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Results of limb reconstruction surgery using a telescopic titanium rod: early findings

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Abstract

Introduction Pediatric limb reconstruction associated with impaired osteogenesis and fragile bone suggests the use of combined techniques with telescopic intramedullary rods left in situ.

The **objective** was to test the hypothesis that transphyseal telescopic rods applied simultaneously with an external fixation device for pediatric femur or tibia lengthening associated with weak and brittle bone in Ollier disease and osteogenesis imperfecta does not lead to the rod blocking during fixation, does not prevent distraction bone regeneration, lengthening and deformity correction.

Material and methods The study involved four male patients with Ollier disease and a female patient with osteogenesis imperfecta who underwent limb lengthening and/or deformity correction using a combined technique. Ilizarov apparatus was used as an external fixator, and a telescopic titanium rod was placed simultaneously with external fixator. With the bone consolidated, the Ilizarov apparatus was removed and the telescopic rod left in place.

Results The length gain and deformity correction intended were achieved in all patients. No loss of fixation of the threaded rod was observed in the femur and tibia epiphyses, or greater trochanter apophysis during distraction. There was no blocking of the rod telescopes during distraction. The external fixation index was 11.6 days/cm for polysegmental lengthening, 22.6 days/cm to 28.8 days/cm with monosegmental femoral lengthening.

Discussion Limb lengthening with a telescopic rod has the advantages of additional reinforcement through the segment with no risk of intramedullary construct migration as compared with combined lengthening techniques using flexible intramedullary nailing. There were no problems with formation of the distraction regenerate and longer period of external fixation, which can be seen with other techniques.

Conclusion Outcomes in this series indicated the possibility of limb lengthening and simultaneous osteosynthesis using external fixator and a telescopic titanium rod in patients with pathological osteogenesis. No loss of fixation of the threaded parts of the intramedullary rod, no blocking of the sliding parts of the rod were observed during limb lengthening.

Keywords: lengthening, Ollier disease, osteogenesis imperfecta, telescopic rod, external fixation

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INTRODUCTION

Treatment of diseases accompanied by a weak and brittle bone (Ollier disease, osteogenesis imperfecta, polyostotic fibrous dysplasia, metabolic osteopathies) can be associated with secondary deformities, pathological fractures, limb length inequalities, which is an indication for combined surgical solutions employed with an intramedullary telescopic rod as a key element [1–5]. A telescopic rod left in situ for many years can reduce the risk of recurrent skeletal deformities and fractures [6, 7]. Prophylactic nailing technologies applied concomitantly with external fixation have been reported [2, 8–10]. Lengthening over a rigid nail and the external fixator or a fully implantable electromagnetic intramedullary devices can be used for patients with congenital skeletal pathologies or Ollier disease to avoid the risk of fractures after removal of the external fixator and reduce the rehabilitation period [11–13]. The use of intramedullary devices may be limited by the presence of growth plates and a relatively small diaphyseal diameter [12, 14–16]. In addition to that, an electromagnetic rod staying inside the bone for a long period of time can cause concern [17].

Schiedel et al. [8] and Grill et al. [9] offered "lengthening then rodding" suggesting prophylactic nailing of the elongated bone at the time of removal of the external fixation device by introducing a rigid or elastic rod. However, the authors admit there is a significant risk of a fracture within a short period of time between removal of the device and introduction of an intramedullary fixator, a risk of infection due to the presence of bacteria in the pin tract [8, 9]. Our experience shows certain advantages of nailing the elongated bone during limb reconstruction with the flexible nail and the external fixator applied concomitantly at the beginning of treatment [18, 19]. Flexible nails introduced through the metaphyses does not provide reinforcement of the newly formed bone areas in the long-term period as the growth zones function in children [2].

In pediatric orthopedics, transphyseal telescopic rods inserted for deformity correction and fixed in the proximal and distal epiphyses (or apophysis of the greater trochanter), provide bone reinforcement along the entire length with the inner part of the rod sliding in the outer part as the child grows [3, 6, 20– 22]. Telescopic rods have advantages over transphyseal elastic reinforcement in terms of maintaining position of the construct and fewer re-operations [23].

The **objective** was to test the hypothesis that transphyseal telescopic rods applied simultaneously with an external fixation device for pediatric femur or tibia lengthening associated with weak and brittle bone in Ollier disease and osteogenesis imperfecta does not lead to the rod blocking during fixation, does not prevent distraction bone regeneration, lengthening and deformity correction.

MATERIAL AND METHODS

Our study is based on a retrospective small series of five patients: four femoral lengthenings and one case of bisegmental limb lengthening (femur and tibia) performed between March 2022 and November 2024 (Table 1). The mean age of the patients was (6.0 ± 1.9) years. Four patients with Ollier disease were males; a female patient was diagnosed with osteogenesis imperfecta. Previously, one patient had undergone tibial lengthening. The patients and their parents reported preoperatively progressive deterioration in motor abilities, leg length inequality and bone deformities. Patients had a history of two to four pathological fractures.

An intramedullary telescopic titanium rod was used (RU No. RZN 2017/5875 dated July 10, 2017, included in the set of implants for pediatric orthopedics "OrthoKid" according to TU 9437-001-73747729-2014).

Table 1

Patient data, type of operation performed

Patient	Diagnosis	Age, years	Aspects of osteotomy and telescopic rodding	External fixation device, surgical procedure performed
S.	Osteogenesis imperfecta, type I	5	Double percutaneous osteotomy of the femur to correct varus and derotate the bone with the proximal osteotomy, to lengthen at the distal femur, 4.2 mm antegrade rodding	Ilizarov apparatus
L.	Ollier disease	4	Distal wedge correction osteotomy of the femur, 5.5 mm antegrade rodding	Ilizarov apparatus, concomitant tibial lengthening over intramedullary flexible rods
R.	Ollier disease	11	Distal wedge correction osteotomy of the femur, 5.5 mm retrograde telescopic rodding	Ilizarov apparatus, removal of antecedent flexible rods
K.	Ollier disease	6	Concomitant lengthening of the femur and tibia, 5.5 mm retrograde rodding of the femur, 5.5 mm antegrade rodding of the tibia	Ilizarov apparatus
N.	Ollier disease	6	Femur lengthening, retrograde rodding, acute correction of the varus deformity	Ilizarov apparatus

The surgical lengthening technique with a telescopic rod consisted of several stages.

A subperiosteal osteotomy was performed in patients with Ollier disease (Fig. 1), if needed, after removal of antecedent implant (two patients) and wedge osteotomy produced for deformity correction.

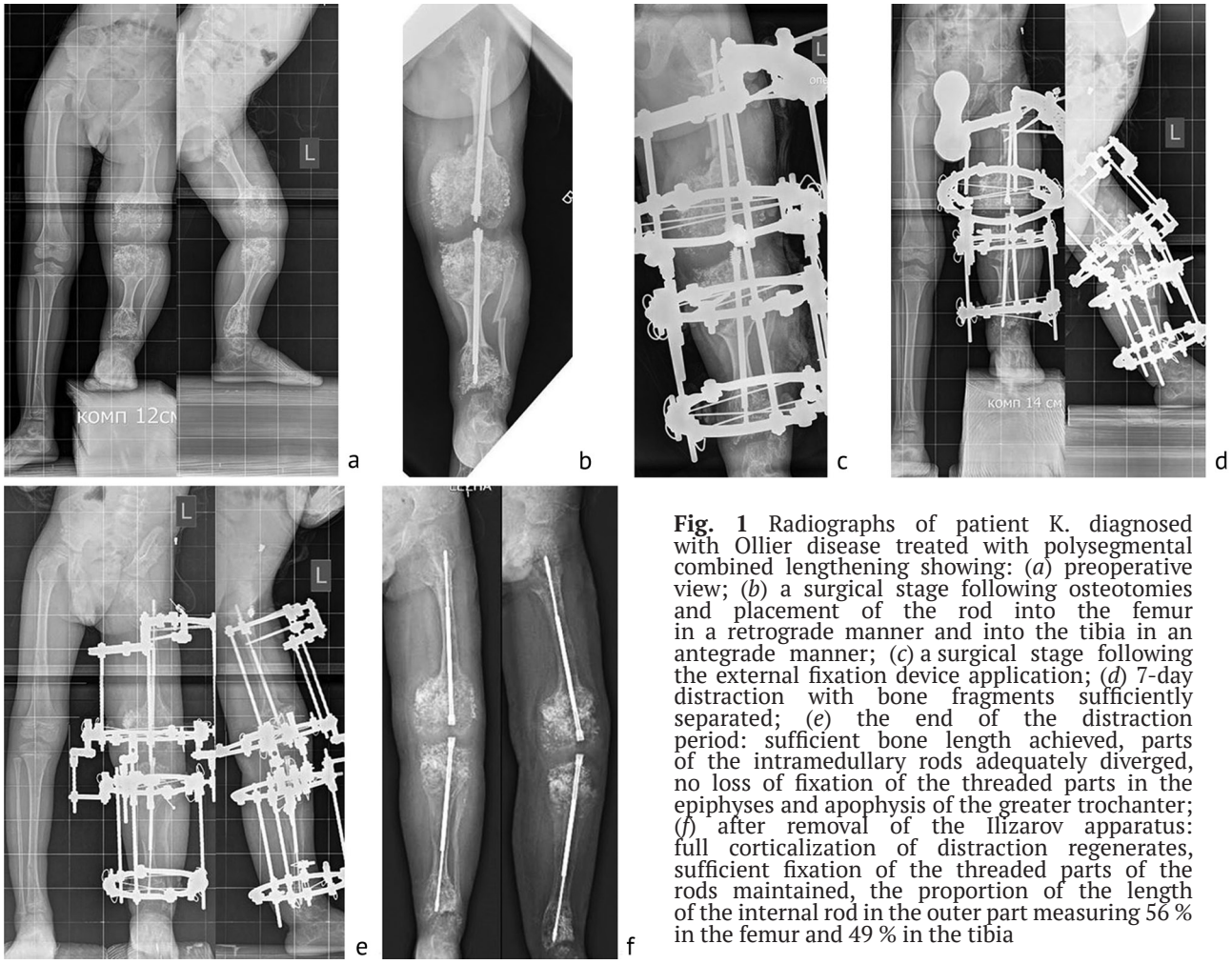

Fig. 1 Radiographs of patient K. diagnosed with Ollier disease treated with polysegmental combined lengthening showing: (*a*) preoperative view; (*b*) a surgical stage following osteotomies and placement of the rod into the femur in a retrograde manner and into the tibia in an antegrade manner; (*c*) a surgical stage following the external fixation device application; (*d*) 7-day distraction with bone fragments sufficiently separated; (*e*) the end of the distraction period: sufficient bone length achieved, parts of the intramedullary rods adequately diverged, no loss of fixation of the threaded parts in the epiphyses and apophysis of the greater trochanter; (*f*) after removal of the Ilizarov apparatus: full corticalization of distraction regenerates, sufficient fixation of the threaded parts of the rods maintained, the proportion of the length of the internal rod in the outer part measuring 56 % in the femur and 49 % in the tibia

The osteotomy level and the magnitude of one-stage correction were determined preoperatively based on the deformity characteristics. Reaming of the canal was performed in the patients with Ollier disease using a guide wire. The wires were inserted in an antegrade manner (through the greater trochanter) in two cases and in a retrograde way (parapatellar approach) in two cases. The inner part of the telescopic rod was placed to the opposite metaphysis after drilling and removing the guide wire without fixation of the threaded portion to the epiphysis/apophysis. The outer (hollow) part of the telescopic rod was shortened, if needed, inserted into the canal, the threaded portion screwed into the distal epiphysis of the femur in the intercondylar space (with retrograde insertion of the rod) and into the greater trochanter so that the thread did not extend beyond the growth site into the metaphyses. Then the inner part of the rod was screwed into the opposite epiphysis/apophysis using a T-shaped handle avoiding the thread being in the metaphysis. Retrograde insertion of the rod was performed in cases of large chondromatous lesions located predominantly in the distal femur. The outer diameter of the diaphyseal part of the inserted rod was 4.2 mm in one case (patient with osteogenesis imperfecta) and 5.5 mm in the remaining cases. The Ilizarov apparatus was mounted at the final stage of the operation to be followed by distraction along the vector being parallel to the intramedullary telescopic rod.

Surgical lengthening of the femur in a female patient with osteogenesis imperfecta suggested percutaneous osteotomy and initial fixation of the threaded external part of the rod as recommended by Birke et al. [3] (Fig. 2). Varus deformity was corrected with percutaneous osteotomy at this level (proximal osteotomy) and a telescopic rod introduced without drilling out the medullary canal. Derotation was produced by twisting maneuver using the Ilizarov rings with the rod in place.

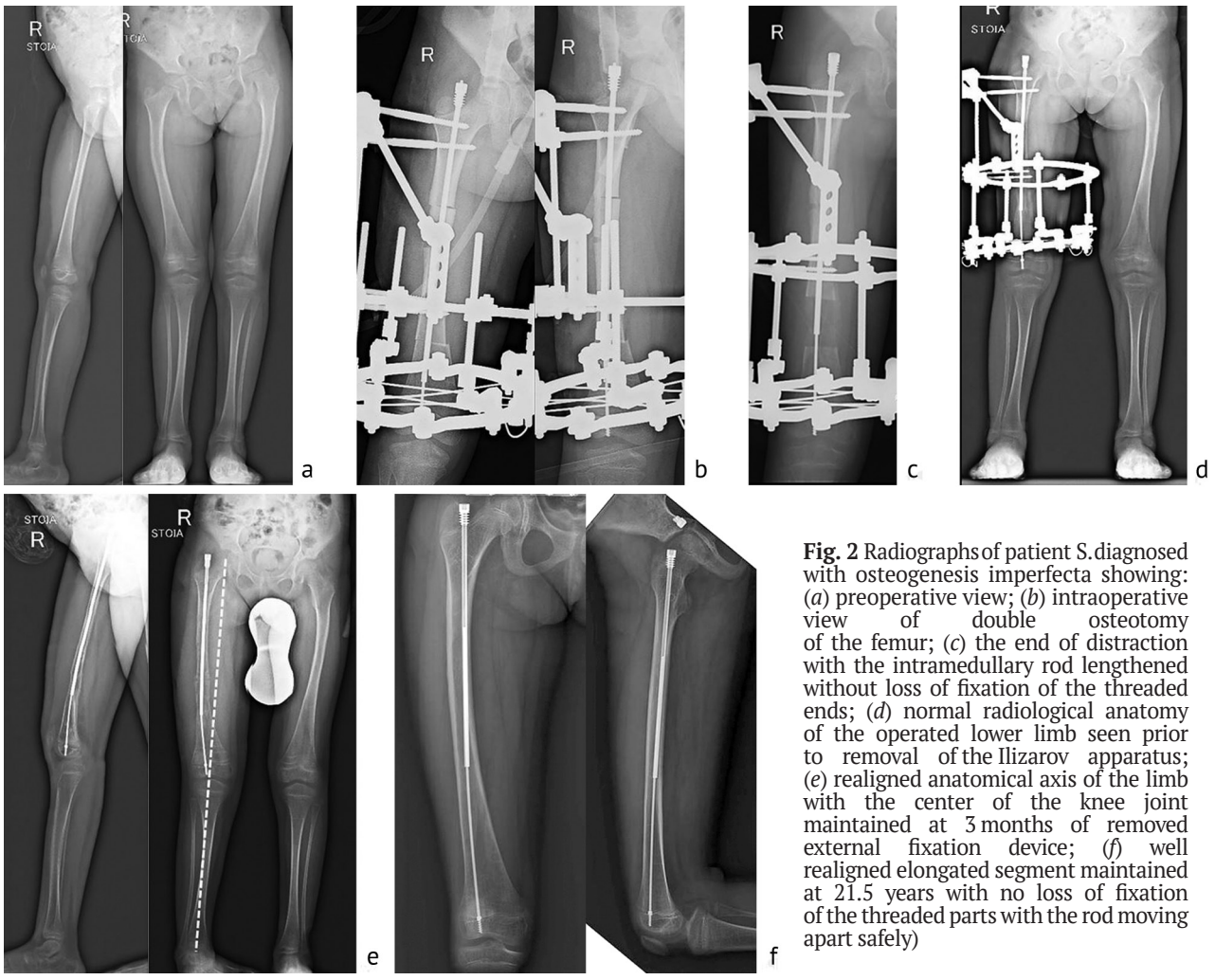

Fig. 2 Radiographs of patient S. diagnosed with osteogenesis imperfecta showing: (*a*) preoperative view; (*b*) intraoperative view of double osteotomy of the femur; (*c*) the end of distraction with the intramedullary rod lengthened without loss of fixation of the threaded ends; (*d*) normal radiological anatomy of the operated lower limb seen prior to removal of the Ilizarov apparatus; (*e*) realigned anatomical axis of the limb with the center of the knee joint maintained at 3 months of removed external fixation device; (*f*) well realigned elongated segment maintained at 21.5 years with no loss of fixation of the threaded parts with the rod moving apart safely)

Patients were encouraged to get verticalized and ambulate using walkers or crutches at 2–3 postoperative days. The latency period was five days with distraction performed at a rate of 1.5 mm/day for 6–7 days prior to the first radiography. An increased rate of distraction was initiated to provide reliable separation of bone fragments in the presence of a telescopic rod and to avoid premature bone consolidation. With adequate interfragmentary diastasis established with the first radiographic control, the distraction rate was reduced to 1 mm/day. Variation in the distraction rate during the lengthening process relied on the intensity of bone regeneration. With evident signs of bone fusion the external fixation device was removed. The study received a favourable opinion from the relevant research ethics committee of the Ilizarov Center (Abstract of minutes № 1 (76) dtd 29.11.2024). Written informed consent was obtained from each subject or the subject's parent/ legally acceptable representative for surgery and publication of the findings without identification.

RESULTS

The bone length and correction pre-planned were achieved in the patients. A plaster splint or a circular plaster cast was used for 3 to 4 weeks after removal of the device, when patients returned to walking with a gradually increasing weight-bearing. The results of elongation with a telescopic rod are presented in Table 2. No complications specific to telescopic intramedullary osteosynthesis (loss of fixation of the threaded parts in the epiphyses and apophysis, migration of the rod into the knee joint, bending and blocking of the rod preventing telescoping) were observed during the distraction phase as most critical from the point of view of the requirements for the position of the intramedullary rod. Sliding of the intramedullary rod was not blocked by external fixation components including wires and half-pins during the distraction period. A superficial infection was observed at a pin site in one case and was treated locally. Another patient experienced premature consolidation of the fibula, which required re-osteotomy and additional wire placement.

Table 2

Results of bone lengthening with telescopic rod

Patient	Length gain		External fixation length, days	IEX; days/cm	Proportion of the length of the inner rod in the outer part, %	Complications
	abs., cm	%				
S.	4.2	16.7	120	61.8	28.8	None
L.	5.8	35.7	131	43.9	22.6	Superficial infection
R.	4.0	15.4	97	69.9	24.3	None
K.	12		139		11.6	Premature consolidation of the fibula, re-osteotomy
femur	6	32.6		56		
tibia	6	33.1		49		
N.	5.5	30.2	134	62.5	23.5	None

DISCUSSION

In pediatric reconstructive orthopedics of the limbs, intramedullary osteosynthesis including telescopic rodding left in situ is essential for deformity correction in patients with systemic diseases (osteogenesis imperfecta, X-linked hypophosphatemia, polyostotic fibrous dysplasia, etc.) to prevent or reduce the risk of pathological fractures and recurrent deformities [2–7]. Consecutive implementation of lengthening and intramedullary nailing at the time of dismantling the external fixation device can be associated with a fracture of the lengthened bone at the time of surgery or infection [8, 9]. Simultaneous introduction of intramedullary components (flexible rods)

and external osteosynthesis helps to avoid the adverse events [10, 25]. However, the combined method confers an increased risk of rod migration in the bone due to weak rod locking and off the bone compromising soft tissues so that the intramedullary rod is to be removed [26]. Introduction of elastic rods suggests channels in the metaphyses to prevent nailing throughout the bone, and transphyseal insertion prevents the central location of the rods relative to the plane of growth plates, which could potentially lead to angulation [23, 27]. Finally, flexible rods telescoping in the medullary canal can be associated with blocking effect during growth and the loss of bone reinforcement at a long term [23].

Transphyseal telescopic rodding is likely to be more reliable than transphyseal telescopic rods inserted from both bone ends in terms of less complication rate and a longer reinforcement effect as demonstrated in recent literature on the correction of limb deformities in children with osteogenesis imperfecta [20, 23, 24]. From this point of view we consider combined use of transphyseal telescopic rodding and external osteosynthesis for limb lengthening in children with genetic diseases and poor bone quality is associated with lower risk of complications, with intramedullary fixator left in situ.

The sample size was too small to draw meaningful conclusions about the efficacy of the method. However, we can discuss other aspects in addition to proved possibility of performing this type of combined osteosynthesis. Telescopic rods used for patients with osteogenesis imperfecta may be predisposed to loss of fixation of the threaded parts, bending of the rod, blocking and absence of telescoping [3, 5, 28–30]. Holmes et al. emphasize that the distal fixation is to be perfectly centered in the epiphysis to improve survival of osteosynthesis and the time before revision [29]. Rod bending is often the fundamental cause of rod failure during developmental growth of the segment and the loss of fixation of threaded parts [29, 31–33]. An additional osteotomy aimed at the limb realignment is important for telescopic system functioning at a long term [7, 33]. We performed careful planning of deformity correction and their implementation to avoid rod bending and blocking during distraction with the telescoping rate being extremely high. A gradual correction of angular deformity should be avoided in preoperative planning with use of telescopic rods during distraction to prevent rod bending and blocking the sliding parts.

To avoid protrusion of the threaded part of the inner rod into the knee or ankle joint during installation of the telescopic fixator, we remain committed to the recommendations of Birke et al. [3], tightening the threads of the inner part of the rod only after screwing the threads of the outer part into the corresponding epiphysis (apophysis). We observed no protrusion of the rod into the joint, no loss of fixation of the threaded parts, no blocked sliding of the internal part in the external portion with lengthening of six segments.

Many authors report isolated use of intramedullary telescopic rods in the deformity correction being accompanied by secondary rotational and longitudinal bone displacement [3, 4, 34, 35]. Cho et al. [4], Franzone et al. [36] report the use of short locking plates for monocortical fixation to avoid the displacements [4, 36]. The approach resulted in bone union achieved in 85.3 % of cases; peri-implant fractures, refractures at screw sites occurred in 18.9 % of cases [37]. In this scenario, external fixation used to correct the deformity and lengthen the limb helps prevent secondary angular and rotational displacements and peri-implant fractures. No delayed bone consolidation was observed in our series.

The external fixation index was the lowest for polysegmental lengthening (11.6 d/cm) and ranged from 22.6 days/cm to 28.8 days/cm for monofocal femoral lengthening. These results are comparable to the results of lengthening in children in whom osteogenesis was stimulated with elastic nails placed in the metaphyses [19, 26, 38]. No other complications that would affect the outcome of treatment were encountered in our series. Premature consolidation of the fibula was the only adverse event requiring unintended intervention with re-osteotomy to continue lengthening.

Telescopic rodding used for limb lengthening is an advanced technique, which is technically challenging to provide the distal fixation to be perfectly centered in the epiphysis, angular deformities to be corrected acutely, limb lengthening to be strictly parallel to the axis of the telescopic rod. This approach prevents gradual correction of angular deformities to avoid rod bending and prevent absence of telescoping in the future. The small sample size, the heterogeneity (two nosologies) are obvious limitations of the study. We plan to expand the sample to 30 or more patients to obtain evidence-based results that would justify the expected duration of treatment and risks of complications. The long-term follow-up period will be increased to two years or more to determine the feasibility of telescoping intramedullary nails.

CONCLUSION

The case series demonstrated the possibility of long bone lengthening in patients with Ollier disease and mild forms of osteogenesis imperfecta with concomitant use of an external fixation device and a transphyseal titanium telescopic rod. The study of the six segment elongations showed that the “accelerated” telescopic rodding during distraction was not associated with failure of sliding and the loss of the required fixation of the threaded parts in the epiphyses. No delay in the formation and maturation of the distraction regenerate was detected in the series.

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Ethical Approval *The study received a favourable opinion from the relevant research ethics committee of the Ilizarov Center (Abstract of minutes № 1 (76) dtd 29.11.2024).*

Informed consent *Written informed consent was obtained from each subject or the subject's parent/legally acceptable representative for surgery and publication of the findings without identification.*

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