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COMPLICATIONS ENCOUNTERED DURING LENGTHENING OVER AN INTRAMEDULLARY NAIL

[SCIENTIFIC ARTICLES]

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Abstract

Background: In limb-lengthening, the quest for increased patient comfort and a reduced period of external fixation has led to techniques such as lengthening over an intramedullary nail. The goals of this study were to investigate the rate and types of complications encountered during lengthening over an intramedullary nail and to identify solutions to these complications.

Methods: Forty-two segments (thirty-five femora and seven tibiae) in thirty-five patients were lengthened. The mean age of the patients was 26.6 years, the mean amount lengthened was 6.3 cm (range, 2.5 to 11.5

cm), the mean external fixation index was 18.7 days/cm, and the mean lengthening index was 31.2 days/cm. The patients were followed for a mean period of forty-four months postoperatively.

Results: Eighteen complications occurred in sixteen (38%) of the forty-two segments for a rate of 0.43 complication per segment. Complications were classified, according to the system of Paley et al., as two problems, thirteen obstacles, and three sequelae. Sixteen of them required additional surgical interventions. A preoperative score of >6.5 on the system of Paley et al., a lengthening of >6 cm, and a lengthening percentage of >21.5% of the original bone length were indicators of a higher probability of the occurrence of complications.

Conclusions: Lengthening over an intramedullary nail provides increased patient comfort and reduces the external fixation period. If the problems encountered are treated aggressively, the result of the treatment can be quite satisfactory.

Level of Evidence: Therapeutic study, Level IV (case series [no, or historical, control group]). See Instructions to Authors for a complete description of levels of evidence.

Lengthening of extremities was first proposed by Codivilla in 1905 [1], but it was abandoned because of a high rate of complications. The Wagner technique [2] was also abandoned because it required two separate surgical interventions, was ineffective in correcting accompanying deformities while lengthening the limb, and was associated with many complications [3]. Ilizarov described his technique of distraction osteogenesis with external fixators on corticotomized bones in 1951 and introduced the technique to the Western world in 1989, opening a new era of limb-lengthening [4]. This method has gained worldwide acceptance because of its accompanying low rate of secondary surgical operations, such as grafting or plate osteosynthesis, and its versatility in correcting accompanying deformities simultaneously. However, the period required for external fixation with this method is quite long and uncomfortable for the patient and still has complications [5,6].

In 1997, Paley et al. described the technique of lengthening over an intramedullary nail in order to provide a more comfortable lengthening, to shorten the external fixation period, and to support the regenerated bone internally [7]. With a greater focus on patient comfort, this method is gaining wider acceptance [8–10], but it also has complications. Kristiansen and Steen reported that they abandoned the technique because of a high

rate of serious complications, and returned to the classic Ilizarov method [10].

We retrospectively reviewed the cases of our patients who had been treated with the technique of lengthening over an intramedullary nail to evaluate the observed complications in terms of prevention and treatment.

Materials and Methods

Between 1997 and 2001, 227 patients with an indication for limb-lengthening presented to our outpatient clinic. Limb-lengthening over an intramedullary nail was performed on forty-two limb segments (thirty-five femora and seven tibiae) in thirty-five patients with closed physes who had no history of infection, no deformity, and a medullary diameter of at least 8 mm. Twenty-six patients had unilateral femoral lengthening, four had bilateral femoral lengthening, two had bilateral tibial lengthening, two had unilateral tibial lengthening, and one had ipsilateral tibial and femoral lengthening (see Appendix). The mean age of the thirty-five patients (forty-two segments) was 26.6 years (range, sixteen to sixty-seven years). The causes for the short limbs were short stature (fourteen segments), poliomyelitis sequelae (thirteen segments), trauma (eight segments), congenital deformities (four segments, including two resulting from hemihypertrophy, one involving fibular hemimelia, and one congenital short femur), sequelae of epiphysitis (one segment), osteogenesis imperfecta (one segment), and hypophosphatemic rickets (one segment). The mean score for the level of difficulty of the procedure, according to the system of Paley et al.[7], was 10.0 (range, 3 to 20), with seventeen segments rated as severe (>=12 points); sixteen, as moderate (7 to 11 points); and nine, as mild (0 to 6 points).

The technique of lengthening over an intramedullary nail described by Herzenberg and Paley was used in all patients [11,12]. A reconstruction type of Russell-Taylor delta femoral nail (Smith and Nephew, Memphis, Tennessee) was preferred in all femoral segments, and a Russell-Taylor tibial nail (Smith and Nephew) was used in all tibial segments. The medullary canal was overreamed by 1 mm. Osteotomy levels were proximal metaphyseal or mid-diaphyseal in all antegrade femoral nailings, distal metaphyseal in all retrograde femoral nailings, and proximal metaphyseal in all tibial nailings, with use of the multiple drill-hole technique. The fibula was only osteotomized in tibial lengthenings in this series. A unilateral dynamic axial fixator (Orthofix LRS; Orthofix, Bussolengo, Verona, Italy) was implanted in all femoral segments except one, which received a Hex-Fix type of fixator (Smith and Nephew). A standard Ilizarov type of circular external fixator was used in all tibial segments except one, which received a unilateral fixator (Orthofix LRS).

Lengthening was initiated on the tenth postoperative day with a distraction rate of 1 mm per day (0.25 mm × 4). The fixator was removed and the intramedullary nail was locked after the desired lengthening amount was achieved. All preoperative and postoperative radiographic examinations consisted of standing long-leg radiographs.

Postoperative analgesia was provided by means of an epidural catheter in all patients. Full range of motion of the knee and walking with full weight-bearing with use of two crutches was initiated on the first postoperative day. After removal of the external fixator, and locking of the intramedullary nail, patients were allowed toe-touch walking with two crutches. The amount of weight-bearing was increased depending upon the quality of the regenerated bone observed on the follow-up radiographs. Full weight-bearing was encouraged after the regeneration of at least three cortices was seen on the radiographs.

Statistical Method

The cut-off points for the comparison of the Paley score for difficulty, the lengthening amount, and the lengthening percentage with the occurrence of complications were calculated with use of the receiver-operating characteristic curve analysis (version 7.2.0.2; MedCalc Statistical Software, Mariakerke, Belgium)[13]. The significance level was evaluated by chi-square and Fisher exact analysis with a significance level set at $p = 0.05$.

Results

The mean amount of lengthening was 6.3 cm (range, 2.5 to 11.5 cm) for all forty-two segments, with a mean lengthening percentage of 17% (range, 7% to 33%), and the mean values for lengthening in the femoral (6.3 cm) and tibial subgroups (6.1 cm) were similar. The preoperative calculated amount of lengthening was achieved in all patients. The mean external fixation index was 18.7 days/cm, and the mean lengthening index was 31.2 days/cm (excluding segments 28 and 29 [Case 26], which required removal of the nails prior to the termination of lengthening). The patients were followed for an average of forty-four months (range, twenty-six to sixty-two months).

A total of eighteen complications occurred in sixteen (38%) of the forty-two segments for an overall complication rate of 0.43 complication per segment. With use of the system of Paley [6], complications were classified as two problems (4.8% of the segments) that did not require additional surgery, thirteen obstacles (31% of the segments) that resolved with additional surgery, and three true complications or sequelae (7.1% of the segments) that remained unresolved at the end of the treatment period (Table I). The complications included premature consolidation in three

segments (7.1%); pin-track infection, poor regenerated bone formation, interlocking screw problems, Schanz screw cut-out, perioperative fracture, equinus contracture, and nail impingement occurring in two segments each (33%, fourteen of forty-two); and angulation at the osteotomy level occurring in one segment (2.4%).

Case	Segment	Limb Segment	Complication Type	Complication	Solution
2	2	Femur	Problem	Distal screw bending	Restricted weight-bearing, union with residual 0.5-cm limb-length discrepancy
3	3	Femur	Obstacle	Distal screw breakage and nonunion	Change of intramedullary nail and bone-grafting
4	5	Tibia	Obstacle	Valgus angulation (6°) of tibia due to use of unilateral external fixator	Change of external fixator to circular external fixator and acute deformity correction
5	6	Femur	Obstacle	Premature consolidation (Hex-Fix lengthener not sufficient)	Recorticotomy and change to Orthofix LRS
7	8	Femur	Obstacle	Grade-2 pin-track infection	Surgical débridement and antibiotics
7	8	Femur	Obstacle	Poor regenerated bone formation (previous open surgery)	Autologous cancellous bone-grafting
8	9	Femur	Sequela	Cut-out of proximal Schanz screws	Removal of intramedullary nail and change to lengthening with circular external fixator
10	11	Femur	Obstacle	Breakage of bone segment at the level of the intramedullary nail due to osteomalacia and mismatch between the curvatures of the bone and intramedullary nail	Lengthening through the fracture site with Orthofix LRS
14	15	Femur	Obstacle	Premature consolidation	Recorticotomy
23	25	Femur	Obstacle	Proximal Schanz screw cut-out due to a fall	Change of Schanz screw
26	28	Femur	Sequela	Failure of distraction due to excessive femoral bowing in the sagittal plane (nail impingement)	Change to conventional lengthening with Orthofix LRS
26	29	Femur	Sequela	Failure of distraction due to excessive femoral bowing in the sagittal plane (nail impingement)	Change to conventional lengthening with Orthofix LRS
29	33	Tibia	Obstacle	Equinus contracture	Percutaneous Achilles tendon lengthening
29	34	Tibia	Obstacle	Premature consolidation of the fibula	Recorticotomy
29	34	Tibia	Obstacle	Equinus contracture	Percutaneous Achilles tendon lengthening
31	36	Tibia	Obstacle	Grade-3 pin-track infection	Débridement, removal of the Schanz screw, antibiotics, and hyperbaric oxygen treatment
32	38	Tibia	Obstacle	Poor regenerated bone formation	Autologous cancellous bone-grafting
34	40	Femur	Problem	Proximal femoral fracture in the coronal plane (excessive reaming of the isthmus)	Observation

TABLE I Complications

One patient (Case 8; Segment 9) experienced cut-out of the proximal Schanz screws related to an inadequate insertion technique. This patient was one of the first cases in the series, and the complication resolved by achieving additional lengthening with a circular external fixator. Another patient (Case 26; Segments 28 and 29) experienced nail impingement in both femora due to excessive anterior bowing. The intramedullary nail was removed, and lengthening was continued on both sides with a unilateral dynamic axial fixator (Orthofix LRS). Subsequently, we either overreamed the medullary canal by 2 mm or performed an additional osteotomy at the apex of the bowing to prevent this complication.

No intraoperative or postoperative neurovascular complications occurred. Malalignment was not observed clinically or identified radiographically at the final examination in any patient.

The relationship between the amount and percentage of lengthening and Paley's score of difficulty and the occurrence of complications was investigated with use of the receiver-operating characteristic curve analysis. It revealed that cut-off points of 8.5 for the Paley score (sensitivity, 81.2; specificity, 50.0), 6 cm for the lengthening amount (sensitivity, 56.2; specificity, 69.2), and 21.5% for the lengthening percentage (sensitivity, 43.7; specificity, 84.6) are levels above which there is a predisposition for the occurrence of complications.

The complication rate was significantly higher in segments with a lengthening amount of >21.5% of the original length (nine of thirteen segments) compared with segments lengthened by <=21.5% (nine of twenty-nine segments) (Fisher exact test, p = 0.004). Similarly, a lengthening amount of <=6 cm (seven of twenty-five such segments had a complication) was significantly safer than longer lengthenings (eleven of seventeen such segments had a complication) (chi-square test, p = 0.04). Finally, a difficulty score of >8.5 was a significant predictor for the occurrence of complications (three of fourteen segments with a score of <=8.5 had a complication compared with fifteen of twenty-eight segments with a score of >8.5) (Fisher exact test, p = 0.023).

Discussion

Lengthening over an intramedullary nail, a technique aimed at providing increased patient comfort and internal bracing for the regenerated bone, should have a decreased complication rate combined with ease of application and cost-effectiveness compared with the classic lengthening methods.

Our results showed a relatively low complication rate compared with other reported series [7]. The overall rate of complications was 0.43 per segment, and the rate dropped to 0.3 complication per segment when superficial pin-track infections were excluded. Paley et al. reported a rate of 1.4 for the overall series and 0.9 when pin-track infections were excluded [7].

One of the interesting results of our study is the definition of cut-off points for some clinical parameters, which could help to predict the occurrence of problems during the lengthening period. Our analysis revealed that a lengthening rate of 21.5%, a Paley difficulty score of 8.5, and a total lengthening of 6 cm were critical cut-off points, above which complications are more likely to occur.

The major drawback of the technique of lengthening over an intramedullary nail is the increased risk of intramedullary infection due to

the combined use of external and internal implants. Paley et al. reported that a deep infection occurred in only one of their twenty-nine patients [7], and they recommended that contact between the nail and the Schanz pins of the external fixator be prevented and interlocking screws be placed medially rather than laterally. As we paid attention to these recommendations, a deep infection occurred in only one (2.4%) of the forty-two segments in our series. This rate remains quite satisfactory compared with the deep infection rates of 3%, 5%, and 15% previously reported by Paley et al.[7], Silberg et al.[14], and Simpson et al.[9], respectively.

Delayed union was observed twice in this series (Segments 8 and 38). In both cases, union was achieved following bone-grafting. We believe the reason for delayed union in Segment 8 was a previous surgical intervention in which an osteotomy had to be performed through an insufficiently vascularized area. In Segment 38, iatrogenic comminution at the corticotomy level was thought to be responsible for the delayed union (Figs. 1-A through 1-E). We believe that, for patients who have had previous surgery, multiple drill-hole osteotomies made through fresh bone are preferable as they preserve the periosteum and surrounding musculature.

Fig. 1-A **Figs. 1-A through 1-E** A patient (Case 32; Segment 38) with a delayed union. **Fig. 1-A** Preoperative standing long-leg radiograph showing tibial shortening of 3 cm on the left side.

Fig. 1-B Anteroposterior radiograph made fifteen months postoperatively.

Fig. 1-C Fig. 1-D Fig. 1-E

Fig. 1-C Lateral radiograph made fifteen months postoperatively. The regenerated bone is of poor quality. **Figs. 1-D and 1-E** Anteroposterior (Fig. 1-D) and lateral (Fig. 1-E) radiographs made twenty months after the index operation and five months after bone-grafting. Solid fusion has been achieved.

Premature consolidation was observed in two femoral (Segments 6 and 15) and one fibular segment (Segment 34). All three were treated with repeat corticotomy. The case of premature fibular consolidation was a result of technical inadequacy of the fibular osteotomy and thus should not be attributed to the technique of lengthening over an intramedullary nail itself. Premature consolidation of one femoral segment (Segment 6) was thought to be due to mechanical problems related to the external fixator (Hex-Fix fixator; Smith and Nephew). This device was not able to

produce a great enough distraction force. As a result, the bar of the device bent, causing compression of the osteotomy site, which resulted in premature consolidation. Following repeat corticotomy, another external fixator (Orthofix LRS) was placed and distraction was successfully completed.

Valgus angulation of 6° was noted in a tibial segment (Segment 5) after consolidation. This complication was thought to have been due to inadequacy of the unilateral fixator in overcoming the resistance of the interosseous membrane. This complication with the unilateral fixator, combined with data in the literature indicating the superiority of ring fixators in the tibia [11], has led us to prefer unilateral fixators for femoral segments and circular fixators for tibial segments.

Lengthening over an intramedullary nail allows distraction only in the anatomical axis. Theoretically, this could create a malalignment in the mechanical axis. Nevertheless, in this group of patients, we did not detect any malalignment in the long-leg standing radiographs made at the last follow-up visit, which was similar to the results that have been reported by other authors [7,9].

Osteonecrosis of the capital femoral epiphysis can occur after intramedullary nailing in adolescents because of an iatrogenic injury to the posterior ascending branch of the medial femoral circumflex artery [15,16]. We have not used the technique in the pediatric age-group, both to avoid this complication and to avoid the risk of enhanced growth and iatrogenic injury to the trochanteric apophysis, resulting in premature closure.

Fat embolism is a major concern of combined intramedullary nailing and external fixation, especially in bilateral and simultaneous procedures. In order to prevent this complication, we decompress the medullary canal, either with a cannulated drill during reaming as described by Herzenberg and Paley [12] or by making multiple drill-holes at the corticotomy site before reaming, allowing the medullary contents to flow out.

We believe that, although the method of lengthening over a nail has potential for additional complications, the overall complication rate remains similar to that of classic lengthening techniques, even for excessive amounts of lengthening, because of the reduced external fixation period and the internal splinting for the regenerated bone by the intramedullary nail [7]. We believe that problems, obstacles, and complications can be effectively addressed if they are treated aggressively when they occur.

Appendix

Symbol A table showing specific data on all study patients is available with the electronic versions of this article, on our web site at jbjs.org (go to the

article citation and click on “Supplementary Material”) and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). [Context Link]

Symbol. No caption available.

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