had a concomitant deformity and also a tibial diameter not allowing for lengthening nail use. The second group of three patients were either Sillence type 1 or 4 with predominantly femoral leg discrepancy, thus allowing the use of an intramedullary lengthening nail. Here the treatment was aided by the use of IV bisphosphonate therapy.

**Results:** In both groups the goal of equalizing the leg length discrepancy as well as correcting the underlying deformity was obtained. In the external fixator group 4 cm of lengthening in both patients were achieved with a mean healing index of 71.25 days/cm. After fixator removal both tibiae were rodded and further protected by an orthosis due to the week regenerate. Thus a refracture or loss of correction were avoided. In the second group an average of 3.65 cm were lengthened, in one patient the nail had to be exchanged prematurely to a trauma nail due to incomppliance of the patients to prevent the risk of fracture. The consolidation time, meaning the effective time until full weight bearing, was in this group 30 days/cm and thus significantly shorter than in group 1.

**Conclusion:** Limb lengthening in osteogenesis imperfecta patients can be performed in a safe and reliable way by internal or external means. If possible the use of fully implantable intramedullary lengthening devices is advocated in combination with a bisphosphonate therapy.

## V 3—Reconstruction of congenital deformities

### V3.01

#### Preparing the limb for reconstruction through femoro-pedal distraction in complete tibial aplasia

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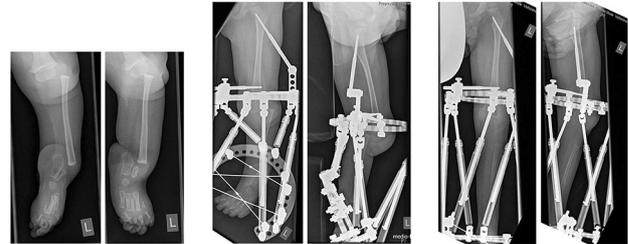
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**Question:** Tibial hemimelia is an extremely rare preaxial longitudinal deficiency (hypoplasia or aplasia) of the tibia alongside a relatively intact fibula. Surgical treatment in complete agenesis of the tibia is challenging and controversial. Through-knee amputation usually provides good results through one single surgery, but many families desire a limb salvage treatment instead. Reconstructive surgery aims to create a weight bearing limb, but it should be staged due to the complexity of the deformity. We evaluated the role of femoro-pedal distraction (FPD) through a circular external fixator to prepare the limb for reconstructive treatment in patients with complete tibial aplasia. The purpose of FPD is to distalize the fibula underneath the femur and to achieve sufficient soft tissue distraction.

**Methods:** We carried out a retrospective study in 8 patients (9 limbs) with complete tibial aplasia who received a staged reconstructive treatment in our department. In the first intervention a circular hexapod external fixator (Taylor Spatial Frame<sup>TM</sup>) was applied. FPD was performed over a course of several months. In the subsequent

intervention a reconstruction of the knee joint and a foot realignment were performed.

**Results:** Mean follow-up period was 6.38 (SD ± 3.42) years. The patients had an average age of 2.81 (SD ± 1.18) years when the fixator was applied, and the mean time under distraction was 132.13 (SD ± 32.23) days. The fibula was distalized by an average 40.56 (SD ± 21.48) mm. In 4 out of 9 cases (44.44%) pin infections occurred, which were handled by administration of oral antibiotics. In one case one pin had to be revised due to an osteomyelitis. In one case a fracture of the femur occurred which had to be reduced surgically. No frame had to be removed prematurely. A sufficient leg realignment and soft tissue distraction was achieved in all cases, allowing subsequent reconstructive surgery.



X-ray series of femoro-pedal distraction

**Conclusion:** In cases of complete tibial aplasia when limb salvage treatment is desired by the family, realignment of the leg as well as soft tissue distraction can be sufficiently achieved by femoro-pedal distraction prior to the ultimate reconstructive surgery. Because knee extension tends to decrease during growth, in some cases FPD has to be repeated until achieving skeletal maturity.

### V3.02

#### Complex forearm reconstruction in ulna hypoplasia Bayne type II

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**Question:** In ulnar hypoplasia with larger deficits of the ulna like in Bayne type II in most cases partial resection and fusion to a single-bone-forearm is recommended. Nevertheless this restricts the arm severely in the range of motion regarding pronation + supination. The objective was to preserve the mobility while stabilizing the forearm with further possibilities of lengthening correction.

**Methods:** Single case report using a Mini-Illizarov device to first lengthen the bony parts of the ulna while distalizing the radius and thus lengthening the complete forearm. During this procedure the distal cartilaginous Anlage was augmented by cancellous autograft two times until the ulna was completely ossified.

**Results:** The follow-up after hardware removal shows good form and function as well as additional ROM in comparison to a single-bone-forearm.

**Conclusion:** In some cases the therapy we used might be a good alternative for a one bone forearm procedure.

### V3.03

#### The reconstruction of congenital longitudinal diminution defects with an internal mini distractor on children's hand and feet. What is possible and necessary? An experience report after 15 years of practice

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**Question:** Longitudinal diminution defects are very rare, congenital, metric malformations affecting the longitudinal growth of small and large bones with a disorder of development of the epiphysis. Affected on hand and feet of children are especially the phalanges as well as the metatarsal and metacarpal bones. Besides the cosmetic anomalies the disorder can lead to substantial functional disabilities and physical constraints. Particularly on feet, the need of an operative treatment must be determined precisely at an early stage for the sake of not compromising the shape change of the child and to avoid late effects on posture and musculoskeletal system through a disorder of the proprioception. Consequently, it's not the cosmetic reasons, but sheer functional aspects, which make a correction of these diminution defects on metatarsals and metacarpals mandatory. Looking back on the last 15 years an experience report is given focusing on necessity and chances of a reconstruction of the above described defects.

**Methods:** Two operative treatment options are available for the reconstruction of these congenital diminution defects (Brachymetacarpia and Brachymetatarsia), whereas, because of the low intra- and post-operative complication rate, the callus distraction by Illizarov prevailed. In contrast to the "one stage" technique this option as well allows the correction of bigger defect zones and shows no donor site morbidity. The method has experienced a renaissance due to the development of an internal mini fixator for the correction of Brachymetatarsia and Brachymetacarpia and has for more than 15 years replaced the external fixator, which turned out to be uncomfortable accompanied by a lot of complications. For the therapy of longitudinal diminution defects on small bones this surgical procedure is nowadays the "Golden Standard" evidenced by the experience and results of over 150 reconstructions.

**Results:** At first, based on impressive examples the meaning and necessity of a correction of longitudinal diminution defects will be pointed out in the lecture. The surgical technique by callus distraction with the internal fixator will be introduced as well as the implant itself, the aftercare and experiences after 15 years of use on over 150 reconstructions of partially very complex congenital malformations on children's hand and feet.

### V3.04

#### Strategies in symptomatic ankle ball-and-socket joints

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**Question:** Ankle ball-and-socket joints are a rare congenital malformation highly associated to longitudinal deficiencies caused by fibular hemimelia. There are varying degrees of severity in form and function. Spherical rotational correction can address overuse symptoms while preserving joint mobility. Finding a way to predict future

symptomatic ankle joints might open pathways for prophylactic treatment like overcorrection hemiepiphyodesis.

**Methods:** Retrospective study evaluating 33 patients with the condition of an ankle ball-and-socket joint. The mean age of the patients was 16, 12 years. In this collective 12 patients were symptomatic regarding deformity and/or function, resulting in pain in 5 patients. Asymptomatic patients had no treatment or insoles with arch support. In 12 cases we performed reconstructive surgery by hemiepiphyodesis, spherical rotation osteotomies and combinations with foot reconstruction procedures.

**Results:** The mean age of the patients operated on was 18, 92 years. In general the symptoms develop at an older age, possibly correlating to weight and signs of joint destruction. Medial hemiepiphyodesis may have a protective value, if used at an early stage with the onset of symptoms. In two cases we found improved balancing in the ankle joint, if the foot deformity itself is limited. In two cases with acute spherical rotation correction (dome osteotomy of 30°) we found correct balancing of the ankle and high satisfaction regarding pain relief.

The combination of lengthening and gradual spherical correction or combined foot reconstruction was performed in five cases with good intermediate results except for the most severely deformed joint, that persisted to be painful after longer walking distances.

In two cases a SHORDT procedure was performed which showed only mild benefit in one case and a quick relapse in the other.

**Conclusion:** The ball-and-socket ankle joints are at risk of early arthritis, especially if unbalanced in valgus deformity. In our collective we saw in one third of our patients pain, that led to the need of intervention at the mean age of 18 years.

To prevent more invasive surgery early hemiepiphyodesis may be a minimal invasive way to help balancing the ankle joint and thus possibly preventing earlier deterioration. In the case of dysbalance in combination with pain the spherical rotation correction is a good motion sparing alternative.

### V3.05

#### Antegrade femoral intramedullary lengthening in combination with axis correction by guided growth

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**Question:** Congenital and acquired femoral limb length defects tend to be associated with a distal femoral axis and also sometimes torsional deformity. For intramedullary lengthening with a lengthening nail a retrograde approach therefore concurs with the antegrade due to the option of correcting all dimensions in one procedure.

The goal was to use a staged, minimally invasive, physis sparing procedure to obtain the equal results than using the retrograde lengthening technique.

**Methods:** We evaluated 10 limbs in 5 girls and 5 boys retrospectively. All had the lengthening procedure by an antegrade magnetic lengthening nail with a proximal femoral corticotomy, when necessary acutely combined with a torsional correction. The etiology was in 8 cases a congenital short femur, 1 Ollier's disease and 1 chondrodysplasia punctata.

The hemiepiphyodesis was either started at the time of nail implantation and lengthening, or about 6–12 months earlier to allow for more correction with growth, if needed.

**Results:** The girls were lengthened by 4.2 cm in average at a mean age of 11.5 years, the boys by 4.5 cm at 12.5 years average age. The

average deformity in the distal femur was measured with 82.3° mL DFA for the girls and with 80.2° for the boys. In 9 of 10 cases the deformity correction resulted in a normalized mL DFA in comparison to the contralateral, normal side within the standard deviation limits. Due to the amount of preexisting deformity and the diminishing physal growth in adolescence one case resulted in 5° residual valgus at the end of growth. In another two cases we found a valgus rebound in the follow up after initial complete correction. In one case of a congenital short femur we had to pause the lengthening procedure due to serious mobility restrictions in the knee caused by the simultaneously implanted growth guiding plate.

**Conclusion:** The use of an antegrade femoral lengthening method is a reliable tool to obtain length and axis correction in the growing child with similar safety of obtaining the correct axis of the limb. However, the timing of the hemiepiphysiodesis is crucial to reach the desired results, rebound phenomena have to be taken in account and the simultaneous implantation can produce problematic knee mobility problems especially in congenital short femur with an instable joint.

### V3.06

## Prospective evaluation of pin site infections in ring fixation utilizing a novel tool in the outpatient clinic

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**Question:** Pin site infection is common in ring fixation in trauma, limb lengthening and deformity surgery. Checketts and Otterburn (CO) developed a grading system that is commonly used to classify pin infections and to support treatment decisions [1, 2].

We developed a paper-based registration tool (Fig. 1) in order to: (1) evaluate pin site infections prospectively and (2) provide a concise overview over the frame's history incl. operations and infections.

**Methods:** Prospective cohort study evaluating pin site infection and feasibility of the novel tool in 40 trauma and limb deformity patients treated with a tibia ring fixator extending to the femur in 6 and foot in 13 cases. There were 25 ♂ and 15 ♀, median age was 56 (12–88) years; median follow-up from surgery: 126 (44–486) days. We use closed pin site care, which comprises of chlorhexidine cleansings and gauze dressings once weekly and more often if infection is present.

**Results:** Twenty-six patients (65%) encountered pin site inflammation (CO1) or infection (CO1–5) in 153 out of 568 pin sites (27%) at least once during the observation time.

Twenty patients (50%) were treated with peroral antibiotics (CO2, 35/568 sites).

Three patients received both antibiotics intravenously (CO3, 6/568 sites). Eight of these 20 patients had a wire removed and three wires were replaced during the observation period.

Three patients received intravenous antibiotics and all three patients had a wire removed. An additional three patients were cured for CO 1–2 pin site infections after wire removal alone. No pin site infection (CO6) was observed after frame removal.

Two patients were amputated during the follow up: 1 patient because of severe osteomyelitis (CO5, 3/568 pin sites) and multiple co-morbidities and 1 patient because of atrophic non-union, which was not amenable to further surgery.

**Conclusion:** Half of our patients had pin site infection, which required either treatment with antibiotics and/or removal of a wire/pin [3, 4].

The paper-based tool was feasible as it was easy to use, provided a concise overview over the frame's history, and guided the reconstructive team to make treatment decisions

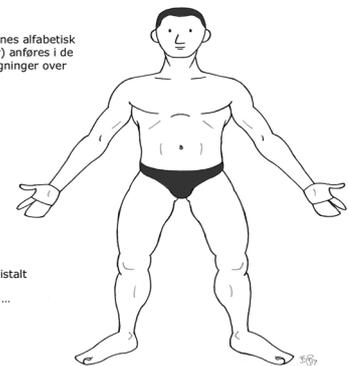
Status for pinsteder ved ringfiksation. Venstre ekstremitet

Patientens navn + id: \_\_\_\_\_

**Operationer**  
(primær ringfiksation, reoperationer, fjernelse af ringe, fodplade, pinde og wire)

	Dato dd/mm-åå	Bemærkninger
1		
2		
3		
4		

**Figur 1:** Rammens placering og ringenes alfabetisk orden indtegnes. Ringenes bogstav(er) anføres i de tilsvarende registreringstabeller og tegninger over wires og halfpins.



#### Systematisk navngivning

Ringene benævnes fra proksimalt til distalt

- Femur: FemurA, FemurB, ...
- Tibia: A, B, C, D, E, ...
- Foot: FootA, ...

#### Halfpins (HP) og Wires (NB: uden bogstav)

- nummerering starter altid mest medialt og posteriort (HP1 og 1) og fortsætter i urets retning for venstre og imod urets retning for højre underekstremitet.
- En wire har to pinsteder: medialt og lateralt (fx 2M og 2L).
- I navngivningen forholder man sig ikke til, om en halfpin eller wire er anbragt proksimalt eller distalt for ringen.

Page 1 of the novel paperbased tool

The infection rates will be used to plan prospective comparative studies regarding pin site care.

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## V 4—Management of complications: the “difficult case”—and what I have learned from it?

### V4.02

#### Treatment of a bilateral congenital luxation of the knee joint and a postpartal (induced?) epiphyseolysis of the proximal Tibiae

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**Question:** A family with a 10 days old baby wished an alternative treatment of the acute corrected congenital luxation of both knee joints at the hospital, where their son was born. The parents reported pain and swelling of the legs after the casting. After removal of the cast in our ambulance, the examination showed prätibial Hämatomas on both sides. The following X-ray and MRI examinations showed an epiphyseolysis of the proximal tibial physis, with flexion of the tibial diaphysis in the plane of the physis, while the epiphysis remained ventrally luxated.

**Methods:** The patient received a treatment with an overhead extension of the legs. Within 1 week the knee joints were brought back in recurvation and a cast was applied for over 2 weeks, to allow a healing of the physis. A new overhead extension followed and a gradual flexion of both knee joints was achieved. The systematic sonographic examination showed a complete correction of the joint luxation. The patient was dismissed with two pairs of casts, which the parents used for alternating flexed and extended positioning of the knee joints.

**Results:** A normal function of the knee joints  $0^{\circ}$ – $0^{\circ}$ – $130^{\circ}$  could be achieved 3 months after initial treatment. The followup showed a new hyperextension of the knee joint up to  $30^{\circ}$ , without signs of a relaxation. The patient received bracing to control the hyperextension and to help with his delayed motor skills. Walking was achieved at the age of 2.5 years, so that a neuropaediatric evaluation is pending.

**Conclusion:** The gradual correction of the epiphyseolysis and flexion with the overhead extension successfully corrected the congenital luxation of the knee joints. The still unclear neuromuscular disorder of the patient lead to a new hyperextension of the knee joints, which is currently being satisfactorily addressed with a bracing of the legs.

### V4.04

#### The impact of primary skeletal foot malformations on adolescents on the example of a rare, congenital, metric and structural combined deformity. A case report

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**Question:** By means of this complex foot malformation the question should be convincingly answered, if not treated, complex, congenital foot deformities only have an impact on the foot itself but also in particular on the gait and standing pattern, posture, pelvic position,

spinal unfolding and psychosocial development of an adolescent. Further the extensive reconstruction of such deformities will be demonstrated.

**Methods:** A 20 years old young patient shows at the first consultation a pronounced, rare, congenital foot malformation with a longitudinal diminution defect, secondary hallux varus, microdactylia and macrometatarsalia double-sided, digitus quintus varus, pes plano valgus double-sided and a secondary splayfoot. Due to an insufficient medical pre-treatment additionally to the pain in the middle-/forefoot and a significant increase of the both-sided foot malposition associated with a conflict in a ready-made shoe, increasing intensity of the pain is shown in the lower back and sacroiliac joint with an inability to do sports, to walk and a progressed stress pain in daily life. Not to forget about the psychosocial problems existing for several years due to the massive “cosmetic” anomalies on both feet.

After comprehensive diagnostic focusing not only on the foot problems, stress fractures on both sides, which were unknown until then and a result from the mislead based on the metatarsalia, have been restored. On the left side this has been done by a surgical approach, on the right side by a conservative treatment.

In the second step on the right side an extensive reconstruction with multiple operations has been performed: shortening Weil osteotomy of the metatarsal 2 and 3, callus distraction metatarsal 1 with the internal fixator, arthrolysis of the MTP1 joint, lengthening of the extensor hallucis longus tendon, bone craft interposition of the metatarsal 1 bone and plate osteosynthesis after removing the internal fixator as well as MTP1 fusion.

**Results:** After the full consolidation of stress fractures and 3 surgeries within a year it was possible to achieve freedom of symptoms, very good functionality and an appealing cosmetic result on the right side. In the final surgical approach, where the material of the first ray is to be removed, a shortening Weil osteotomy of the metatarsal 4 as well as a mini chevron osteotomy will be conducted. After 1 year at the earliest and an adequate load capacity of the right foot the surgical reconstruction of the left side can be undertaken.

**Conclusion:** This impressive example shows, that such extensive congenital foot deformities should be treated operatively in the age of 8–12 to avoid blatant secondary symptoms and a long ordeal with eventual comprehensive surgeries.

### V4.06

#### Patient-specific cutting guides (PSCGs): a precise and safe tool for the revision case of double level osteotomy? A Casereport

R. Habelt

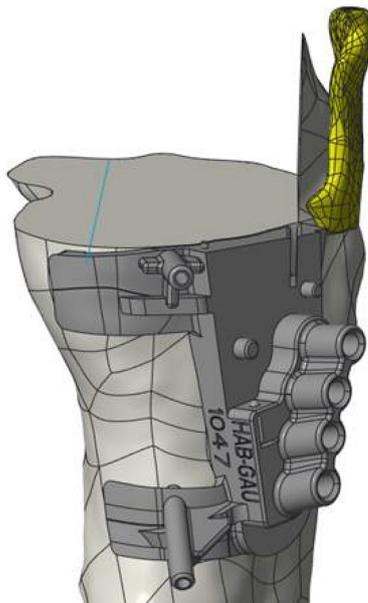
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**Question:** The patient (male, 38 years old) suffers from a medial osteoarthritis due to a genu varum deformity of the left leg. At the age of sixteen a temporal epiphysiodesis of the lateral distal femur and the lateral proximal tibia were performed. About 10 years later a remaining varus led to an open wedge HTO without correction of the pathological LDFA. In 2018 he subsequently presented himself for a correction of his persistent deformity of  $16.5^{\circ}$  varus.

Treatment of medial tibiofemoral osteoarthritis with a high-tibial osteotomy (HTO) is most effective when the optimal angular correction is achieved. Pilot study [1] has shown the benefit of PSCGs (for the open wedge HTO) The challenge is even greater when a double level osteotomy is necessary.

Are patient-specific cutting guides (PSCGs) a precise and safe device even in the revision case—performing closed and open wedge osteotomies?

**Methods:** In order to achieve optimal correction we used PSCGs in preoperative planning of the double level osteotomy. This was based on long-leg radiographs and CT scans utilising 3D reconstruction. Two PSCGs were used to align the osteotomy cuts and the position of the screw holes on the plate—one for a lateral closed wedge distal femur osteotomy (DFO from LDFA 96.4° to 86.5°) and the other for a medial open wedge high tibial osteotomy (HTO from 85.1° to 91.5°). The cutting guides were constructed following a detailed and thorough exchange with the engineer of the manufacturing company. The desired correction was successfully achieved in the three planes when the holes on the plate were aligned with the holes drilled based to the PSCGs.



Patient specific cutting guide: proximal tibia

**Results:** The intraoperative use of the PSCGs was efficient and the procedure was successful with a precise fit on the bone. Following the osteotomies, the screws and the plate position matched the preoperative planning of the procedure. The postoperative long-leg radiographs showed a LDFA of 86.5° and a MPTA of 91.6°, matching the planned correction corridor.

**Conclusion:** Although it appears to be a precise and reliable tool for osteotomy, preoperative planning and experience is essential in achieving the desired result. Nonetheless, more studies comparing PSCGs with the standard technique will be needed in order to substantiate the benefits of this method.

#### References:

[1] M. Munnier et al. (2016) Can three-dimensional patient-specific cutting guides be used to achieve optimal correction for high tibial osteotomy? Pilot study, Elsevier Masson SAS, Orthopaedics & Traumatology: Surgery & Research 103 (2017) 245–250, 245–350, 103

## V4.08

### Complications and errors during guided growth

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**Question:** We reviewed the clinical results of guided growth (GG) for varus/valgus deformities (VVD) or limb length discrepancies (LLD) with an emphasis on describing adverse events (AE).

**Methods:** AEs were collected and analyzed for all cases treated at a single institution with guided growth for VVD or LLD. AE were classified into five categories: Improper indication, misplaced implants, wrong timing of hardware removal, general surgical complication, and implant failure/incomplete removal.

**Results:** During the defined time period, we treated 136 patients for VVD and 103 patients with LLD. In total, we had 97 AEs: improper indication (26), misplaced implant (25), wrong timing of hardware removal (23), general surgical complication (14), and implant failure/incomplete removal (9).

**Conclusion:** Optimizing clinical outcomes when treating children with GG requires careful radiological preoperative planning to define the amount and location of the deformity. A preoperative long standing radiograph should be used to conduct a systematic analysis of limb alignment. Furthermore, it is essential to place the implant precisely and ensure regular follow-up evaluations. Most AEs can be avoided through correct radiological analysis of limb alignment and a basic understanding of guided growth. While ostensibly a simple procedure, decisions regarding planning of GG need to be thoughtfully made, the actual GG surgery should not be relegated to the most junior team member, and careful follow-up is essential.

## V 5—Planning and navigation

### V5.01

#### Limb alignment measurement in long-leg standing X-ray via 3D simulation, influence of different deformities in various rotations to the measurements

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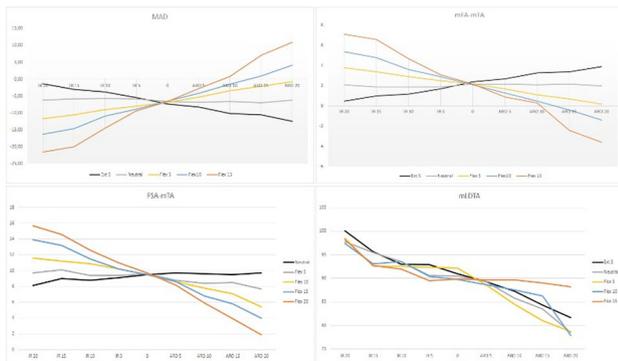
**Question:** For deformity corrections standing long-leg radiographs are used for planning the surgery. In most cases, especially in the beginning of the correction a more severe deformity is given. Based on clinical experiences, different positioning of the limb to conduct the radiographs can influence the measurements of the hip knee ankle alignment. The aim of the study was to analyze the influence of different limb positions on the measurement of limb alignment.

**Methods:** A CT scan of a healthy human individual was used. Femur, patella, tibia and talus were segmented with Mimics Research (Materialise, Leuven, Belgium) and then imported to 3-Matic Research (Materialise, Leuven, Belgium). Then anatomic landmarks were defined. A generated axis through femoral head centre and ankle joint centre was used to rotate the leg in the frontal plane. We used 5° steps to 20° internal and external rotation. Further, we generated 5° hyperextension, 5°, 10° and 15° flexion in the knee joint and repeated

the previously mentioned rotation-step. Then, we used the X-ray module to generate long-leg standing-like X-rays in ap view out of the CT-data.

Afterwards, these X-rays were imported into MediCAD (Hectec GmbH, Altdorf, Germany) and standardized limb alignment parameters were calculated.

**Results:** Our results are illustrated in the figure Influence of Rotation presenting the influence of knee position on deformity measurements. In summary, if the knee joint is fully extended, 5°–10° of internal or external rotation will have little influence on AMA, mL DFA, FSA-mTA and mFA-mTA. However, it had already an influence on mL PFA and mLDTA. Rotation of more than 10° leads to a variation of 6.4°–15.3° (7.7°–19.3°) for mL PFA (mLDTA). The flexion of the knee joint had strong influence on the measured values of the MAD, mL PFA, FSA-mTA, mFA-mTA and mMP TA. Rotating the bended knee resulted in even higher deviations.



Influence of rotation

**Conclusion:** Our preliminary results proofed the feasibility of the study. It shows a high influence of the rotation in the alignment measurements for a deformity. Therefore, long-leg standing radiographs must be taken consistently with no rotation to avoid wrong measurements. Even rotation deviations of 5°–10° have a significant influence of certain important alignment parameters.

## V5.02

### The double-line grid for intraoperative control of the Mikulicz-Line

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**Question:** Preoperative planning is mandatory to perform deformity corrections of the lower limbs especially if internal devices are used. The question is, how to transpose the planning to the patient on the operation table (OT) accurately. The cable of the electrocautery is very improper due to a high parallaxes failure. What can be an easy and cost effective alternative?

**Methods:** The Double-Line Grid is a plate with a thickness of 3 mm and a dimension of 1282 × 376 mm which can be placed on the OT. Inside of the radiolucent grid are thin orthogonal metal lines in a distance of 50 mm. One longitudinal double-line on each side enable the surgeon to have orientation along the full leg because the image intensifier has only a small focus. The leg has to be rotated in the correct position and should not be moved during the measurements.

Usually the patella is faced forward. Depending on the side which has to be examined the right or rather the left double-line has to be placed exactly into the center of the screen on the hip joint level by moving the C-Arm. After that the patient has to be shifted until the femoral head is centrally placed on the double-line. The image intensifier is moved now parallel to the OT to the level of the ankle joint. If the double-line will not stay in the center of the screen, small corrections can be made by adjusting the slide of the C-Arm. Now the ankle joint is also placed centrally on the double-line without changing the rotation of the leg. To verify the position of the knee joint the image intensifier has to be moved backwards parallel to the OT to the knee joint, with the double-line staying in the center of the screen. The position of the knee joint in relation to the double-line has to be evaluated.

**Results:** The Double-Line Grid was used in our Center successfully since 15 years in more than 2500 cases mostly for deformity corrections mit the FITBONE-Device delivering reproducible results. The following sources of error were identified:

- The C-Arm (and the X-ray) is not vertical to the Grid-Plate.
- The double-line is not in the center of the screen for each measurement.
- The limb was moved or rotated during the measurement.

**Conclusion:** The Double-Line Grid is an accurate and cost effective tool to verifying the course of the Mikulicz-Line with an image intensifier during operative deformity correction of the lower limbs. A smaller version of the grid (1282x186 mm) is available for the use on a trauma table where one leg is positioned aside.

## V5.03

### The use of a rotational rod to control limb rotation leads to more standardized long-leg radiographs when using the Taylor Spatial Frame

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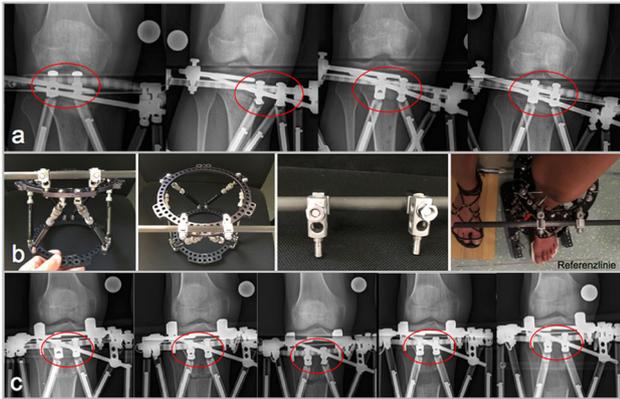
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**Question:** Long-leg radiographs are used to plan and supervise the correction of complex bone deformities with the Taylor spatial frame (TSF). However, positioning the limb with the patella pointing forward is challenging—especially in patients with severe deformities. This leads to malrotated radiographs resulting in wrong measurements of the alignment.

The aim of this retrospective study was to show the usefulness of a simple device which enhances the reproducibility of limb positioning on radiographs.

**Methods:** This study included 20 patients with TSF treatment and at least three long-leg radiographs ( $4.9 \pm 1.3$ ) according to Paley's method. 8 out of 20 patients received radiographs using the so-called rotational rod. The device consists of two clamps and a carbon fibre tube. It is placed at the master tab of the reference ring while conducting the radiograph, so limb positioning can be better controlled (Fig. b). To show the usefulness of the device the following calculations were made: The relation of the distances from the centre hole of the master tab to the medial and lateral fourth hole on the reference ring was determined (rotation index). The standard deviation (SD) and the range of this measurement of the conducted radiographs of

each patient was calculated. We compared (Wilcoxon test) the SD and the range of patients with and without the rod.



Radiographs without the rod (a), with the rod (b) and how the rod is used

**Results:** Radiographs of a patient without (Fig. a) and a patient with the rotational rod (Fig. c) are shown. Limb rotation can be estimated by the location of the master tab and by calculating the rotation index. Average rotation indices were with the rod  $1.00 \pm 0.06$  and without the rod  $1.03 \pm 0.15$ . By comparing the SD of rotation indices of both groups, significant smaller deviation ( $p = 0.0279$ ) of limb rotation was found when using the rod. A significant smaller range within one patient ( $p = 0.0339$ ) of the rotation index was found.

**Conclusion:** The rotational rod is a simple, cost-efficient device. When using the rod, the variance of limb position regarding rotation on radiographs was lower. Therefore, more reproducible, more accurate and better comparable radiographs can be conducted. In addition, radiologic exposure for the patient can be reduced as repetitions of wrongly positioned limbs on radiographs are less frequent.

## V 6—Basic science and innovative techniques

### V6.01

#### Structural and cellular characterization of cement-spacer-induced membranes

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**Question:** Bone grafting in context of two-stage induced membrane technique is recommended at 4–6 weeks after cement-spacer implantation assuming the highest bioactivity of the induced membranes. However, literature regarding histological characteristics and membrane biology is rare. Therefore, the aim of this study was the structural and cellular characterization of cement-spacer-induced membranes and the analysis of membrane bioactivity over time.

**Methods:** Membrane biopsies from 65 patients (35–82 years) were analyzed. Based on the time point of biopsy, four groups were

formed: group 1: 8–28 days, group 2: 29–49 days, group 3: 50–63 days, and group 4: 78–113 days. The bioactivity of the membranes was histologically and immunohistologically studied by analysis of protein profiles of membrane lysates using protein microarrays. In addition, after co-culture of membranes with mesenchymal stem cells (MSC) outgrowth and osteogenic differentiation of MSC were measured. Osteogenic differentiation was assessed by calcification (alizarin red), alkaline phosphatase (ALP), C-terminal propeptide of procollagen I (CICP), osteoprotegerin (OPG), osteopontin (OPN), osteocalcin (OC), bone-specific alkaline phosphatase (BAP).

**Results:** Microarray analyses revealed increased protein expression of angiogenesis factors, inflammatory mediators, and osteoinductive growth factors in induced membrane lysates. The angiogenesis factors showed highest expression in the early time group (8–28 days). The expression of osteoinductive growth factors was comparable at all time points. Histologically, increased vascularization occurred especially in group 1. Immunohistochemical analyzes confirmed increased angiogenesis by the expression of angiogenin, CD31, CD34, CD90, CD105 and EMMPRIN. In group 2 predominantly fibrotic tissue with parallel collagen fiber orientation was detected. In addition, the osteogenic markers (MMP-9, AP, OP and OC) and osteoclasts could be detected by TRAP staining. Mesenchymal stem cells (CD105/CD73) were found at all time points.

**Conclusion:** The induced membranes showed specific time-dependent, but not significantly different stages of development with increased angiogenesis and vascularization in the early phases and increased fibrosis in later phases. Comparable osteoinductive bioactivity and mesenchymal stem cells were observed at all time points. Thus, the previously postulated narrow time frame of 4–6 weeks until bone grafting can be questioned.

### V6.02

#### Taylor spatial frame versus TL-HEX: a biomechanical study of two computer-assisted ring fixators

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**Question:** The Taylor Spatial Frame (Smith & Nephew) and the TL-HEX (Orthofix) are two computer-assisted hexapod ring fixators. The advantages compared to classic ring fixators such as the Ilizarov frame are computer-assisted correction planning and simultaneous correction of multidirectional malalignment. The successful application of the ring fixators depends on various biological and biomechanical factors. This study was performed to measure and to compare the biomechanical characteristics regarding stiffness and stability of the TSF and the TL-HEX ring fixator.

**Methods:** In this in vitro biomechanical modelling study five tibial Sawbones<sup>®</sup> (4th Generation) were attached with three half-pins on each segment into a two ring TSF- and TL-HEX fixator and osteotomized in the middle of the shaft to create a mid-diaphyseal bone defect. Each bone/fixator model was tested for 1000 testing cycles (Fa. Instron Typ.: 8874) under axial (+ 60 N–640 N) and rotational ( $\pm 20$  Nm) loading. Load/displacement curve data for the fixators as well as for the tibia in the osteotomy gap were registered and analyzed by a digital optical measurement system (ARAMIS 3D Camera; GOM<sup>®</sup>).

**Results:** For axial stiffness, as well as for rotational stiffness there were no significant differences between the two ring fixators (441.8 N/mm vs. 482.1 N/mm;  $p = 0.68$ ; 110.86 Nm/degree vs. 94.5 Nm/degree;  $p = 0.17$ ). Moreover, the detected interfragmentary bone movements in the osteotomy gap showed no significant differences, nor under axial ( $p = 0.056$ ) neither under rotational ( $p = 0.19$ ) loading.

**Conclusion:** Both hexapod ring fixators are suitable for clinical use of gradual correction of multidirectional deformities with comparable biomechanical properties.

## V6.03

### Hip dysplasia—reduction of proximal migration before arthroplasty using a fully implantable motorized distraction nail

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**Question:** In cases of proximal migration of the femoral head due to dysplasia of the acetabulum total hip arthroplasty (THA) is a challenge and combined with shortening of the leg, a high risk of nerve palsy or a risk of infection using an external fixator to distalize the femur. Fully implantable distraction devices have been used frequently for leg lengthening and are offering new perspectives to solve the problem.

**Methods:** In combination with a new developed, patented pelvic support plate the fully implantable distraction nail (FITBONE) is able to perform soft tissue distraction of the thigh. The energy necessary for the distraction can be delivered wireless through the skin by an external power and control unit. 17 patients (8 m, 9 f) with a mean age of 37 years (15–67) were treated using a fully implantable nail to distalize the thigh before arthroplasty. The mean distraction amount was 58 mm (32–77). In an initial surgery the femoral head was resected and the cup of THA was implanted in anatomic position with or without enhancement of the acetabulum. After surgery distraction was started with 2–3 mm/day and the proximal migration was compensated completely. In a second surgery the distraction nail was removed and the stem was inserted to finalize the THA.

**Results:** In all patients the soft tissue distraction of the thigh was finished as planned preoperatively, so that THA could be performed in anatomic position. The first nine patient had a high pain level because the connection to the pelvis was too rigid using a modified cobra-plate. After that the new pelvic support device was used allowing more mobility leading to a significant better range of motion and a lower pain level. In summary no infection occurred, in two patient temporary nerve palsy was observed due to intraoperative stretching and in another two patient a spiral fracture due to intensive inward rotation inserting the shaft had to treated additionally by cerclage wires. In one patient with reduced bone density the screws of the plate had to be refixedated after loosening.

**Conclusion:** A fully implantable motorized distraction nail seems to be a favourable option for reduction of a high hip dislocation by continuous soft tissue distraction before THA in loco typico and to

reach equal leg length. Acute intraoperative stretching and intensive inward rotation of the thigh for stem insertion should be avoided.

## V6.04

### Correlation between the interscrew-angle and the degree of mechanical axis correction in temporary hemiepiphysodeses using a 1/3 tubular plate

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**Question:** Temporary hemiepiphysodesis using a 2 holes 1/3 tubular plate is one of the treatment options for correcting axial limb deformities in the growing skeleton. During the postoperative course, a progressive angulation of the used screws can be observed on long standing radiographs (LSR), which have to be taken repeatedly.

We hypothesized, that there was a correlation between the change of the interscrew-angle and the amount of the achieved axis correction.

**Methods:** We retrospectively enrolled 87 children (108 femoral, 19 tibial, 14 combined femoral and tibial corrections), who were treated between 2006 and 2015 with a temporary hemiepiphysodesis (using a 2 holes 1/3 tubular plate) for correction of axial deformities of the femur and/or the tibia. In all patients the mechanical axis deviation (MAD) as well as joint angles such as the mechanical lateral distal femur angle (mLDFA) as well as the mechanical medial proximal tibia angle (mMPTA) were measured on pre- and post-operative LSR. The interscrew-angle was additionally assessed on both intraoperative as well as postoperative X-rays. The association between the change of interscrew angles and the change of the MAD as well as the mLDFA in femoral corrections/mLDFA in tibial corrections was evaluated and a statistical analysis performed.

**Results:** Statistical analysis revealed a strong association between the change of interscrew-angles and the amount of correction of the MAD as well as the corresponding joint angles (mLDFA, mMPTA), respectively. In femoral corrections, the predictive model suggested a 1,11 mm change of the MAD and a 0.37° of the mLDFA per 1° change of the interscrew-angle. Likewise, a change of 1° in the interscrew-angle resulted in a 1.11 mm change of the MAD and 0.37° in the mLDFA of the corrected tibiae.

**Conclusion:** There is a strong statistical association between the change in interscrew-angles and the amount of correction of the MAD, mLDFA as well as mMPTA. However, the clinical significance of these findings will have to be determined in future studies.

## V6.05

### Distal fibula fixation by syndesmotic screw in limb lengthening procedures

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**Question:** Subluxation of the distal tibiofibular joint during limb lengthening is a well known complication, that should be avoidable by protection of the syndesmosis. Although in short lengthenings the risk may be low, the incidence of subluxation is not known and the potentially arising problems may be severe. If the syndesmosis is protected by screw, the question remains, whether there is the need for early removal to prevent implant failure as described for fracture stabilization.

**Methods:** In this retrospective study we examined 49 lengthenings of the lower leg, that had a protection of the distal fibula position by a syndesmotic screw or a specially positioned half-pin. We used the method in 33 lengthenings with external frame systems and in 16 lengthenings by an intramedullary lengthening device.

The technique requires a descending tibiofibular direction of the screw or half-pin in order to provide maximum stability against the distraction forces and also the forces generated during weight bearing.

**Results:** In all lengthening cases the goal to protect and safeguard the distal tibiofibular joint was achieved completely. In two cases we found failure of the implants at the site of the syndesmosis. Both implants were cannulated screws. After changing the protocol to using non-cannulated screws or half-pins the problem did not arise again, thus leaving the implant in place until complete implant removal was no problem. In five cases we found loosening of the screw in the fibular bony interface without any clinical correlates.

**Conclusion:** Using the descending tibiofibular syndesmotic screw during lengthening procedures is a reliable, minimally invasive mean to protect the ankle joint from subluxation with increased patient comfort.

## V 7—Correction of posttraumatic malalignments

### V7.02

#### Deformity correction after apophyseal trauma of the tibial tuberosity

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**Question:** Apophyseal trauma of the tibial tuberosity may result in severe deformities if the anterior growth of the proximal tibia is inhibited. Typically a recurvatum deformity, often associated with length discrepancy as well as valgus or varus axis deviation, may result. Depending on the severity of the trauma and/or the growth

stage of the child, different therapeutic approaches have to be considered.

**Methods:** All proximal tibial avulsion injuries treated in our clinic from 06/05 to 03/18 were prospectively investigated. Included were all patients of growing age, regardless of sex, who were treated operatively as well as conservatively.

In addition, two patients with proximal lower leg fractures and one child with cruciate ligament rupture and posttraumatic deformity were analyzed.

The age at the time of the injury, sex, side injured, accident mechanism and therapy were examined, including the different surgical procedures. In particular, the evaluation of the concomitant injuries, as well as the post-traumatic complications and their therapeutic consequences were in focus.

**Results:** A total of 61 patients with proximal tibial avulsion injuries were treated. The average age was 14.41 years. 9 girls were on average 2 years younger than the 52 boys. One boy had two independent injuries during the study period, 3 other boys had bilateral tuberosity tibiae injuries. 4 of the adolescents showed a refracture.

According to the Ogden classification, 5 type 1, 11 type 2, 17 type 3 injuries and 28 type 4 injuries were found, in about 75% a surgical treatment was necessary. In 19 patients complications occurred, in 7 patients a leg length difference (LLD) of < 1 cm had developed after trauma, 4× ≥ 1 cm. 5× there had been premature bridging in the epiphyseal joint and 4 adolescents had developed a genu recurvatum, 2 patients of them accompanied by a genu valgum. Another genu valgum was accompanied by an accompanying LLD with at the same time proven partial rupture of the anterior cruciate ligament. One genu valgum and/or genu recurvatum occurred in 4 out of 9 girls. The function/outcome was generally unrestricted when secondary measures were taken into account.

Both patients with the proximal lower leg fracture showed a genu valgum et recurvatum with LLD > 1 cm, the child with VKB rupture showed a genu varum et recurvatum. A multidimensional correction was necessary for these three cases.

**Conclusion:** The proximal tibia is a vulnerable underestimated area due to its anatomical properties. The overall collective showed a high complication-related course. Due to the high growth potential of the proximal tibial physis, false growth is to be expected in spite of the upcoming closure.

Regular monitoring until the end of growth, are recommended in order to be able to intervene adequately at an early stage of an imminent development of leg deformity.

### V7.03

#### Treatment of lower limb deformities and leg length discrepancies with intramedullary lengthening nails in skeletally immature patients

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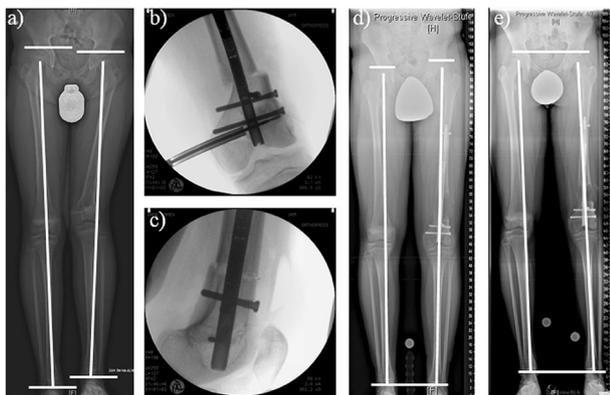
**Question:** Limb lengthening with motorized intramedullary lengthening nails is a well-established method in the treatment of adults. In contrast to external fixators, intramedullary lengthening nails provide a more comfortable and equally safe treatment. The applications of intramedullary lengthening nails for skeletally immature patients remains a challenge due to the patient's anatomy and growth considerations.

Is limb lengthening with intramedullary lengthening nails a safe procedure for children and adolescents?

**Methods:** A retrospective radiographic analysis (2016–2019) of skeletally immature patients who underwent femoral or tibial limb lengthening with motorized intramedullary nails was performed. Leg length discrepancy, mechanical axis deviation were assessed before and after lengthening. Patients who underwent antegrade femoral lengthening procedures were screened for avascular necrosis (AVN) of the femoral head.



Antegrade femoral approach using a lateral trochanteric entry to avoid damaging the proximal femoral blood supply and growth plate of the greater trochanter



Retrograde femoral lengthening nail with blocking screws to control

the distal segment and permanent distal femoral epiphysiodesis in a 13-year-old boy with leg shortening and valgus deformity due to partial damage of the distal femoral growth plate

**Results:** On a total of 54 patients 60 procedures were performed. Three different types of nailing approaches were used: antegrade femoral (n = 42), retrograde femoral (n = 10), and antegrade tibial (n = 8). Mean age at the time of surgery was 13.8 years. The average length of callus distraction was 45 mm.

n 58/60 cases (96.7%) the desired amount of lengthening was achieved, while two patients experienced complications that required interruption of the treatment. None of the patients developed complications associated to the nailing approach. No AVN was observed.

**Conclusion:** Different approaches for intramedullary lengthening nails can be used in children and adolescents to correct leg length discrepancy with or without concomitant deformities. The treatment is limited by the size of the available nails, the residual growth and characteristics of the deformity. Larger trials will be needed to further validate the application of lengthening nails in skeletally immature patients.

## V7.04

### The acute correction of post-traumatic cubital axis deformity

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**Question:** Fractures around the elbow represent the most common skeletal trauma in childhood and adolescence. However, its sufficient management remains often challenging. An inadequate initial treatment leads to malunion that causes abnormal growth, which further develops into cubital axis deformity.

The purpose of this study is to evaluate the acute correction of cubital axis deformity through three different surgical approaches: the supracondylar dome-osteotomy, the lateral/medial closing/open-wedge-osteotomy and the unilateral external fixation.

**Methods:** A cubitus varus was defined with a Baumann's angle more than 81° while a cubitus valgus with a Baumann's angle less than 64° that was measured in an anteroposterior radiograph of the elbow.

During a period of 10 years, a total of 40 cases of post-traumatic cubital axis deformity, of which 23 cases of cubitus varus and 17 cases of cubitus valgus, underwent acute surgical correction at the age of 13 ± 4.3 years with the initial trauma dated 4.8 ± 3.2 years back.

A dome-osteotomy was performed in 16 cases, while 13 cases were corrected through a wedge-osteotomy and the other 11 cases through an external fixation.

**Results:** The aimed reference range of the Baumann's angle was achieved in all cases.

The age upon correction was significantly younger in the external fixation sub-cohort with 8.3 ± 2.3 years compare to those in the dome-osteotomy and the wedge-osteotomy sub-cohorts with 14.8 ± 3.5 years.

The consolidation period was considerably longer in the external fixation sub-cohort with  $8.5 \pm 2.2$  weeks compare to those in the dome-osteotomy and the wedge-osteotomy sub-cohorts with  $6.8 \pm 1.8$  weeks.

**Conclusion:** The age upon correction, and more specifically, the age-correlated geometry of the distal humerus plays a critical role in choosing the optimal surgical approach. A sufficient implant implementation of an internal fixation is challenging in the younger patients.

The correction results in the dome-osteotomy sub-cohort and those in the wedge-osteotomy sub-cohort are generally comparable.

However, the risk of intraoperative injury of the ulnar nerve during a wedge-osteotomy through a medial incision and the wedge-induced prominence of either the lateral condyle or the medial epicondyle are contraindications that must be taken into consideration.

Concurrently, the dome osteotomy is proceeded through a dorsal incision that doesn't put the ulnar nerve at risk and its non-wedge approach results in a more balanced anatomical proportion of the distal humerus.

## V7.05

### Fully implantable distraction nails for humerus lengthening

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**Question:** Fully implantable motorized nails based on an external computerized control unit and a wireless energy transmission were used in our Center for more than 2000 lengthening of femur and tibia. What are the indications for the use of the system in the humerus and which results can be expected?

**Method:** The humerus as the best healing bone in the body is suitable for lengthening with a nail as well but the indication is rare in comparison with the lower legs. Especially when driving a car or when working on a tablet length discrepancies of the arms of more than 4-5cm may cause severe hardening of the cervical muscles and chronic pain in the upper spine. We have used a fully implantable lengthening device (FITBONE®) in 4 cases for humerus lengthening. The nail was inserted in all cases from proximal. The mean age of the patients was 32 years. No patient was lengthened before with an external device. The mean lengthening amount was 62mm (55-100). In one case the system was exchanged to reach the desired length (40mm + 60mm).

**Results:** Lengthening was done as usually with 1mm/day in 3 steps and was completed in all cases as planned. The bone healing was circular around the nail and very fast. The arm was used functionally without any restrictions after wound healing beside carrying heavy load until the regenerate seems to be strong enough. There was no infection, no radial nerve irritation and no chronic shoulder pain.

**Conclusion:** The preliminary results of our 4 cases demonstrate, that a fully implantable lengthening nail is not only a favorable option for lengthening the lower leg but also advantageous for lengthening the

humerus. In some cases especially in achondroplastic patients the initial length of the humerus may be too short to allow the insertion of a regular nail and custom made implants may be needed. In comparison with the use of external fixators the functional outcome, the comfort of treatment and the cosmetic result is amazing.

## V7.06

### Functional radius head resection through external ring fixator in children with chronic Monteggia lesions

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**Question:** Monteggia lesions in children are defined as an ulna fracture with radial head dislocation. The acute type of this injury can be treated with closed reduction and internal stabilization of the ulna fracture. In contrast the treatment of chronic Monteggia lesions is more challenging because of anatomic changes especially of the radial head and consecutive osteoarticular remodeling with loss of joint congruence. Untreated the Monteggia lesion can be compensated for months or even years. In long term observations the radial head dislocation will lead to pain, mobility limitation, progressive valgus deformity, radius lengthening, lateral elbow instability, late ulnar nerve paralysis and osteoarthritis. Correction of the deformity in early stages can be performed with ulnar osteotomy and elongation with monolateral external fixator, open reduction of the radial head through capsulotomy, removal of interposed tissue and eventually anular ligament reconstruction. In late stages the anatomic joint reconstruction is not reasonable because of the joint incongruence. In this situations a functional head resection through ulnar osteotomy and lengthening and therefor distal distraction of the radial head can reduce pain and improve mobility limitations.

The purpose of this study was to identify the clinical outcome of these patients.

**Methods:** From 2010 to 2018, 46 patients (18 girls and 28 boys) with chronic radius head dislocations were retrospectively analyzed with special view on patients with an incongruent joint situation. We always did an ulnar osteotomy and implantation of an external ring fixator (Taylor spatial frame; Smith and Nepew) for lengthening and angulation. We analyzed the surgical data as well as the clinical outcome of the patients measured by DASH and Mayo Elbow score.

**Results:** 16 patients (girls 6, boys 10) filled up the criteria for functional radius head resection. We had an average follow-up of 5.1 years (range 1–9 years). The mean delay of therapy after injury was 4.14 years (range 4 months–12 years). The mean time in frame was 105.8 days (range 56–182 days), the lengthening was 21 mm (range 12–42 mm). The average degree of sagittal angulation 14.5° (0°–32°), coronal angulation 4.1° (0°–25°). DASH score showed a very good result with 8.82 (0–100) and also the MAYO elbow score was excellent (90/100).

**Conclusion:** Functional radial head resection with external ring fixator is an appropriate and secure method to treat chronic posttraumatic radius head dislocations.