Journal of Orthopaedic Surgery and Research

RESEARCH Open Access

Clinical and radiological outcomes of magnetically controlled intramedullary lengthening nails in adolescents and young adults: a retrospective cohort study

Mehmet Ali Talmaç[1*], Melih Civan[1] and Ergün Mendes[2]

Abstract

Background Magnetically controlled intramedullary lengthening nails offer a fully internal approach to limb lengthening, avoiding complications associated with external fixators such as pin site infections and soft tissue transfixation. While their use in adults is well-documented, evidence regarding their safety and efficacy in adolescents and young adults remains limited.

Methods This retrospective cohort study evaluated the clinical and radiological outcomes of 24 limb lengthening procedures performed in 18 adolescent and young adult patients between 2022 and 2024 using PRECICE® intramedullary lengthening nails. Patients aged ≤ 18 years with a minimum of 9 months follow-up were included. Lengthening parameters, regenerate morphology, complication rates, and inter-group comparisons were analyzed.

Results A total of 24 long bone segments (femur, tibia, and humerus) underwent lengthening in 19 sessions. The mean follow-up period was 18.8 months. The average length gained was 45.7 ± 10.5 mm, with a distraction rate of 1.0 ± 0.1 mm/day. Complications requiring return to the operating room occurred in 16% of cases, while 5.3% had minor unresolved issues at treatment completion. Radiographic analysis revealed favorable regenerate morphology, and no case showed regenerate insufficiency. Statistical comparison revealed a significantly higher distraction rate in femoral versus tibial lengthenings ($p = 0.036$).

Conclusions Fully internal limb lengthening using magnetically controlled nails is a safe and effective option for adolescents and young adults, with a low rate of complications and high-quality regenerate formation. These findings support broader adoption of internal lengthening in younger patients, particularly in centers with trained teams and appropriate patient selection.

Keywords Limb lengthening, PRECICE, Adolescent orthopedics, Internal nailing, Deformity correction

*Correspondence:
Mehmet Ali Talmaç
drtalmac2@gmail.com
[1]Department of Orthopaedics and Traumatology, Başakşehir Çam ve Sakura City Hospital, Istanbul, Turkey
[2]Department of Anesthesiology and Reanimation, Faculty of Medicine Hospital, Koç University, Istanbul, Türkiye

In recent years, fully internal limb lengthening techniques have gained preference in deformity correction and limb reconstruction. The main goals of these approaches are to minimize transfixation of soft tissues, facilitate early and efficient rehabilitation, avoid complications specific to external fixation—such as pin site infections—and achieve a more cosmetically acceptable surgical site. In addition to preserving joint range of motion in adjacent joints, excellent regenerate bone healing has been reported with these methods [1].

However, the application of these internal lengthening techniques remains limited in the pediatric population. The primary concern lies in the potential risk of physeal injury during nail insertion. Therefore, these methods are generally reserved for patients with minimal remaining growth potential, or in cases where the adjacent physis is already damaged or functionally closed. When internal lengthening is feasible in such cases, motorized nails have demonstrated notably low complication rates [2]. In patients where this approach is contraindicated, external fixators or growth-guidance techniques remain the mainstay.

Recently, an increasing number of case series involving adolescent patients undergoing fully internal limb lengthening have been published [3]. These studies predominantly focus on complications, particularly those requiring reoperation [4, 5].

In this study, we aimed to evaluate the clinical and radiological outcomes of limb lengthening procedures performed with magnetically controlled intramedullary nails in adolescent and young adult patients treated in our institution.

Materials and methods

Between 2022 and 2024, all limb lengthening procedures performed using a fully internal, magnetically controlled intramedullary lengthening nail (PRECICE®, Ellipse Technologies, Inc., Irvine, San Diego, CA) under national health insurance coverage were retrospectively reviewed after receiving approval from the institutional review board (IRB). The study included all patients aged 18 years or younger who had undergone fully internal limb lengthening and had a minimum follow-up duration of 9 months (Table 1). Inclusion criteria were: age ≤ 18 years

Table 1 Demographic, clinical, and treatment characteristics of patients undergoing ıntramedullary limb lengthening with magnetic nails

No	Etiology	Age	Follow-Up (months)	Segment */†	Lengthening Amount (mm) / Distraction Rate (mm/day)	Complications	How it is solved
1	Fibular Hemimelia (Final Lengthening)	17	30,9	Femur	70 / 1,08	none	
2	Idiopathic	14	29,5	Tibia	30 / 0,94	none	
3	Konjenital Short Femur	16	29,0	Femur	60 / 1,11	none	
4	Short Stature	18	22,9	Tibia (b)	50 / 0,94	Abnormal Mechanical Axis Deviation	Planned Revision during Implant Removal
5	Konjenital Short Femur	16	22,7	Femur	30 / 0,94	none	
6	Post Infectious	10	22,2	Tibia	45 / 0,96	none	
7	Post Traumatic	11	20,5	Femur	40 / 1,00	none	
8	Idiopathic	16	18,5	Tibia	30 / 0,94	none	
9	Congenital Short Femur	16	17,8	Femur	40 / 1,11	none	
10	Osteogenezis İmperfecta / Post Traumatic	15	17,1	Femur	45 / 0,96	none	
11	Bilateral Blount Sequela + Short Stature	14	17,1	Tibia (B)	50 / 1,00	none	
12	Short Stature	18	16,9	Femur (b) †	50 / 1,00	none	
13	Skeletal Dysplasia	11	15,5	Femur	50 / 1,06	none	
14	MHE**	13	13,5	Femur †	50 / 0,96	Mechanism Not Worked	Nail extraction, control, re-reaming, reimplanting
15	Post Traumatic	10	11,1	Femur	50 / 1,22	none	
16	Idiopathic	16	10,1	Tibia	30 / 0,94	Ankle Equinus Contracture	Gastrocunemicus Recession
17	Achondroplasia	16	15,8	Humerus (b)	50 / 1,04	none	
18	Achondroplasia	15	13,3	Femur (b) †	50 / 1,00	none	
19	CFD Type 1***	14	14,6	Femur	48 / 1,09	Knee Flexion Contracture	Phsical Therapy

*(b): Bilateral lengthening performed in the same session, **MHE: Multiple Hereditary Exositozis, †: Retrograde nailing direction, ***CFD: Congenital Femoral Deficiency

at the time of surgery, use of the PRECICE nail for lower or upper limb lengthening, and availability of clinical and radiographic data for at least 9 months postoperatively. Exclusion criteria included: patients older than 18 years at the time of surgery, patients with metabolic bone diseases (e.g., rickets, osteomalacia), active or recent infections at the surgical site, previous surgeries on the same segment that may interfere with regenerate quality assessment, and incomplete or missing follow-up data**.** Patients older than 18 years, including 8 procedures in 7 patients, were excluded from the analysis.

All procedures were performed using different lengths and diameters of the same intramedullary nail system. A 4.5 mm drill was used to create a percutaneous vent hole prior to reaming. Sequential reaming was performed to 1.5 mm above the planned nail diameter. Osteotomy was achieved using a multiple-drill percutaneous technique. Minor deformity corrections were made intraoperatively using poller screws during nail insertion. Postoperative rehabilitation was conducted by a dedicated orthopedic rehabilitation team experienced in limb lengthening.

Distraction was initiated at a rate of 1 mm per day and continued until the target length was achieved. Full weight-bearing was permitted from the first postoperative day, as tolerated by the patient. To prevent joint contractures during the distraction phase, all patients were enrolled in a structured physiotherapy program supervised by a specialized team. Bracing was used selectively depending on the osteotomy site and adjacent joint risks. For femoral lengthenings, dynamic knee extension braces were employed when quadriceps tightness or reduced range of motion was observed. In tibial lengthenings, ankle-foot orthoses (AFOs) were prescribed as needed to maintain neutral ankle positioning. Compliance with bracing and therapy protocols was monitored during follow-up visits.

Follow-up evaluations were conducted biweekly and included physical examination and plain radiographs. Regenerate bone quality was assessed on standard anteroposterior and lateral radiographs taken at each visit. The Li classification system was utilized to grade regenerate quality, considering five morphological shapes (fusiform, cylindrical, concave, lateral, and central) and three density categories: low, intermediate, and normal, in addition to the number and continuity of visible cortices and overall radiodensity across the distraction gap [6]. Decisions regarding full weight-bearing and nail removal were made based on these standardized radiographic criteria.Full weight-bearing was achieved in all patients within the first month after completion of the distraction phase. Patients were categorized into two groups based on the occurrence of complications during treatment. These groups were compared in terms of age, etiology, lengthened segment, laterality (unilateral/bilateral), distraction parameters, and regenerate quality.

Descriptive statistics were presented as mean, standard deviation, median, minimum, maximum, frequency, and percentage. Group comparisons between patients with and without complications were performed using the independent samples t-test or the Mann–Whitney U test, depending on the distribution of the variables. Categorical variables were compared using the Chi-square test. Spearman correlation analysis was used to assess the relationship between the distraction rate and the lengthened segment. All analyses were performed using SPSS version 27.0.

Results

A total of 24 long bones in 18 patients underwent intramedullary lengthening in 19 separate sessions (Table 1). Five of these cases involved bilateral lengthening (Cases 4, 12, 17, and 18), including bilateral tibia, femur, and humerus procedures. The mean follow-up period was 18.8 months (range: 10.3–30.9 months). The average length gained was 45.7 ± 10.5 mm (range: 30–70 mm). The mean latency period before distraction began was 6.7 ± 2.8 days (range: 1–10 days). The mean distraction duration was 44.9 ± 9.1 days (range: 32–65 days), with a mean distraction rate of 1.0 ± 0.1 mm/day (range: 0.9–1.2 mm/day).

A total of four complications occurred in four patients during treatment. Two of these required return to the operating room. In one case, reoperation was recommended but postponed at the patient's request. One complication was resolved with orthopedic rehabilitation alone.

In Case 4, a patient undergoing bilateral tibial lengthening for short stature, abnormal mechanical axis deviation was observed. Retrospective analysis indicated that this was due to an incorrect entry point and lack of poller screw use. The deformity was corrected during implant removal with a controlled osteotomy.

In Case 14, a patient with Multiple Hereditary Exostosis underwent femoral deformity correction and lengthening. On postoperative day 10, nail distraction was found to be nonfunctional. The nail was removed and tested intraoperatively, showing normal function. A repeat reaming was performed, the nail was reinserted, and distraction proceeded without further issues (Fig. 1).

In Case 16, despite a relatively small length gain, a persistent ankle equinus contracture was observed at the end of treatment. The patient underwent open gastrocnemius recession and was immobilized with a soft cast. Recovery was completed after 6 weeks.

In Case 19, a patient developed increased knee flexion contracture after completion of treatment, which was resolved with aggressive physical therapy.

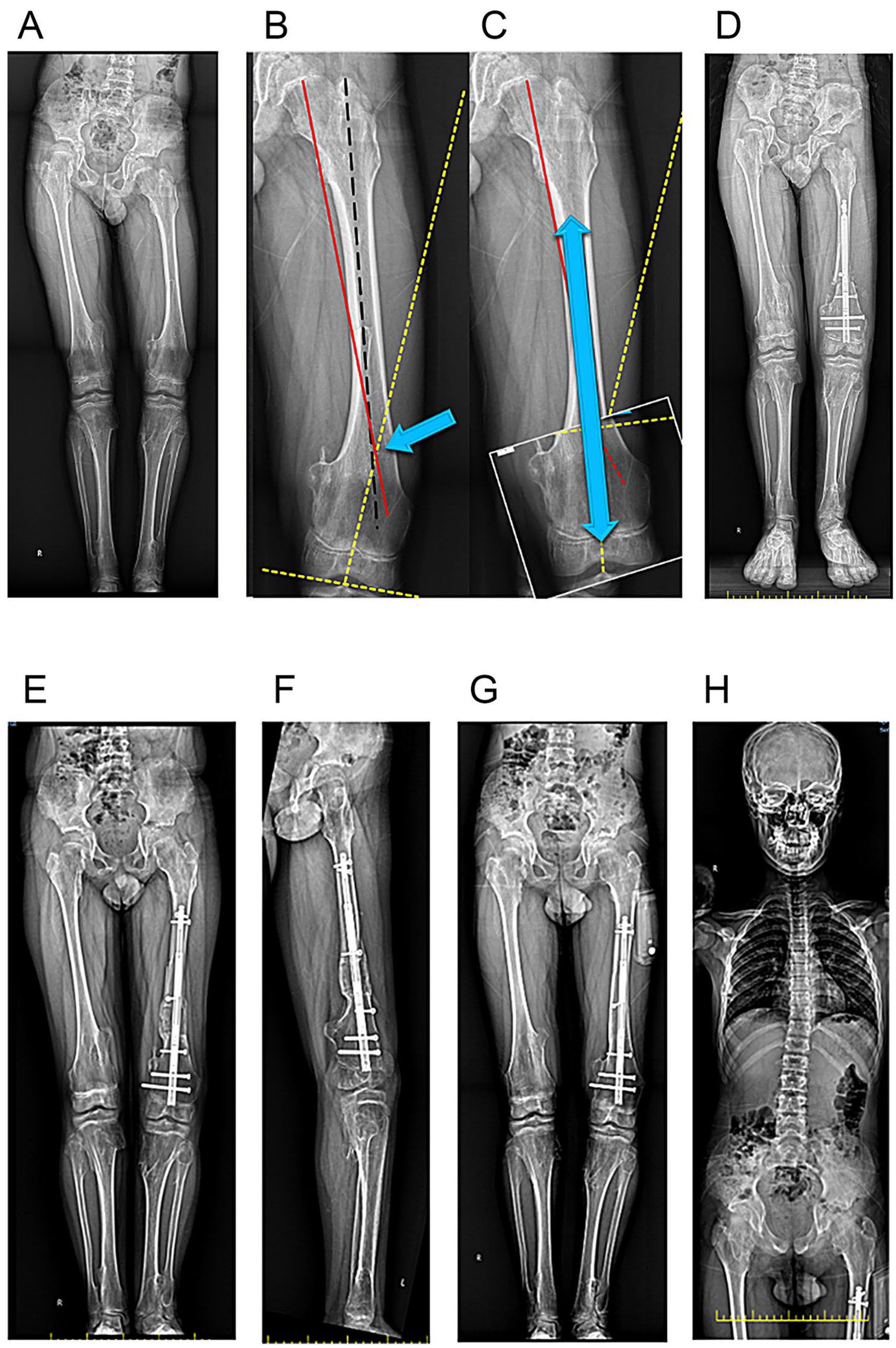

Fig. 1 Preoperative planning and complication management in a patient with Multiple Hereditary Exostosis undergoing femoral lengthening. (**a**) Preoperative orthoroentgenogram showing left distal femoral varus deformity and limb length discrepancy in a 13-year-old male patient. (b-c) Solid red line indicates the ideal mechanical axis of the femur; dashed yellow line represents the mechanical axis of the tibia extended proximally. The single headed blue arrow shows the planned osteotomy level; the double-headed blue arrow indicates the direction of intramedullary nail placement post-deformity correction. (**b**–**c** (d) Postoperative radiographs on day 10 showing failure of the lengthening mechanism. (**d** (**e**–**f**) Three-month postoperative radiographs demonstrating a Type 1 regenerate with good density and maturation. (**g**–**h**) One-year postoperative long-standing AP orthoroentgenogram and whole spine standing x-ray showing levelled pelvis. t

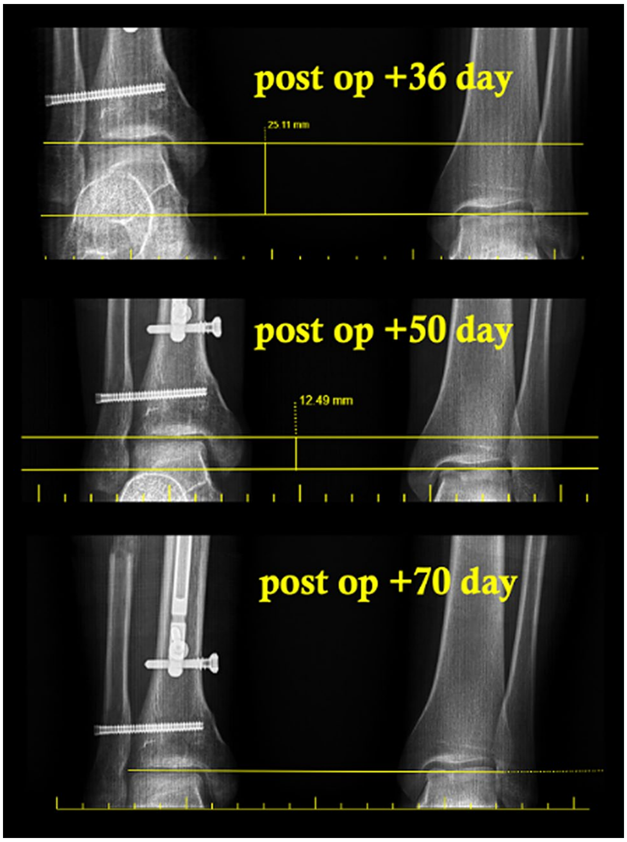

Fig. 2 Gradual correction of ankle equinus contracture during rehabilitation in a 16-year-old patient. Sequential standing orthoroentgenograms of Case 8 show elevation of the heel due to equinus contracture of the ankle. Over time, with targeted orthopedic rehabilitation, the ankle joint levels equalized and heel strike improved

Among the 24 lengthening procedures, Type 1 or 2 callus morphology was observed in 6 cases, Type 3 in 5 cases, and Type 4 in 2 cases. In 12 procedures, the regenerate bone exhibited moderate to high radiological density. No case demonstrated poor or insufficient callus formation.

Although transient reductions in joint range of motion were noted during treatment in several patients, these resolved spontaneously after regenerate maturation and treatment completion. Therefore, in line with previous literature, these were not considered complications (Fig. 2) [7, 8].

When patients were grouped based on the presence or absence of complications, no statistically significant differences were found in age, etiology, amount of lengthening, latency period, duration of distraction, distraction rate, direction of nailing, or regenerate quality ($p > 0.05$). However, correlation analysis revealed that the distraction rate was significantly higher in femoral lengthening procedures compared to tibial procedures ($p < 0.05$).

Specifically: Femur group: min–max = 0.938–1.220 mm/day, median = 1.032, mean ± SD = 1.043 ± 0.084, Tibia group: min–max = 0.938–1.000 mm/day, median = 0.940, mean ± SD = 0.952 ± 0.025 (Kruskal–Wallis test, Mann–Whitney U post hoc; $p = 0.036$).

Discussion

Fully internal limb lengthening using magnetically controlled intramedullary nails has become increasingly popular in recent years due to their low complication rates, the absence of transfixation-related issues such as pin site infections, and the facilitation of early and effective rehabilitation. Compared to circular external fixators—complex systems requiring a steep learning curve—magnetic nails offer a technically straightforward alternative, broadening the appeal of lengthening procedures for both surgeons and patients. These nails allow for safe and comfortable distraction osteogenesis without the mechanical or electronic failures historically associated with earlier systems.

However, disparities in healthcare access and economic resources across countries limit the availability of motorized internal lengthening nails, particularly in developing regions. In Turkey, their use is permitted under national health insurance only under specific indications and with prior authorization. Approval is granted for patients with a limb length discrepancy greater than 2 cm and no contraindications to intramedullary nailing, as well as for patients with height percentiles below the 10th percentile due to congenital, genetic, or metabolic conditions.

Our center opened in May 2020 as the largest and most advanced hospital in our region. The first magnetic nail procedure was performed in 2022, and the limb lengthening program remains active. All procedures in this study were performed by surgeons with formal fellowship training in limb lengthening and deformity correction. To maintain a homogenous adolescent and young adult cohort, patients older than 18 years—most of whom had post-traumatic etiologies—were excluded.

In our retrospective cohort, the rate of complications requiring reoperation was 16%, and minor complications unresolved at the end of treatment were seen in 5.3% of cases. These complications were infrequent and generally manageable. Among the 19 patients, three required reoperation: one for planned correction of a mechanical axis deviation during implant removal, one for distraction mechanism failure necessitating re-reaming and re-implantation, and one for gastrocnemius recession due to ankle equinus contracture. These cases posed both technical and biological challenges but were successfully resolved without long-term sequelae.

Compared to previous studies, our overall reoperation rate (16%) is lower than those reported by Shabtai et al. (38.9%) and Vogt et al. (26.6%), both of which included higher proportions of complex congenital deformities [3, 5]. Minor complications, such as knee flexion contractures or mild axis deviations, were observed but did not require surgical intervention in most cases. Similar patterns were reported by Iliadis et al. and Masci et al., who noted transient complications that resolved with conservative management [9, 10].

The relatively low rate of complications in our series may reflect the experience of the surgical team, strict adherence to physiotherapy protocols, and the structured patient selection criteria used in our institution. Furthermore, the use of internal lengthening systems eliminates risks associated with external fixators, such as pin site infections or neurovascular tethering, contributing to an overall safer profile.

Although we did not perform a separate statistical analysis comparing bone regeneration rates between congenital and acquired etiologies due to sample size limitations, it is important to note that congenital cases may present with unique anatomical and biological challenges. Previous studies have suggested that such deformities can be associated with prolonged healing indices and higher complication rates compared to post-traumatic or idiopathic etiologies [3, 5]. However, in our cohort, clinical outcomes were favorable across both congenital and acquired groups, and no consistent trend of delayed consolidation was observed in congenital cases. This suggests that with proper patient selection and surgical technique, magnetically controlled limb lengthening can be successfully applied in congenital conditions. Further subgroup analyses in larger series may help to clarify whether etiology significantly influences regenerate quality or healing time.

The application of magnetically controlled intramedullary nails in pediatric and adolescent patients has become increasingly feasible, with some studies reporting safe use in children as young as 8 years, especially with femoral antegrade nailing [4, 11, 12]. In our series, one 10-year-old patient underwent antegrade femoral lengthening without complication, supporting findings from the literature. Iobst et al. confirmed the safety and efficacy of these devices even in patients with programmable implantable devices, with all patients achieving target lengths without mechanical failure [13]. Iliadis et al. (2020) and Masci et al. (2021) both reported effective outcomes with low complication rates in pediatric populations using the PRECICE system [9, 10]. Calder et al. (2019) showed that both antegrade and retrograde femoral approaches using PRECICE nails yielded comparable results [14].

In bilateral applications, Vogt et al. reported no major complications resulting in permanent sequelae but did note minor issues, including two repeat osteotomies and one nail exchange [5]. In contrast, none of our bilateral cases resulted in long-term impairment, though one required planned deformity correction during implant removal and another involved a temporary distraction mechanism failure, resolved surgically. Similarly, Al-Sayyad et al. reported effective lengthening with minimal complications using magnetically driven nails in 15 patients [15].

The primary limitation of our study is the relatively small sample size and its retrospective design. Nevertheless, we believe our findings provide meaningful insights into the clinical and radiological outcomes of internal limb lengthening in adolescents and young adults. Future prospective studies with larger, more homogeneous cohorts are needed to validate these findings and enhance the evidence base. Despite its limitations, our study supports the expanding role of magnetic intramedullary lengthening in routine pediatric and adolescent orthopedic practice.

Conclusion

Magnetically controlled intramedullary lengthening nails represent a safe and effective option for limb lengthening in adolescent and young adult patients, offering low complication rates and favorable radiological and functional outcomes. When applied by experienced teams under appropriate indications, this technique provides a reliable alternative to external fixation, especially in centers with access to modern limb reconstruction technologies. However, further prospective studies with larger cohorts are needed to validate and generalize these findings.

Author contributions

Mehmet Ali Talmaç: Conceptualization, data collection, surgical procedures, supervision, manuscript writing and critical revision. Melih Civan: Study design, data analysis, manuscript drafting, literature review, and figure/table preparation. Ergün Mendes: Data curation, clinical follow-up coordination, statistical analysis, and manuscript review. All authors read and approved the final manuscript.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data availability

The datasets generated and/or analyzed during the current study are not publicly available due to institutional policy and patient confidentiality but are available from the corresponding author upon reasonable request.

Declarations

Ethical approval

This study was conducted in accordance with institutional guidelines and approved by the local ethics committee prior to data collection.

Competing interests

The authors declare no competing interests.

Received: 22 May 2025 / Accepted: 9 June 2025
Published online: 16 June 2025

References

1. Iobst CA, Rozbruch SR, Nelson S, Fragomen A. Simultaneous acute femoral deformity correction and gradual limb lengthening using a retrograde femoral nail: technique and clinical results. J Am Acad Orthop Surg. 2018;26(7):241–50.
2. Black SR, Kwon MS, Cherkashin AM, Samchukov ML, Birch JG, Jo CH. Lengthening in congenital femoral deficiency: A comparison of circular external fixation and a motorized intramedullary nail. J Bone Joint Surg Am Volume. 2015;97(17):1432–40.
3. Shabtai L, Specht SC, Standard SC, Herzenberg JE. Internal lengthening device for congenital femoral deficiency and fibular hemimelia. Clin Orthop Relat Res. 2014;472(12):3860–8.
4. Frommer A, Rödl R, Gosheger G, Vogt B. [Application of motorized intramedullary lengthening nails in skeletally immature patients: indications and limitations]. Unfallchirurg. 2018;121(11):860–7.
5. Vogt B, Laufer A, Gosheger G, Toporowski G, Antfang C, Rölfing JD, et al. Evaluation of simultaneous bilateral femoral distraction osteogenesis with antegrade intramedullary lengthening nails in achondroplasia with rhizomelic short stature: a retrospective study of 15 patients with a minimum follow-up of 2 years. Acta Orthop. 2024;95:47–54.
6. Li R, Saleh M, Yang L, Coulton L. Radiographic classification of osteogenesis during bone distraction. J Orthop Res. 2006;24(3):339–47.
7. Kocaoglu M, Eralp L, Kilicoglu O, Burc H, Cakmak M. Complications encountered during lengthening over an intramedullary nail. J Bone Joint Surg Am Volume. 2004;86(11):2406–11.
8. Paley P D. Problems, obstacles, and complications of limb lengthening by the Ilizarov technique. Clin Orthop Relat Res. 1990;250:81–104.
9. Masci G, Palmacci O, Vitiello R, Bonfiglio N, Bocchi MB, Cipolloni V, et al. Limb lengthening with PRECICE magnetic nail in pediatric patients: A systematic review. World J Orthop. 2021;12(8):575–83.
10. Iliadis AD, Palloni V, Wright J, Goodier D, Calder P. Pediatric lower limb lengthening using the PRECICE nail: our experience with 50 cases. J Pediatr Orthop. 2021;41(1):e44–9.
11. Radler C, Mindler GT, Stauffer A, Weiß C, Ganger R. Limb lengthening with precice intramedullary lengthening nails in children and adolescents. J Pediatr Orthop. 2022;42(2):e192–200.
12. Hammouda AI, Jauregui JJ, Gesheff MG, Standard SC, Herzenberg JE. Trochanteric entry for femoral lengthening nails in children: is it safe?? J Pediatr Orthop. 2017;37(4):258–64.
13. Iobst CA, Hatfield DN, Forro SD, Quinnan SM. Magnetically driven intramedullary limb lengthening in patients with Pre-existing implanted programmable devices: A case series. Strategies Trauma Limb Reconstr. 2023;18(2):111–6.
14. Calder PR, McKay JE, Timms AJ, Roskrow T, Fugazzotto S, Edel P et al. Femoral lengthening using the precice intramedullary limb-lengthening system: outcome comparison following antegrade and retrograde nails. Bone Joint J. 2019;101–b(9):1168–76.
15. Al-Sayyad MJ, Alshoaibi FA, Alshuaibi AA, Almohammadi AF, Almaghrabi HA, Alsaady AM, et al. Results of lower limb bone lengthening by using motorized and Magnet-Driven intramedullary nails to treat limb length discrepancy. Cureus. 2025;17(1):e77212.

Publisher's note