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Intramedullary skeletal kinetic distractor in lower extremity lengthening

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Objective: The aim of this study was to report the clinical and radiological results of patients with Intramedullary Skeletal Kinetic Distractor (ISKD) lengthening.

Methods: Ten femoral and 2 tibial lengthening were performed in 12 patients (7 male, 5 female; mean age: 27 years (13-40)) by using ISKD nail. The mean limb length discrepancy of the patients was 4.41 cm (2-7). On the postoperative 7th day the patients were trained about lengthening and the lengthening started. Follow-up X rays were taken weekly during the distraction period and every second weeks during the consolidation period. One patient with tibia lengthening was lost to follow-up after completing the distraction period.

Results: The planned lengthening amounts were achieved in all of the cases. The mean lengthening was 4.41 cm (2-7). The mean bone healing index was 37.8 day/cm (28.5-78.0). There were uncontrolled distractions in 4 cases. Autogenous bone grafting was necessary in a case with incompetent bone formation. The kinetic nail was locked and failed to distract in a patient, in which the problem was solved with closed manipulation under anesthesia. No patient had a joint stiffness.

Conclusion: Intramedullary extensible nails decrease the risk of joint contractures and infection. This procedure can be well tolerated by the patients and they can return to their daily activities earlier.

Key words: Kinetic distraction; limb lengthening; extensible intramedullary nail; deformity.

Distraction osteogenesis with external fixator is a common technique in the treatment of limb length discrepancies. Pin-tract infection, contractures, joint stiffness, and fracture at the distraction site after fixator removal are commonly seen complications of this method.[1] Combined techniques are used to shorten the treatment time and complications related to external fixator.[2-4] In these techniques the external fixator is removed following the distraction period and the distraction site is protected with internal devices during the consolidation period. Complications of external fixators may even be seen in these combined techniques.[5]

From the early 2000s totally implantable devices that can distract the bone segments without any need for external fixators has been used with increasing popularity. The first clinical use of Intramedullary Skeletal Kinetic Distractor (ISKD) nail was reported by Cole.[6] ISKD nail is a mechanically distractible nail and it is designed as two telescopic nails connected with a cogwheel system.

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The aim of this study was to report the clinical and radiological results of patients with Intramedullary Skeletal Kinetic Distractor (ISKD) lengthening.

Patients and methods

Ten femoral and 2 tibial lengthening were performed in 12 patients (7 male, 5 female; mean age: 27 years (13-40)) by using ISKD nail between 2008 and 2011. The mean limb length discrepancy of the patients was 4.41 cm (2-7). The shortening was due to a fracture sequel in 5 cases, and the remaining cases were due to a previous physeal injury, congenital tibia pseudoarthrosis, and developmental dysplasia of the hip or poliomyelitis. Three patients with shortening due a fracture sequel were previously treated with computer assisted external fixator, intramedullary nailing and plate and screw fixation. A patient with malunion after gunshot injury and a patient with congenital tibia pseudoarthrosis had already undergone an 8 cm lengthening in their previous treatments. In all tibia cases and 9 cases of femoral lengthening an antegrade nailing technique were used. Retrograde nailing technique was used in a case of femoral lengthening.

The range of motions, muscle strengths, joint stiffness and rotational alignments were recorded during preoperative evaluation. The deformity and shortening were evaluated with standard standing radiographs. The medullary diameters were measured on real size radiographs.

While the patient was in lateral decubitus position the first insertion wire was placed in to the fossa piriformis and a 3 cm skin incision was made around the wire. In the cases where femur will be lengthened with a tibial nail the first insertion point was chosen adjacent to the tip of the trochanter major. The previously planned osteotomy site of the bone was drilled before reaming in order to decrease intramedullary pressure of the bone and to lower the risk of fat embolism. During osteotomy a cannulated drill was used on the distal 1/3 of the femur to prevent an increase in intramedullary pressure. The medulla was over reamed 1.5-2 mm on a guide wire. The osteotomy was made after one Schanz screw was placed to both proximal and distal ends of the femur to prevent iatrogenic rotational deformities. ISKD nail was adjusted for providing lengthening according to shortening amount which had been calculated preoperatively. After that the nail was placed into the medulla and the locking screws were placed.

The medulla was reamed through the standard entry point on lateral eminentia less than 2 cm distal to the joint line while the patient was in supine position. Percutaneous diaphyseal osteotomy was made. In order to prevent pain caused by cortical contact of fibula and early fibular union resulting in deformity formation or interruption of the lengthening 1.5-2 cm bone segment was resected from the middle third of fibula. Tibia ISKD nail was placed and locked with standard technique.

The activity was limited in the first five days after surgery and confirmed with magnetic control device that there was no lengthening. Distraction rate which is the activity level was measured and adjusted for each patient. The measurement with the magnetic monitor was taught to the patients at least 5 times a day (preferably 10).

The exercises were planned for obtaining 1.33 mm lengthening per day. Control radiographs were taken weekly during the distraction period of the lengthening. On the consolidation period radiographs were taken every 4-6 weeks. Until the consolidation the patients were allowed partial weight bearing whit 20% of their body weight and then the weight was increased gradually. One patient with tibia lengthening was lost to follow-up.

Results

The mean lengthening was 4.41 cm (2-7). The mean bone healing index was 37.8 day/cm (28.5-78.0). The mean postoperative full weight bearing time was 5.35 months (3-7). The mechanical axis deviations of all of the patients were within physiological limits. Preoperative range of motion was achieved in all of the patients.

In a femoral lengthening patient there was early consolidation on the 6th week and a new osteotomy, 2 cm distal to the previous osteotomy site was performed without extracting the nail. In a case with no lengthening during the first 2 weeks, manipulation was performed under general anesthesia.

Lengthening was too fast in 4 cases (1 tibia, 3 femora). Two of them had 2 cm, one 1 cm and one 1.2 cm lengthening in the first week. Due to lack of consolidation on the lengthening site, femoral bone grafting was performed on the fifth month for one of these cases. A positioning screw was used in a case with fast lengthening of the femur to narrow the medullary canal in order to slow down the lengthening (Fig. 1). There was no infection complication in our series.

Discussion

In recent years, fully implantable, mechanical or motorized expandable nails have been developed to avoid the problems caused by external fixators. Mechanically distractible Albizza nail (DePuy, Villeurbanne, France) was developed in 1990. Twenty degrees of rotational movements of the extremity was necessary to expand that

nail. This rotational movement was causing severe pain. In another fully implantable nail called Fitbone (Wittenstein, Igersheim, Germany) lengthening is achieved with an engine activated by a transmitter from outside the body. There is reports of easy usage and good functional outcomes in the literature.[7,8]

ISKD was developed by Cole at al. in 2001. Its design includes 2 separate nails with different diameters connected with a ratchet within each other. Lengthening is achieved with 3 to 9 degrees of rotational movements. These movements correspond with the rotational movements of the extremity during physiological gait. ISKD was found safe and successful for extremity lengthening in the literature. However, the failure of lengthening with the nail needs manipulation under general anesthesia.[9] It is difficult to control the distraction amount and duration. Too slow distraction may cause early consolidation, while too fast distraction may result in a poor regenerate formation.

Extremity lengthening operations are open for complications. Lengthening with the conventional Ilizarov method and lengthening over intramedullary nail has several risks including pain, joint stiffness and infection. Küçükkaya et al. described the use of three Schanz screws over a retrograde nail to decrease the rate of complications in lengthening over nail method. They reported that the use of decreased number of Schanz screws decreases the risk of infection.[10] In recent years

Fig. 1. A 32-year-old male patient with left distal femoral malunion and 4.5 cm of shortening. **(a)** Preoperative clinical view. **(b)** The standing orthorontgenogram. **(c, d)** Anteroposterior and lateral radiographs. **(e)** Early postoperative radiograph after implant and allograft extraction and reosteosynthesis with plate and screws and proximal femoral osteotomy and ISKD nail placement. There is uncontrolled lengthening of nail. **(f)** A positioning screw was placed to the distal fragment to control the lengthening. **(g)** Follow-up orthorontgenogram during the treatment. **(h)** Anteroposterior radiograph after consolidation. **(i)** Orthorontgenogram after the treatment. **(j)** Final clinical photograph. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

Table 1. Demographic data and clinical characteristics of the patients.

No	Sex	Age	Etiology	Bone	Shortening (cm)	Lengthening (cm)	Full weight bearing time (month)	Healing index (day/cm)	Complication
1	Male	24	Idiopathic	Femur	4	4	4	30.0	
2	Male	29	Club foot sequelae	Femur	4.5	4.5	5	33.0	Early consolidation
3	Male	33	Shortening after fracture	Femur	3.5	3.5	3	28.5	Fast lengthening of 1cm
4	Male	40	Shortening after fracture	Femur	5.5	5.5	7.3	39.0	
5	Female	14	Dysplasia of the hip sequelae	Femur	2	2	5.2	78.0	Fast lengthening of 2 cm, requiring autogenous bone grafting
6	Female	22	Congenital tibia pseudoarthrosis	Tibia	4	4			Lack of distraction, requiring manipulation under general anesthesia
7	Male	32	Shortening after fracture	Femur	4.5	4.5	4.3	28.5	Fast lengthening of 1.2 cm, requiring a position screw was applied to control lengthening
8	Male	30	Poliomyelitis sequelae	Femur	3.5	3.5	5	42.0	
9	Female	24	Physeal injury	Tibia	3.5	3.5	5	39.0	Fast lengthening
10	Male	36	Shortening after fracture	Femur	7	7	6	28.5	
11	Female	27	Shortening after fracture	Femur	6	6	7	34.8	
12	Female	13	Fibular hemimelia	Femur	5	5	6	36.0	

totally implantable self-expandable nails have been developed. In this method no Schanz screws or K wires are used, which will lower the infection risk. Successful results with no infection has been reported with totally implantable expandable nails.[7,11] In agreement with this data, we had no infection in our series.

Albizza nail is a mechanically distractible nail. The extremity must have rotational movements of 20 degrees to obtain lengthening. Therefore the lengthening procedure is painful and may require anesthesia.[12] Because ISKD nail needs small degrees of rotational movements this mechanically distractible nail cause no severe pain. None of our cases needed narcotic analgesic during the treatment.

In lengthening procedures with intramedullary nails medullar reaming does not disturb new bone formation in the distraction area. Rozbruch et al. compared intramedullary nailing and conventional Ilizarov method for lengthening. The mean bone healing index was 57 day/cm for Ilizarov method and 24 day/cm for intramedullary nail.[13] Krieg et al. reported 35 day/cm of healing index in their 32 cases of lengthening with Fitbone nail[7] Dinçyürek et al. reported the healing index as 43.7 day/cm in their 15 cases lengthened with Fitbonesnail. Wank et al.[8] reported a healing index of 47.8 day/cm in their 26 cases of lengthening whit ISKD.[14] In our study the mean healing index of 11 cases was 37.8 day/cm (28.5-78.0).

Recently several authors reported their experiences about the use of ISKD. The main problem with ISKD is the difficulty in controlling the lengthening in the initial weeks of the treatment. While too fast lengthening can cause poor regenerate formation, a slow lengthening may result in an early union.[9,15]

Simpson et al.[7] reported cases of uncontrolled fast lengthening in their series of 33 patient of ISKD lengthening. They reported that in cases of uncontrolled fast lengthening the bone segment on the thin part of the nail was shorter than 80 mm which was statistically significant.[9] They reported also over reaming of more than 2.5-3 cm results in uncontrolled fast lengthening. In our study we noted uncontrolled fast lengthening in 1 case in which we used a positioning screw to decrease the canal diameter to slow down the lengthening.

Kenaway et al. reported poor regenerate formation in 8 of 37 cases of intramedullary nail lengthening.[16] In their study they compared the risk factors for poor regenerate formation. While the major risk factor was uncontrolled fast lengthening, other risk factors were age older than 30 years, lengthening more than 40 mm and smoking. Wang et al. reported poor regenerate formation in 6 of their 16 cases of ISKD lengthening

and they hold responsible the previous operations on the lengthened segment.[14] In our series we treated one of the 4 cases of uncontrolled lengthening with autogenously bone grafting and obtained union without any problem.

When the nail does not expand postoperatively lengthening can be started with manipulation under anesthesia. Kenawey et al. had pause of expansion of the nail in 3 of their 57 ISKD lengthening cases. They started lengthening with forced exercises in two cases and it was necessary to manipulate under anesthesia to start lengthening in one case.[11] Simpson et al. detected no lengthening in 6 cases out of 33. They did open osteoclasis with the help of one Schanz screw in order to obtain lengthening. They reported statistically significant relationship between not lengthening of the nail and having a distal fragment longer than 125 mm.[9] Wang et al. reported halt of lengthening in 3 of their 16 cases and they restarted lengthening with forced exercises.[14] In one of our cases lengthening had stopped and we started lengthening with manipulation under general anesthesia. We faced with early consolidation in one case in which the problem was solved with a second osteotomy.

Dinçyürek et al. reported complications including late consolidation in 3 patients, not lengthening of the nail in 2 patients and superficial infection in one case out of 15 patients who had undergone lengthening with Fitbone nail.[8] No complications were reported by Al-Sayyad in 10 cases that were lengthened with Fitbone.[17] Baumgard et al. reported a complication rate of 13% in 150 patients lengthened with Fitbone.[18] In our series there were early consolidation in one patient, locking of the nail in one patient, delayed consolidation in one patient and too fast lengthening in 4 patients. These complications show similarity with other types of expandable intramedullary nails but the complications related to the expansion mechanism of the nail have different solution methods according to the nail.

Our experience shows that lengthening with ISKD lowers the risk of joint contracture and infection. However this method has difficulties such as uncontrolled fast lengthening and locking of the nail. ISKD can be tolerated better by the patients and the patients can return to their daily activities earlier with this method.

Conflicts of Interest: No conflicts declared.

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