ORIGINAL ARTICLE

Cost Comparison of Tibial Distraction Osteogenesis Using External Lengthening and Then Nailing vs Internal Magnetic Lengthening Nails

Aleksey Dvorzhinskiy[1], David T Zhang[2], Austin T Fragomen[3], S Robert Rozbruch[4]

Abstract

Aim and objective: Tibial lengthening can be performed by distraction osteogenesis via lengthening and then nailing (LATN) or by using a magnetic lengthening nail (MLN). MLN avoids the complications of external fixation while providing accurate and easily controlled lengthening. Concerns exist still regarding the high upfront cost of the magnetic nail, which serves to limit its use in resource-poor areas and decrease adoption among cost-conscious surgeons. The purpose of this study was to compare the hospital, surgeon, and total cost between LATN and MLN when used for tibial lengthening.

Materials and methods: A retrospective review was performed comparing consecutive tibial lengthening using either LATN ($n = 17$) or MLN ($n = 15$). The number of surgical procedures and time to union were compared. Surgeon and hospital payments were used to perform cost analysis after adjusting for inflation using the consumer price index (CPI).

Results: Patients treated with MLN underwent fewer surgeries (3.6 vs 2.8; $p < 0.001$) but had a longer time to union as compared with patients treated with LATN (19.79 vs 27.84 weeks; $p = 0.006$). Total costs were similar ($50,345 vs $46,162; $p = 0.249$) although surgeon fees were lower for MLN as compared with LATN ($6,426 vs $4,428; $p < 0.001$).

Conclusion: LATN and MLN had similar overall costs in patients undergoing tibial lengthening. MLN was associated with fewer procedures but a longer time to union as compared with LATN.

Clinical significance: Despite an increased upfront cost in MLN, there was no difference in total cost between LATN and MLN when used for tibial lengthening. Thus, in cases where either method is feasible, cost may not be a deciding factor when selecting the appropriate treatment.

Keywords: Bone lengthening, Circular external fixation, Distraction osteogenesis, Internal fixation combined with external ring fixation, Internal lengthening nail, Intramedullary lengthening, Leg length discrepancy, Lengthening nail, Motorized implantable nail, Tibia.

Strategies in Trauma and Limb Reconstruction (2021): 10.5005/jp-journals-10080-1513

Introduction

The development of the Ilizarov method of distraction osteogenesis represented a major advance for the treatment of limb length discrepancy and deformity correction. Although the original technique has been modified numerous times, the basic tenets remain unchanged: osteotomy, distraction, and subsequent consolidation of bone. Numerous modifications to the technique have sought to shorten the healing time, limit complications, and decrease the burden on the patient.

In the treatment of long bone deformity, the classic Ilizarov method described an osteotomy, subsequent distraction, and eventual consolidation using an external fixator. While achieving impressive results, it required the patient to tolerate long periods in a cumbersome external device. This led to the development of hybrid techniques with the principle being that the external fixator only needed to be used during the distraction phase. Consolidation could then be achieved using internal fixation (i.e., an intramedullary nail). For the lower extremity, at least two of these methods were developed; these were lengthening over a nail (LON) and LATN. Both offered several theoretical advantages over the traditional technique. Firstly, a decreased time in external fixation resulted in fewer device-related complications including pin site infections and joint contractures. Secondly, there was an improvement in the patient's satisfaction with the treatment process owing to the shorter period in external fixation. Finally, the presence of an internal intramedullary nail was thought to decrease the risk of regenerate fracture as it could be maintained for much longer periods of time compared to a frame.[1–9] Both LATN and LON, while representing significant advances, still required the use of an external fixator during the distraction phase and did not eliminate totally the disadvantages of using this device.

The development of a fully implantable lengthening nail to obviate the need for external fixation altogether was the next advance. While early designs were plagued with complications,[10,11] a newer generation of magnetic internal lengthening nails has been shown to be effective and reliable for treating limb length

[1–4]Department of Limb Lengthening and Complex Reconstruction, Hospital for Special Surgery, New York, United States

Corresponding Author: Aleksey Dvorzhinskiy, Department of Limb Lengthening and Complex Reconstruction, Hospital for Special Surgery, New York, United States, Phone: +1 212 606 1000, e-mail: advorzh@gmail.com

How to cite this article: Dvorzhinskiy A, Zhang DT, Fragomen AT, *et al.* Cost Comparison of Tibial Distraction Osteogenesis Using External Lengthening and Then Nailing vs Internal Magnetic Lengthening Nails. Strategies Trauma Limb Reconstr 2021;16(1):14–19.

Source of support: Nil

Conflict of interest: None

discrepancy.[12–19] Recent comparative studies have noted that internal lengthening via a MLN may reduce many complications associated with the use of an external fixator namely, pin site infection, skin traction, knee stiffness, and regenerate fracture.[8,9,13,14,20–23] In addition, MLN in the femur has been associated with improved patient satisfaction and perception of an improved cosmetic result of the surgery.[9,24]

Concerns exist still over the high upfront cost of the nail that can serve to limit its use in resource-poor areas and decrease adoption among cost-conscious surgeons. While the actual device is more expensive, the costs of MLN-based treatment may be offset by fewer surgical procedures required and fewer complications. A recent study[25] compared the costs of femoral lengthening via LON vs MLN and found no significant difference in total costs between groups but at this time, no data have been published comparing LATN with MLN in the tibia. The purpose of this study was to compare the hospital, surgeon, and total cost between LATN and MLN when used for tibial lengthening.

Materials and Methods

Patient Population

All patients who underwent unilateral or bilateral tibial lengthening via distraction osteogenesis at our institution between 2001 and 2018 were included in the study. All surgical procedures were performed by the two senior authors of the study (S.R.R., A.T.F.) and included patients with a minimum of 2-year follow-up. Patients who underwent additional procedures at the time of lengthening (e.g., ankle distraction arthroplasty and subtalar fusion) were excluded from the study. Changes in practice preference of the treating surgeons meant that patients earlier in the study period underwent LATN ($n = 17$), while those later had MLN ($n = 15$). LATN was performed with the expectation of three procedures: (1) osteotomy with placement of an external fixator; (2) removal of external fixator and insertion of intramedullary nail, and (3) removal of the intramedullary nail. MLN was performed using the PRECICE nail (NuVasive, San Diego, CA, USA) with the expectation of two surgical procedures: (1) osteotomy with insertion of the MLN and (2) removal of the MLN. The typical treatment protocols, as demonstrated by serial radiographs, may be seen in Figure 1.

Outcomes

Patient clinical records were retrospectively reviewed, including demographics, the number of operative procedures, and total distraction length. Bony union was determined based on continuity of three of four cortices on AP and lateral radiographs as well as the ability to fully weight-bear without discomfort.

Cost analysis was performed from the payer's perspective. We compiled the total payments received by the hospital for all care related to tibial lengthening, including surgical, inpatient, and outpatient visits. This total was included as the total hospital cost paid by the payer. For each surgical procedure performed, the current procedural terminology (CPT) codes billed were recorded and used to calculate an expected surgeon fee using the Medicare Physician Fee Schedule (https://www.cms.gov/apps/physician-fee-schedule/), represented as the surgeon cost. A list of the included CPT codes can be found in Table 1. These two components were summed for the total cost. For patients who underwent bilateral procedures, costs were normalized to an average cost of the procedure on a single limb. Similarly, the number of procedures was only counted once for a single limb per patient, whichever limb underwent a greater number of procedures. To allow dollar values to be accurately compared over the study period, costs were adjusted for inflation and recorded in 2018 dollars using the chained CPI (https://data.bls.gov/pdq/SurveyOutputServlet).

Statistical Analysis

Clinical and cost data were compared between LATN and MLN groups using a chi-squared test for categorical data and Mann–Whitney U-test for continuous data. Analyses were performed using SPSS (IBM, Armonk, NY, USA).

Results

Demographics

A total of 32 patients were included in the study (17 having undergone LATN and 15 had MLN). The average age for each group, respectively, was 35 years in LATN and 39 years for MLN. No notable differences were observed in the demographics between LATN and MLN cohorts.

Clinical Results

The total length distracted was longer in the LATN vs the MLN group (5.51 vs 4.29 cm in LATN and MLN, respectively; $p = 0.044$). There were significantly more bilateral cases in the LATN group as compared with the MLN group (65 vs 13%, $p = 0.003$). Time to union was lower in the LATN group as compared with MLN (19.79 vs 27.84 weeks; $p = 0.006$).

As shown in Figure 2, patients undergoing LATN underwent nearly one more surgical procedure than MLN (3.6 vs 2.8, $p < 0.001$). There was no difference in outpatient visits between groups (10.2 vs 10.0 in LATN vs MLN, respectively; $p = 0.682$). A summary of the findings can be found in Table 2.

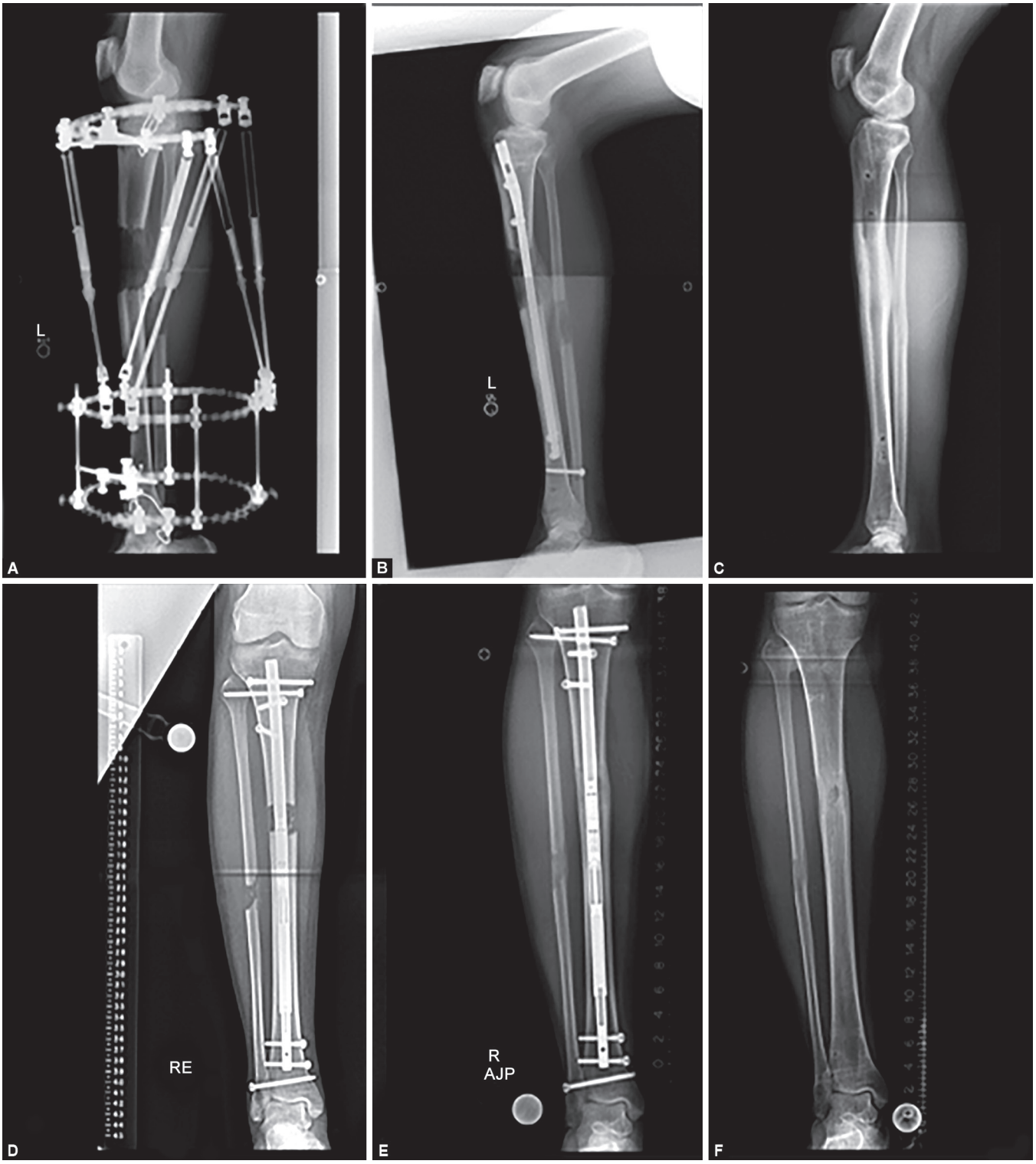
Costs

Hospital costs were similar between LATN and MLN groups ($43,919 vs $42,130, respectively, $p = 0.439$). Surgeon payments were higher for patients treated with LATN vs MLN ($6,426 vs $4,032, respectively, $p < 0.001$). There was no significant difference in total cost (hospital + surgeon) between LATN and MLN ($50,345 vs $46,162, $p = 0.249$). A comparison of costs is shown in Figure 3.

A *post hoc* analysis revealed that the given sample size allowed for a power of 0.8 to determine a total cost (hospital + surgeon) difference of $25,000 or greater.

Discussion

In this retrospective comparison of patients undergoing tibial distraction osteogenesis, treatment with MLN resulted in lower surgeon costs with no difference in hospital or total costs as compared with the LATN technique. Patients within the MLN group achieved final union while undergoing approximately one fewer operative procedure and a similar amount of office visits. A previous study by our research group comparing hybrid (internal + external fixation) with MLN in the femur found very similar results with no difference in total costs and fewer procedures in the MLN group.[25] Although MLN has a higher implant cost, it is likely that this is offset by the corresponding decrease in operative procedures. Aside from the economic considerations, MLN has been shown to have many advantages over hybrid lengthening procedures because it avoids the use of external fixators, which can result in increased pain, skin traction due to pin migration, joint stiffness, and social stigma.[3,4,6,9]



Figs 1A to F: Radiographs depicting treatment with LATN and MLN. (A to C) LATN: lengthening of the tibia using an external fixator (A). Consolidation of the regenerate after removal of the external fixator and insertion of an intramedullary nail (B), and ultimate removal of the intramedullary nail after union (C). (D to F) MLN: insertion of the MLN (D), consolidation of the regenerate after lengthening was completed (E), and the final result after removal of the nail (F). LATN, lengthening and then nailing; MLN, magnetic lengthening nail

Previous studies performed in the femur have shown a decreased time to union in the MLN group vs lengthening over a nail (LON).[9,25] On the contrary, in our study, the time to union of the LATN group was significantly shorter than the MLN group (19.79 vs 27.84 weeks). One explanation for this phenomenon is that in LATN, the canal is reamed after formation of the regenerate while in MLN and LON, the canal is reamed prior to distraction and before the creation of regenerate. Reaming may have a detrimental effect on

Table 1: A listing of the CPT codes used in the calculation of surgeon fees

Techniques	*Encounter*	*CPT code*	*Patients*	*Description*
LATN	Surgery #1	20692	17	Application of external fixator
		27715	17	Osteoplasty tibia/fibula
	Surgery #2	27745	17	Prophylactic stabilization of the tibia
		20694	17	Removal of external fixator
	Surgery #3	20680	17	Removal of implant, deep
	Other codes	20610	1	Injection of major joint/bursa
		20670	1	Removal of implant, superficial
		20693	5	Adjustment/revision external fixator requiring anesthesia
		20974	4	Electric stimulation of bone to aid in healing
		20979	1	Low intensity ultrasound stimulation of bone
		27394	1	Lengthening of hamstring tendon
		27687	9	Gastrocnemius recession
		27720	1	Repair non-union, tibia
		27829	6	Open treatment of distal tibiofibular joint
		29405	1	Short leg cast
MLN	Surgery #1	27745	15	Prophylactic stabilization of the tibia
		27715	15	Osteoplasty tibia/fibula
	Surgery #2	20680	15	Removal of implant, deep
	Other codes	11981	1	Insertion antibiotic beads lower extremity
		20902	2	Major bone graft, iliac crest
		20974	5	Electric stimulation of bone to aid in healing
		27687	6	Gastrocnemius recession
		27892	1	Left leg anterior and lateral compartment fasciotomy
		38220	1	Bone marrow aspiration

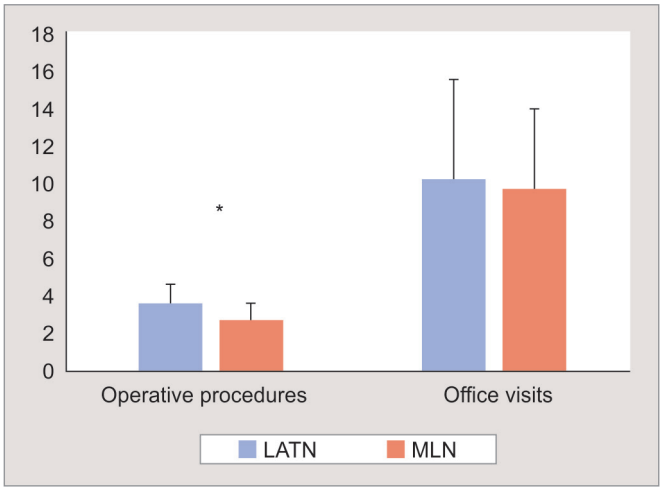


Fig. 2: Comparison of the number of procedures performed and office visits for patients treated with LATN vs MLN. *Signifies $p < 0.05$. LATN, lengthening and then nailing; MLN, magnetic lengthening nail. Bars represent standard deviation

Table 2: Demographic, clinical, and cost comparison between patients who underwent treatment with LATN vs MLN

Parameters	*LATN*	*MLN*	*P-value*
Patients	17	15	–
% Female	35	60	0.162
Age (yr)	35.2 ± 13.49	38.73 ± 12.61	0.278
% Cases bilateral	65%	13%	0.003
Length distracted (cm)	5.51 ± 1.73	4.29 ± 1.32	0.044
Time to union (weeks)	19.79 ± 5.25	27.84 ± 8.56	0.006
Operative procedures	3.6 ± 1.0	2.8 ± 0.9	<0.001
Outpatient office visits	10.2 ± 5.3	9.9 ± 4.4	0.682
Hospital costs ($)	43,919 ± 22,601	42,130 ± 28,822	0.439
Surgeon costs ($)	6,426 ± 1752	4,032 ± 1687	<0.001
Total cost (hospital + surgeon, $)	50,345 ± 24,353	46,162 ± 30,509	0.249

regenerate formation but a positive effect on ultimate union after a regenerate has been created.[22,26]

The hospital cost data used in this study was compiled from a sum of all payments made to the hospital by the payer. This is a more accurate assessment of cost than total billings as it reflects what the patient or insurance company actually paid for the treatment received and, thus, the direct cost of the treatment to the healthcare system. The downside of this method is that it is dependent on the payer mix (i.e., insurance plan) of the patient cohort and this varies with different populations. The surgeon billing data were calculated based on the Medicare Physician Fee Schedule to standardize reimbursement as each patient's individual data was unavailable. Although relatively uniform regardless of location, this cost may differ and not be generalizable to patients with private payer insurance.

This study had several limitations. First, the review of this data was performed retrospectively and thus there may be inherent biases between the two groups which underwent treatment at different time periods and with variable lengths of follow-up. The distraction length of the LATN group was significantly longer

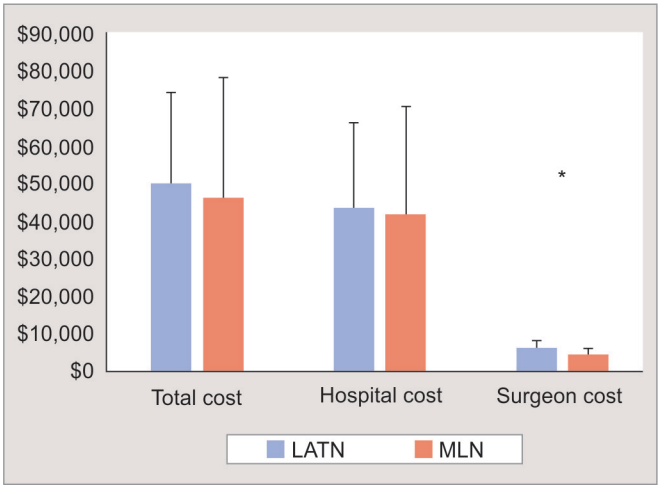


Fig. 3: Comparison of total, hospital, and surgeon costs for the patients treated with LATN vs MLN. *Signifies $p < 0.05$. LATN, lengthening and then nailing; MLN, magnetic lengthening nail. Bars represent standard deviation

as compared to the MLN group (5.51 vs 4.29 cm). This may have increased the overall cost in this group, regardless of the effect of the procedure itself. Additionally, the LATN group had significantly more patients undergoing bilateral procedures as compared with the MLN group. Great care was taken to adjust the payment amount for the bilateral procedures to be an average of the two limbs and each patient was only counted a single time in the analysis, regardless of whether they underwent surgery for one or two limbs. Similarly, for the analysis of number of procedures, only a single limb was counted per patient, whichever underwent a greater number of procedures. For the hospital costs, this produced an underestimation of the cost for patients with bilateral procedures as the hospital costs were divided by two and thus biased in favor of LATN over MLN. The exact costs of various components of treatment would help for precise adjustments to be made but were not available.

Our protocol called for the intramedullary nail to be removed in both the LATN and MLN group at the end of treatment. Although this is the standard at our institution, modifications to this protocol, such as declining to remove the intramedullary nail in either group would change the cost comparison significantly.

This study focused on direct costs and did not capture indirect or opportunity costs. This can have an important effect as MLN had a significantly longer course of treatment and therefore may have resulted in additional time away from work or other activities. Conversely, the less prohibitive nature of MLN treatment may have allowed patients to return to work during lengthening while LATN prevented them from doing so. Unfortunately, while these indirect costs play an important role in the burden of the therapy on patients and society, these were not available for the measure.

Conclusion

The results of this study indicate that in patients undergoing isolated lengthening of the tibia, there is no difference in total payments between LATN and MLN despite the increased cost of the implants in the latter group. This can be attributed to the additional procedures and hospital care required for the LATN technique.

Clinical Significance

Despite an increased upfront cost in MLN, there was no difference in total payments between LATN and MLN when used for tibial lengthening. Thus, in cases where either method can be used, cost may not serve as a deciding factor when selecting the appropriate treatment.

References

1. Kim HJ, Fragomen AT, Reinhardt K, et al. Lengthening of the femur over an existing intramedullary nail. J Orthop Trauma 2011;25(11):681–684. DOI: 10.1097/BOT.0b013e3181f92d6e.
2. Sangkaew C. Distraction osteogenesis of the femur using conventional monolateral external fixator. Arch Orthop Trauma Surg 2008;128(9):889–899. DOI: 10.1007/s00402-007-0437-1.
3. Wan J, Ling L, Zhang XS, et al. Femoral bone transport by a monolateral external fixator with or without the use of intramedullary nail: a single-department retrospective study. Eur J Orthop Surg Traumatol 2013;23(4):457–464.DOI: 10.1007/s00590-012-1008-x.
4. Gordon JE, Manske MC, Lewis TR, et al. Femoral lengthening over a pediatric femoral nail: results and complications. J Pediatr Orthop 2013;33(7):730–736. DOI: 10.1097/BPO.0b013e3182a122a1.
5. Paley D, Herzenberg JE, Paremain G, et al. Femoral lengthening over an intramedullary nail. A matched-case comparison with ilizarov femoral lenghtening. J Bone Joint Surg Am 1997;79(10):1464–1480. DOI: 10.2106/00004623-199710000-00003.
6. Song HR, Oh CW, Mattoo R, et al. Femoral lengthening over an intramedullary nail using the external fixator: risk of infection and knee problems in 22 patients with a follow-up of 2 years or more. Acta Orthop 2005;76(2):245–252. DOI: 10.1080/00016470510030652.
7. Watanabe K, Tsuchiya H, Sakurakichi K, et al. Tibial lengthening over an intramedullary nail. J Orthop Sci 2005;10(5):480–485. DOI: 10.1007/s00776-005-0939-z.
8. Xu W. Comparison of intramedullary nail versus conventional Ilizarov method for lower limb lengthening: a systematic review and meta-analysis. Orthop Surg 2017;9(2):159–166. DOI: 10.1111/os.12330.
9. Laubscher M, Mitchell C, Timms A, et al. Outcomes following femoral lengthening: an initial comparison of the precice intramedullary lengthening nail and the Irs external fixator monorail system. Bone Joint J 2016;98-B(10):1382–1388. DOI: 10.1302/0301-620X.98B10.36643.
10. Mahboubian S, Seah M, Fragomen AT, et al. Femoral lengthening with lengthening over a nail has fewer complications than intramedullary skeletal kinetic distraction. Clin Orthop Relat Res 2012;470(4):1221–1231. DOI: 10.1007/s11999-011-2204-4.
11. Lee DH, Ryu KJ, Song HR, et al. Complications of the Intramedullary Skeletal Kinetic Dissiteor (ISKD) in distraction osteogenesis. Clin Orthop Relat Res 2014;472(12):3852–3859. DOI: 10.1007/s11999-014-3547-4.
12. Rozbruch SR, Birch JG, Dahl MT, et al. Motorized intramedullary nail for management of limb-length discrepancy and deformity. J Am Acad Orthop Surg 2014;22(7):403–409. DOI: 10.5435/JAAOS-22-07-403.
13. Paley D. PRECICE intramedullary limb lengthening system. Expert Rev Med Devices 2015;12(3):231–249. DOI: 10.1586/17434440.2015.1005604.
14. Kirane YM, Fragomen AT, Rozbruch SR. Precision of the PRECICE® internal bone lengthening nail. Clin Orthop Relat Res 2014;472(12):3869–3878. DOI: 10.1007/s11999-014-3575-0.
15. Bernstein M, Fragomen AT, Sabharwal S, et al. Does integrated fixation provide benefit in the reconstruction of posttraumatic tibial bone defects? Clin Orthop Relat Res 2015;473(10):3143–3153. DOI: 10.1007/s11999-015-4326-6.
16. Rozbruch SR, Fragomen AT. Lengthening of the femur with a remote-controlled magnetic intramedullary nail: antegrade technique. JBJS Essent Surg Tech 2016;6(1):e2. DOI: 10.2106/JBJS.ST.O.00063.
17. Fragomen AT, Rozbruch SR. Lengthening and deformity correction about the knee using a magnetic internal lengthening nail. SICOT J 2017;3:25. DOI: 10.1051/sicotj/2017014.

18. Rozbruch SR. Adult posttraumatic reconstruction using a magnetic internal lengthening nail. J Orthop Trauma 2017;31(6 Suppl):S14–S19. DOI: 10.1097/BOT.0000000000000843.
19. Fragomen AT, Rozbruch SR. Lengthening of the femur with a remote-controlled magnetic intramedullary nail: retrograde technique. JBJS Essent Surg Tech 2016;6(2):e20. DOI: 10.2106/JBJS.ST.15.00069.
20. Horn J, Grimsrud Ø, Dagsgard AH, et al. Femoral lengthening with a motorized intramedullary nail. A matched-pair comparison with external ring fixator lengthening in 30 cases. Acta Orthop 2015;86(2):248–256. DOI: 10.3109/17453674.2014.960647.
21. Wiebking U, Liodakis E, Kenawey M, et al. Limb Lengthening using the PRECICETM nail system: complications and results. Arch Trauma Res 2016;5(4):e36273. DOI: 10.5812/ATR.36273.
22. Rozbruch SR, Kleinman D, Fragomen AT, et al. Limb lengthening and then insertion of an intramedullary nail: a case-matched comparison. Clin Orthop Relat Res 2008;466(12):2923–2932. DOI: 10.1007/s11999-008-0509-8.
23. Liu H, Cella D, Gershon R, et al. Representativeness of the patient-reported outcomes measurement information system internet panel. J Clin Epidemiol 2010;63(11):1169–1178. DOI: 10.1016/j.jclinepi.2009.11.021.
24. Fragomen AT, Kurtz AM, Barclay JR, et al. A comparison of femoral lengthening methods favors the magnetic internal lengthening nail when compared with lengthening over a nail. HSS J 2018;14(2):166–176. DOI: 10.1007/s11420-017-9596-y.
25. Richardson SS, Schairer WW, Fragomen AT, et al. Cost comparison of femoral distraction osteogenesis with external lengthening over a nail versus internal magnetic lengthening nail. J Am Acad Orthop Surg 2019;27(9):e430–e436. DOI: 10.5435/JAAOS-D-17-00741.
26. Ryu KJ, Kim BH, Hwang JH, et al. Reamed intramedullary nailing has an adverse effect on bone regeneration during the distraction phase in tibial lengthening. Clin Orthop Relat Res 2016;474(3):816–824. DOI: 10.1007/s11999-015-4613-2.