

Use of a magnetic bone nail for lengthening of the femur and tibia

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ABSTRACT

Purpose. To report our experience with the PRECICE nail for limb lengthening in 23 patients.

Methods. Records of 15 female and 8 male patients aged 14 to 38 (mean, 23.6) years who underwent lengthening of the tibia (n=6) or femur (n=21) using the PRECICE nail were reviewed. The reasons for lengthening included trauma (n=7), hemihypertrophy (n=2), focal femoral deficiency (n=2), Ellis-van Creveld syndrome (n=1), hip septic arthritis sequelae (n=1), hereditary multiple exostosis (n=1), club foot sequela (n=1), congenital tibial pseudoarthrosis (n=1), fibrous dysplasia (n=1), idiopathic limb length discrepancy (n=7), and cosmetic (n=1).

Results. The mean follow-up duration was 20.72 months. The mean lengthening was 48.20 mm, and the mean acute angular correction was 15.5°. The mean time to full weight-bearing was 5.15 months, and the mean consolidation index was 1.12 months/cm. The mean maturation index was 0.78 months/cm. One patient had nail breakage during the consolidation phase. The nail was replaced by an

intramedullary nail until consolidation, after which another PRECICE nail was used to treat the residual shortening. Eight patients had over-lengthening and the nails were driven back to the desired length. No patient had infection.

Conclusion. The PRECICE nail is a viable option for lengthening of the femur and tibia.

Key words: bone lengthening; bone nails; leg length inequality

INTRODUCTION

The use of external fixators is effective for limb lengthening secondary to trauma or congenital deformity and for cosmetic lengthening. The use of an intramedullary nail or a plate is superior to external fixators in terms of complications (pin tract infections, joint stiffness), the time required for interventions, early joint exercises, and patient comfort and compliance.¹ The use of telescopic lengthening nails through a mechanical mechanism such as the intramedullary skeletal kinetic distractor (ISKD) nail (Orthofix; Lewisville [TX], USA), Albizzia

nail (DePuy, Villeurbanne, France), and implantable motorised lengthening nails (Fitbone; Wittenstein, Igersheim, Germany) has become popular,²⁻⁵ as has use of lengthening nails through a magnetic mechanism such as the Phenix M21 bone-lengthening nail (Phenix Medical, France), and the PRECICE nail (Ellipse Technologies, Irvine [CA], USA).

The PRECICE nail comprises a telescopic nail with a magnet-driven distraction mechanism and an external remote control to lengthen or shorten the nail through the magnetic field. This study reports our experience with the PRECICE nail for limb lengthening in 23 patients.

MATERIALS AND METHODS

Records of 15 female and 8 male patients aged 14 to 38 (mean, 23.6) years who underwent lengthening of the tibia (n=6) or femur (n=21) using the PRECICE nail between 2011 and 2014 were reviewed. The reasons for lengthening included trauma (n=7), hemihypertrophy (n=2), focal femoral deficiency (n=2), Ellis-van Creveld syndrome (n=1), hip septic arthritis sequelae (n=1), hereditary multiple exostosis (n=1), club foot sequela (n=1), congenital tibial pseudoarthrosis (n=1), fibrous dysplasia (n=1), idiopathic limb length discrepancy (n=7), and cosmesis (n=1).

The amount of discrepancy, the amount of bone to be lengthened, and the diameter of the medullary canal were measured using standing long-leg radiographs. Any rotational deformity was evaluated using a drawing software and the end-point-first method.⁶

Of the 21 femurs, 11 were lengthened antegradely with fossa piriformis entry (n=4) or trochanteric entry (n=7) and 10 were lengthened retrogradely. For the retrograde femoral technique, the patient was placed supine on a radiolucent operating table under anaesthesia. To control rotation after osteotomy, one Schanz screw was fixed to the proximal femur and another was fixed to the distal femur, with the screws parallel to each other at the beginning of the procedure. The knee was flexed to 30°. A guide wire was inserted through the patellar tendon to the standard entry point for retrograde femoral nailing. The guide was pushed into the medullary canal, and the proximal femur was reamed. In the distal femur, rigid reamers were used to reshape the curved medullary canal to fit the straight nail to avoid anterior cortex impingement of the nail tip. An osteotomy was made. In 4 patients with associated angular deformity, a positioning screw was placed

to obtain acute deformity correction. After insertion of the lengthening nail, the rotational position of the segments was adjusted and the associated rotational deformity was corrected with the help of the parallel Schanz screws in 3 of the patients. Then, proximal and distal locking screws were affixed. The location of the internal magnet of the nail was marked on the skin. Before ending the procedure, the nail was lengthened by 1 mm to check the mechanism.

For the antegrade technique, the patient was placed supine on a radiolucent table under anaesthesia. A guide wire was inserted through the fossa piriformis or tip of the trochanter major for the femoral cases, and the anterior site of the proximal tibia for the tibial cases. After inserting the guide wire into the medullary canal, the medulla was over-reamed by 0.5 mm and an osteotomy was performed at a point 8 cm distal to the nail entry point using the drill osteotome technique in both the tibia and femoral cases. The nail was inserted and fixed with 2 proximal and 2 distal locking screws.

Postoperatively, non-weight-bearing mobilisation with 2 crutches was allowed on day 1. Active knee exercises were encouraged. Patients were instructed to use the remote control for lengthening starting on day 7 and followed up weekly. Before the end of the lengthening phase, the amount of lengthening was measured using a biplane radiography system for those cases where there was a possibility of inaccurate measurement using standard long leg radiographs. If any over-lengthening was noted, the nail was driven back until the planned length was achieved. Patients were followed up every 4 to 6 weeks until bone consolidation and full weight-bearing.

RESULTS

The mean follow-up duration was 20.72 (5–45) months. The mean lengthening was 48.20 (34–120) mm, and the mean acute angular correction was 15.5° (7°–25°). The mean time to full weight-bearing (consolidation time) was 5.15 months, and the mean consolidation index was 1.12 (standard deviation [SD], 0.28; range, 0.87–1.71) months/cm. The mean maturation index was 0.78 (SD, 0.28; range, 0.47–1.38) months/cm.

In the 2 patients with hemihypertrophy, both the tibia and femur were over-lengthened by 0.5 cm due to a 1-cm discrepancy in the calcaneal malleolar distance (Fig.). In a patient with a 12-cm femoral length discrepancy secondary to traumatic physeal damage, the PRECICE nail broke after lengthening by 6.5 cm during the consolidation phase and was replaced by

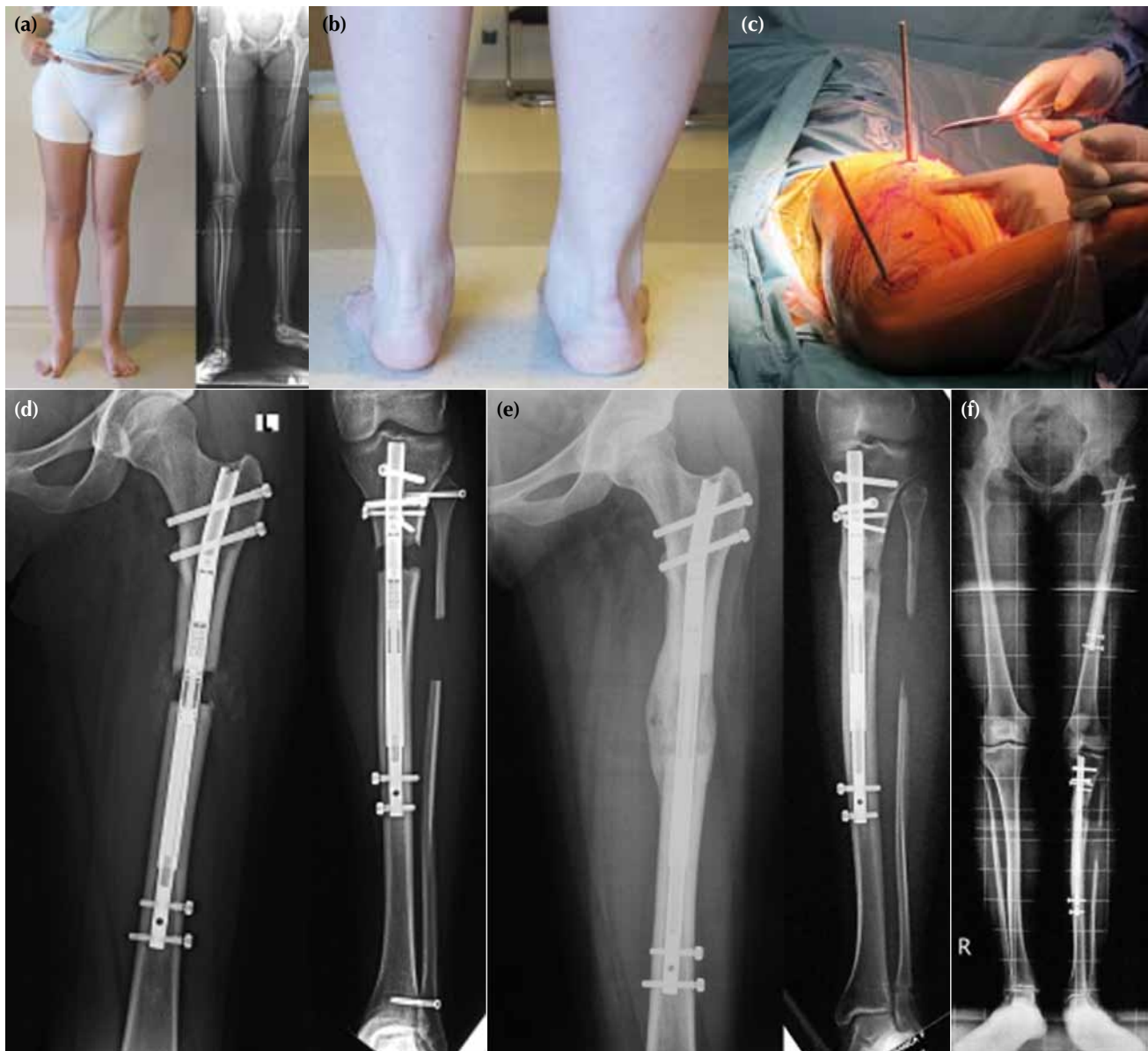


Figure In a 17-year-old female, (a) shortening of the left leg (45-mm in femur and 30 mm in tibia) is secondary to hemihypertrophy. The tibia and femur are over-lengthened by 0.5 cm due to (b) a 1-cm discrepancy on the calcaneal malleolar distance. (c) Two parallel Schanz screws are placed onto distal and proximal ends of the femur to check the rotational positions of the segments. Radiographs showing the (d) lengthening phase, (e) consolidation phase, and (f) at the end of the treatment.

a standard intramedullary nail. After consolidation, another PRECICE nail was used to lengthen further 5.5 cm. In one patient with focal femoral deficiency treated with a Fitbone nail, regeneration on the distraction site was poor and thus treated with freshly frozen strut allograft combined with autogenous cancellous bone grafting (Sandwich technique).⁷ A PRECICE nail was then used to lengthen the femur by 6.5 cm, with osteotomy on the grafted site. After consolidation, another PRECICE nail was used to treat the residual discrepancy of 5.5 cm, with an osteotomy

at the same site. Eight patients had over-lengthening, and the nails were driven back to the desired length. Scar formation was minimal at the incision sites, and cosmetic outcome was acceptable in all patients. No patient had infection.

DISCUSSION

In 36 patients with the Albizzia nail system, 8 reported excessive pain during the lengthening manoeuvres

and required anaesthesia.⁸ In 12 patients with the ISKD nail, 4 reported a runaway phenomena.⁴ In 10 patients with the Phoenix nail, 3 reported an arrest of distraction in which small nails were used.⁹ In 24 patients with the PRECICE nail, one experienced an arrest.¹⁰ In another 24 patients with the PRECICE nail, 2 reported an arrest.¹¹ Excessively thick soft tissue around the bone acts as a barrier to communication between the external remote control and the nail mechanism and leads to the arrest.¹¹ In our series, no problem with the magnet-driven mechanism was encountered.

Patients with a higher body mass index have a larger medullary canal, and wider nails should be used. When a thin nail is used in an obese patient, the nail can be damaged during the insertion procedure and the mechanism may not function.

All telescopic intramedullary nails are straight because of the magnetic mechanism contained within. As a result, a common problem in femoral applications is anterior cortex impingement and fractures around the nail tip.¹² Over-reaming of the entire medullary canal is a solution but may result in a very thin cortex. We managed to solve this problem using posterior cortex rigid reaming and reshaping of the canal; no problem regarding the nail tip, anterior impingement, fractures, or a thin femoral cortex was encountered. Nonetheless, exaggerated posterior cortex reaming can negatively affect bone regeneration. The smallest-diameter Fitbone nail is 12 mm and the shortest Fitbone nail is 245 mm (it can be customised to 163 mm). The smallest diameter of the ISKD nail is 10.7 mm and the shortest nail is 215 mm. The smallest PRECICE nail is smaller, with 8.5 mm in diameter and 195 mm in length. This results in a smaller amount of reaming and it can be used in patients with smaller femurs. In addition, the PRECICE nail has an acute proximal angle to prevent acute displacement of the osteotomy site and sagittal plane angulation after insertion. The PRECICE nail has options for trochanteric and fossa piriformis entry. With fossa piriformis entry, the medullary canal can be reshaped using rigid reamers. Nonetheless, to avoid the risk of femoral neck fracture and femoral head avascular necrosis in young adults, it is safer to use the transtrochanteric entry point.

In mechanical nails such as the Albizzia and ISKD, rotational manoeuvres are necessary to obtain lengthening. During the early stages of lengthening, such manoeuvres can cause severe pain owing to the contact of the 2 segments at the osteotomy site and necessitate anaesthesia.⁸ To minimise pain, a smooth osteotomy should be made using a Gigli saw. In linear expandable nails such as Fitbone, Phoenix, and PRECICE, a smooth osteotomy is not necessary.

In our study, the osteotome drill technique was used, in which the bone biology is minimally affected. Early fibular consolidation necessitates fibular re-osteotomy.⁹ In our study, 1-cm fibular block resection was used to avoid early consolidation.

In lengthening using the Ilizarov frames, the optimum lengthening speed is 4×0.25 mm daily. The same principle is applied for intramedullary nail lengthening. The ISKD nail has a system to monitor the instantaneous amount of lengthening. In 57 patients with the ISKD nail, the ISKD monitoring system was not successful in detecting 3 cases of acute lengthening.⁵ For the Fitbone nail, a stethoscope is used to determine the nail mechanism function and to count the actual lengthening. For all such nails, the actual amount of lengthening can only be detected by weekly radiographic follow-up. Thereafter, the rate of lengthening can be slowed down or accelerated as necessary¹³ by teaching the patient to change the frequency of lengthening. The PRECICE nail contains an automatic calculation system that gives the amount of lengthening according to the rotation of the magnet within the nail. But the transmission of the magnetic force to the nail is affected by the thickness of surrounding soft tissue. The calculation from the PRECICE external unit is not reliable, and therefore weekly radiologic follow-up is necessary to monitor lengthening. One study reported a mean calculated lengthening of 34.47 mm, compared with the actual mean lengthening of 33.65 mm.¹⁰

The mean consolidation index for ISKD, Fitbone (in 2 studies), and Phoenix nails has been reported to be 37.8 day/cm,⁴ 1.07 months/cm,¹² 24 day/cm,¹⁴ and 27 day/cm,⁹ respectively, which is consistent with 1.12 months/cm in our study.

Motorised and mechanical nails can only lengthen the nail segments and do not allow shortening when overlengthening occurs. The PRECICE nail allows both lengthening and shortening but cannot be used in sites containing previously applied metallic implants. It is not suitable for patients with excessive angular deformities, infections, or inappropriate medullary canal.

CONCLUSION

The PRECICE nail is a viable option for lengthening of the femur and tibia.

DISCLOSURE

No conflicts of interest were declared by the authors.

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