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Comparison of fixator-assisted nailing versus circular external fixator for bone realignment of lower extremity angular deformities in rickets disease

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Abstract
Purpose In rickets patients, limb deformities are usually multiapical and complex even with medical treatment; residual deformities remain necessitating surgical correction. In our study we aim to compare the results of correction of lower limb deformities, in rickets patients, treated with circular external fixator versus fixator-assisted intramedullary nail.
Materials and methods Seventeen rickets patients, with 39 deformed lower extremity segments (femur and or tibia), underwent deformity correction procedures in our institution. Ten patients with 26 segments were treated using fixator-assisted nailing. Nine patients with 17 segments were treated using Ilizarov technique with circular frame. All patients were evaluated by long-standing true anteroposterior and lateral orthoroentgenograms of lower extremities preoperatively. Joint alignment, joint orientation, and apices of deformities were calculated and noted. The postoperative results of MAD, MPTA, LDFA, PPPTA and functional criteria were compared with preoperative values and assessments made in SPSS 13.0 for Windows by using McNemar, Pearson Chisquare, and Fisher exact statistical tests.
Results Mean age for the fixator-assisted nailing (FAN) group patients at the time of surgery was 23.8 years (14–37 years). There were 16 femur and 10 tibiae operated on 6 female and 4 male patients. The mean follow up time is 42.6 months (6–71 months). In the Ilizarov group patients the mean age at the time of surgery was 16.7 years (13–22 years). There were 14 tibiae and 3 femur operated on 6 female and 3 male patients. The mean follow-up time was 19 months (6–48 months). Results were evaluated according to the Paley et al. classification of bone and functional results. According to those criteria we had 1 fair, 1 good, and 7 excellent bone results and 1 fair, 1 good, and 7 excellent functional results in the circular ring fixator group. In the FAN group we found 3 good and 7 excellent bone results; 1 fair, 2 good, and 7 excellent functional results. Nearly all patients complained of pain, limping, instability, and walking problems at their first preoperative visit. In both groups there was no union problem; in the FAN group, in one patient correction loss occurred and in another one screw loosening was encountered; in the Ilizarov group, 66% of patients had pin tract infections and one premature fibula consolidation occurred. Statistical analysis revealed no significant difference between two groups in correction ratios.(pearson chi square $p = 0.332$ for MAD; pearson chi square $p = 0.477$ for LDFA; Paley functional criteria fisher exact $p = 0.684$).
Conclusion The results indicated that fixator-assisted nailing carries deformity correction accuracy comparable with Ilizarov-type external fixators. FAN provides great patient comfort and the total treatment time is less. In patients with rickets, the retained IM nail can further provide protection against recurrence even if the metabolic pathology reoccurs.

Keywords Fixator-assisted nailing · Rickets · Deformity

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Introduction

Skeletal deformities in the lower limbs of the growing children and adolescents are common sequelae of metabolic

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disorders manifested especially in the form of multiapical angulations and shortening of the limbs. Even with medical treatment, residual deformities remain necessitating surgical correction [1].

Deformity correction with the help of single or multiple osteotomies is now a well-established procedure in orthopedic surgery. The major difference lies in the choice of implant for stabilization and correction. Following osteotomy, stabilization can be achieved either by internal fixation (K-wires, screws, plates and screws or intramedullary nails) or external fixation (unilateral or circular), casting and bracing [2–4]. Osteotomy coupled with acute correction and internal fixation provides immediate restoration of alignment, early return to normal life, and high patient comfort. Neurovascular injury, compartment syndrome, delayed union and nonunion, recurrence of deformity, postoperative infection, lack of corrective accuracy, and postoperative corrective adjustability limits the use of this technique for deformity correction where lengthening is also required [3].

In patients with metabolic bone diseases, limb deformities are usually multiapical and complex [1, 2, 5, 6]. The poor quality of bone in these patients prevents optimal correction of malalignment [1, 2]. Therefore, they require modified fixation methods. The use of circular external fixator (CEF) for the management of these patients gives good results at the cost of patient comfort, the usual problem of pin site/track infection and prolonged treatment period. Fixator-assisted nailing (FAN) combines the accuracy, minimal invasiveness, and safety of external fixation together with patient compliance and comfort of internal fixation [4]. Moreover, the retained IM nail may prevent reoccurrence of deformity in the long term, even if the patient becomes metabolically decompensated. The purpose of this study was to compare the results of correction of lower-limb deformities, in rickets patients, fixed with circular external fixator (CEF) versus fixator-assisted intramedullary nail.

Patients and method

Between May 1998 and May 2005, 17 patients, affected by rickets, with 39 deformed lower extremity segments (femur and/or tibia), underwent deformity correction procedures in our institution. Nine patients with 24 segments were treated using fixator-assisted nailing. Eight patients with 15 segments were treated using CEF. Mean age for the FAN group patients at the time of surgery was 23.8 years (14–37 years). There were 16 femora and 8 tibiae operated on 5 female and 4 male patients. The mean follow-up time is 46.7 months (12–71 months). In the Ilizarov group patients the mean age at the time of surgery was 16.7 years (13–22 years). There were 12 tibiae and 3 femur operated on 5 female and 3 male patients. The mean follow-up time is 25.5 months (12–48 months; Table 1).

All patients were evaluated by long-standing true anteroposterior and lateral orthoroentgenograms of lower extremities preoperatively [4, 7, 8]. Joint alignment, joint orientation, and apices of deformities were calculated and noted [4, 7, 8] (Fig. 1a–d). As the fixator assisted nailing is a newer technique, until the year 2002 we preferred Ilizarov method. Afterwards, fixator-assisted nailing was used in our patients.

Osteotomy levels were determined [4, 7], according to the Paley's principles for multiapical deformity correction. The anatomical axis was used in the femur for FAN-treated patients. Patients with deformity and limb length discrepancy were not included.

In the FAN group when more tha one osteotomy levels were considered, extra holes for segmental fixation were custom drilled on the intramedullary nail preoperatively. An extra hole on the corresponding plane was added to increase stability of small bone fragments. One additional hole, perpendicular to the first custom hole, was also drilled to increase stability in both frontal and sagittal planes (Fig. 2a, b).

Two patients had FAN application on four limb segments, two patients were operated on three limb segments, and six patients were operated on two limb segments. Four patients had a three-level osteotomy to correct the bony deformity. All other deformities were corrected by single- or double-level osteotomies. Patients, who had more than two limb segment corrections, were operated on two separate sessions to decrease the risk of fat embolism. In all distal femoral and proximal tibial varisation osteotomies exceeding 15°, prophylactic peroneal nerve release was performed prior to the osteotomy [9].

At the end of treatment there has to be found no limb length discrepancy in any patients.

In FAN group patients with a femoral varus malalignment, the mean preoperative mechanical lateral distal femoral angle (mLDFA) was 107 (104°–118°). In patients with a femoral valgus malalignment, the mean preoperative mLDFA was 78° (56°–111°). In patients with a proximal tibial varus malalignment, the mean preoperative mechanical medial proximal tibial angle (mMPTA) was 79° (76°–86°). In patients with a proximal tibial valgus malalignment, the mean preoperative mechanical medial proximal tibial angle (mMPTA) was 89°. In a patient with varus ankle malorientation, the preoperative mLDTA was 111°. In the femoral deformity group the mean anatomical posterior distal femoral angle (aPDFA) was 74 (60°–89°).

In patients treated with Ilizarov circular frame, the mean pre-operative mechanical axis deviation (MAD) was

Table 1 Clinical data of the FAN group

FAN		Etiology	Age	Def.	MAD pre/post	MPTA pre/post	mLDFA pre/post	ND	Comp.	Paley bone/function
1.	R tibia	Rickets	35	Tib. vara	67/40	78/89	108/108	3	(–)	Exc./Exc.
	L tibia			Tib. vara	82/51	76/89	105/105	3	(–)	Exc./Exc.
2.	R femur	Rickets	20	Fem. valga	112/5	97/87	56/85	4	(–)	Exc./Exc
	L tibia			Fem. vara	92/0	95/85	108/88	3	(–)	Exc./Exc
				Tib. vara	92/0	82/86	108/88	3	(–)	Exc./Exc
3.	R femur	Ren. Ost	21	Fem. valga	20/3	89/88	83/92	4	(–)	Good/Exc
	L femur			Fem. valga	50/18	89/88	74/91	3	(–)	Good/Exc
4.	R femur	Rickets	23	Fem. valga	52/7	89/81	73/89	4	(–)	Exc./Exc
	L femur			Fem. vara	86/32	89/81	103/90	4	(–)	Exc./Exc
	L tibia			Tib. vara	86/32	89/81	103/90	4	(–)	Exc./Exc
5.	R femur	Rickets	37	Fem. vara	102/15	89/84	112/102	4	Corr. loss	Poor/good
	L femur			Fem. vara	108/80	89/90	108/94	3	(–)	
	R tibia			Tibia vara	102/15	89/84	112/102	3,5	(–)	
	L tibia			Tibia vara	108/80	89/90	108/94	3	(–)	
6.	R femur	Rickets	20	Fem.vara	102/0	89/84	118/92	3	(–)	Exc./Exc.
	L femur			Fem.vara	120/0	89/87	117/91	3	(–)	
7.	R femur	Rickets	27	Fem.valga	55/0	89/85	111/96	3	(–)	Exc./Exc.
	L femur			Fem.valga	22/15	89/90	108/97	3	(–)	
	R tibia			Tibia valga	55/0	89/85	96/96	3	(–)	
	L tibia			Tibia valga	22/15	89/90	96/96	3	(–)	
8.	R femur	Rickets	14	Fem. valga	57/20	89/93	78/80	2.5	(–)	Exc./Exc.
	L femur			Fem. vara	15/11	89/83	105/92	2.5	(–)	
9.	R femur	Rickets	19	Fem. vara	42/19	89/88	104/91	3	Pin loos (–)	Good/Good
	L femur			Fem. vara	30/23	89/85	92/94	3.5		

Def deformity; *ND* nail duration time in month; *Comp* complication; *Pin loos* pin loosening; *corr. loss* correction loss; *Exc* excellent; *pre* preoperative; *post* postoperative

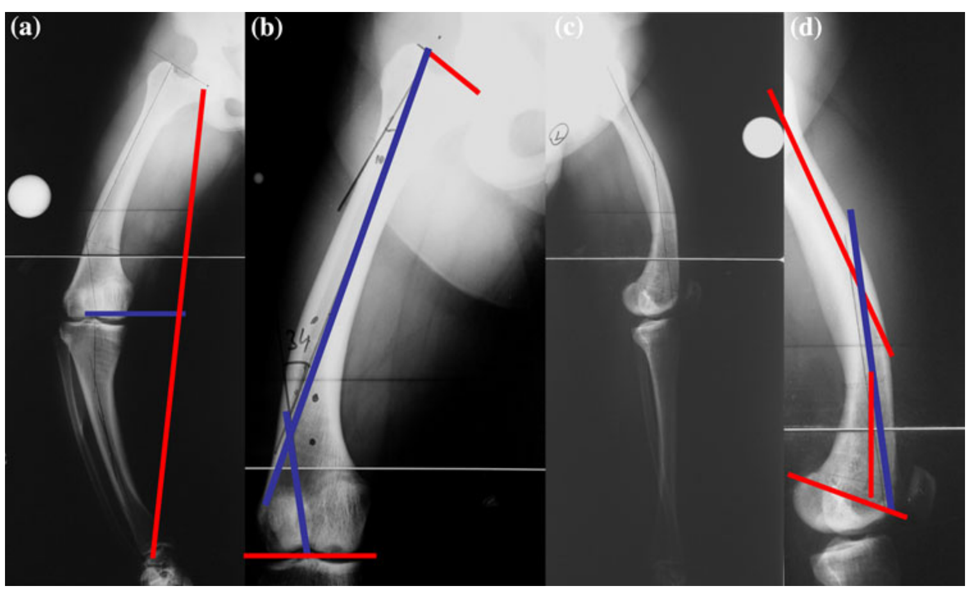


Fig. 1 A patient with distal femoral varus and proksimal tibial varus deformity. **a** An AP view ortorontgenogram, **b** showing deformity analysis and calculation of CORA (34°) in AP plain, **c** A lateral view ortorontgenogram, **d** showing deformity analysis and calculation of CORA and presumptive corrective osteotomy levels in lateral plan

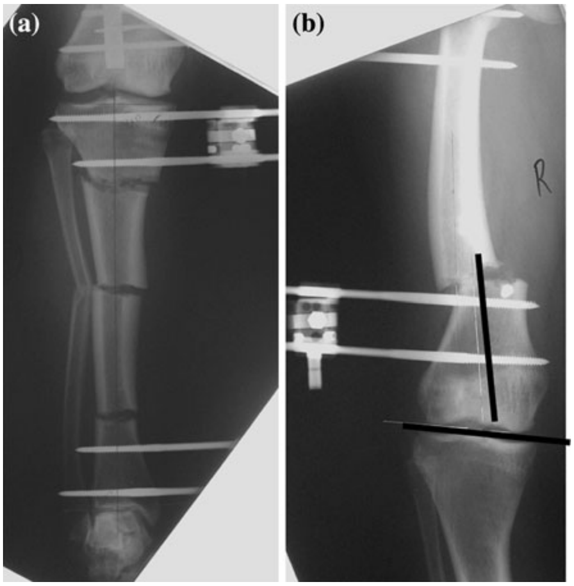


Fig. 2 **a** The roentgenogram shows intraoperative control view prior to IM nailing of a patient with tibial deformity. **b** The roentgenogram shows intraoperative control view prior to IM nailing of a patient with femoral deformity

58.7 mm (range 15–112), the mLDFA was 97° (56°–127°), the mMPTA was 85.7° (74°–110°), and the LDTA was 89° (65°–101°). Among 12 tibia segments there were 11 oblique plane deformities; the mean preoperative aPPTA was 70.3° (53–78). In three femora segments the mean preoperative aPDFA was 66° (62–70).

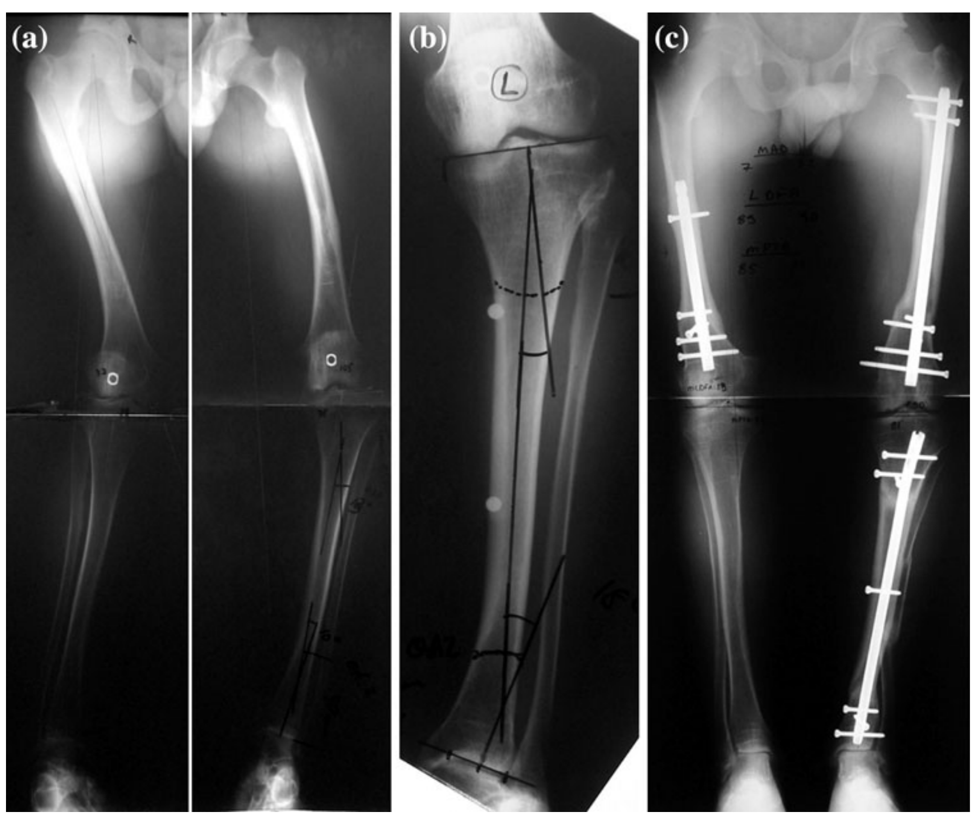
Surgical technique

Fixator-assisted nailing

All operations were performed on a radiolucent table. In every procedure, a unilateral external fixator (Hexfix–Smith & Nephew, Nashville–Tennessee) was used for deformity correction. The fixator was applied laterally on the femur and medially on the tibia as described by Paley et al. [3]. In order not to interfere with the intramedullary nail, the external fixation pins were inserted posteriorly in the proximal femur and posteriorly in tibia under fluoroscopic control (Fig. 3).

The direction of the pins was perpendicular to the corresponding fragment in the frontal and sagittal planes. After proper application of the pins, a focal dome osteotomy was performed at the predetermined levels of deformity correction by multiple drill holes technique [4, 7]. A pre-calculated translation was added by manipulation of the osteotomy site [4, 7]. The fixator was applied to correct the deformity, providing acute adjustment in all three planes. At this step, intra-operative radiographs are taken and malalignment tests performed (Fig. 4a, b) [4, 7].

Fig. 3 A 23-year-old patient with hypophosphatemic rickets and windswepth deformity. **a** Preoperative orthoroentgenogram, **b** preoperative deformity analysis of left tibia, **c** postoperative orthoroentgenogram after 1 year



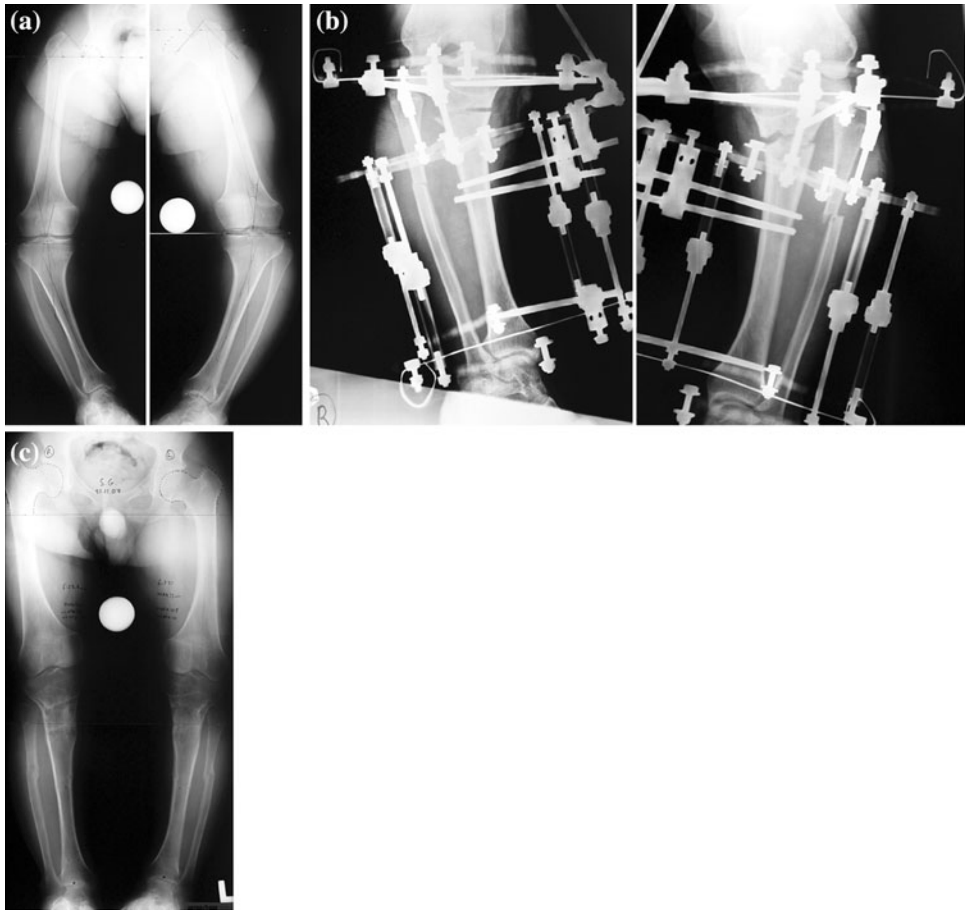


Fig. 4 A 17-year-old girl with bilateral genu varum deformity. **a** Preoperative ortoroentgonegram, **b** postoperative first week, **c** after 1 year

When the desired amount of correction was not achieved, readjustment was made and new radiographs taken. After confirmation of achieving the required correction we proceeded to intramedullary nailing (Russell-Taylor or Trigen intramedullary nail—Smith & Nephew, Nashville–Tennessee).

Retrograde femoral nailing was performed percutaneously through an one-inch long transpatellar mini arthrotomy [3]. A guide wire was inserted through a drilled hole under fluoroscopic control. The intramedullary canal was over-reamed 1 mm more than the diameter of the IM nail to be used and the nail was inserted per-cutaneously. Distal, proximal, and segmental locking screws were inserted under image intensifier by the free hand technique. The tibial nails were applied conventionally as for all tibial nailing. The locking screws were inserted by free hand technique. When the medullary canal was considered large compared with the diameter of the nail, especially in the metaphyseal area, pollar screws were inserted perpendicularly to the locking screws to narrow the medullary canal in both the frontal and sagittal planes [4, 7, 9, 10]. After appropriate fixation, the external fixator was removed and radiographs were taken to control if there was any loss of correction. A suction drain was inserted into knee joint to prevent hemarthrosis after retrograde femoral nailing.

Circular external fixator

The Ilizarov fixator is pre-assembled in the deformed configuration corresponding to the deformity of the extremity; minor adjustments are made during the application. The first two wires are parallel to the joints, one for proximal and the other for the distal most ring, and perpendicular to the bone in both plains. After checking the position of the bone in the ring either wires or half pins are used to secure the bone to the frame. Gradual correction is achieved after the osteotomies are made, using the multiple drill holes [9, 11, 12].

Post-operative management

An epidural catheter was applied to all patients for postoperative analgesia. A cryo-cuff was applied on the knee to prevent hemorrhagic effusion. Isometric quadriceps exercises and ankle pumping were initiated on the same day. On the first postoperative day, knee range of motion and walking exercises with two canes were encouraged. Weight bearing was allowed reaching full weight bearing at the end of the fourth week.

Each patient in FAN group was examined regularly every 4 weeks for clinical and radiographic evaluation to examine bone union, but in the Ilizarov group deformity was corrected gradually, so the patient was examined regularly every 2 weeks until deformity correction was achieved.

The postoperative results of functional criteria have been compared with preoperative values.

Results were evaluated according to the Paley et al. classification functional results. Functional results included five criteria: pain, significant limp, contracture of the foot, ankle or knee, soft tissue dystrophy (skin hypersensitivity, insensitivity of sole or decubitus, and inactivity (unemployment because of the leg injury or inability to return daily activities because of the leg injury). An excellent result was an active individual with none of the other four criteria; a good result was an active individual with one or two of the other four criteria; and a fair result was an active individual with three or four of the other criteria or an amputation. An inactive individual was considered a poor result regardless of the other criteria [10].

Statistical analysis

The McNemar test was used for comparing preoperative and postoperative MAD, MPTA, LDFA, and PPTA values. For the comparison of correction ratios between Ilizarov and FAN groups, Pearson Chi-Square test was used. Fisher exact test was used for assessing Paley functional scores. p value <0.05 with a confidence interval of 95% has been accepted as significant (SPSS for Windows, version 13.0).

Results

All patients were clinically and radiologically evaluated at each visit. The radiological parameters used for preoperative assessment and postoperative follow-up have been previously described by Paley et al. [4, 7]. In the FAN group the mean value of postoperative MAD was 20 mm in femora vara group, 9.7 mm in femora valga group, 40 mm in tibia vara group, and −7.5 mm in tibia valga group. The postoperative distal femoral mean alignment as calculated by mLDFA was 92° (88°–102°) in femora vara group and 89° (85°–92°) in femora valga group. The postoperative proximal tibial mean alignment as calculated by mMPTA was 86° (81°–89°) in tibia vara group and 87.5° (85°–90°) in tibia valga group. The postoperative ankle alignment calculated by LDTA was 92° on the patient with ankle malorientation. Out of 16 femoral segments, 13 had abnormal aPDFA in the FAN group. Postoperatively 11 patients had normal aPDFA (79°–87°). In the 8 tibial segments 6 segments had abnormal aPPTA and two had normal; after FAN in 6 segments aPPTA was in normal range (77°–84°; Table 2). In our 21 tibia segments, we did not observe rotational deformity.

In patient number 1, because of the deformity on both femur and tibia, MAD and mLDFA still remained pathological in spite of the bilateral tibial operation.

In one of our FAN patients, femoral fracture occurred peroperatively by the IM nailing because of excessive amount of femoral varus deformity, and in another one correction loss occurred because of mechanic insufficiency, but the patient refused the revision operation. One patient had gone revision of the pin due to pull out of the screw. According to Paley`s classification minor complications were listed as problems that did not require additional surgery; major complications were listed as obstacles that resolved with additional surgery, and true complications or sequelae are those complications that remained unresolved at the end of the treatment period. In the FAN group there was one problem one obstacle and one sequela.

According to our data, no deep venous thrombosis or fat embolism occurred.

In the circular external fixator group the mean value of postoperative MAD was 9.5 mm in femora valga group, 25.4 mm in tibia vara group, and −9 mm in tibia valga group. The mean postoperative femoral distal mean alignment as calculated by mLDFA was 91° (90°–92°) in femora valga group. The mean postoperative tibial proximal mean alignment as calculated by mMPTA was 88° (84°–91°) in tibia vara group and 89° (87°–93°) in tibia valga group. The postoperative ankle alignment calculated by LDTA was 92° on the patient with ankle malorientation (Table 2). In 11 tibia segments there were oblique plane deformities, and after Ilizarov surgery in 7 patients postoperative aPPTA was in normal range; the mean postoperative aPPTA was 76.6° (65°–84°), and in the rest 3 femorae segments the mean postoperative aPDFA was 82° (81°–83°).

In the circular external fixator group, in six patients (66%) there was pin tract infection, which was healed with conservative treatment (antibiotherapy and local wound care) and considered as minor complication. In two patients as an obstacle premature consolidation of fibula occurred and recorticotomy was made. We removed the frame after at least three cortice unions were seen in the plain radiographs. No refracture were seen after the removal of the Ilizarov frame.

Results were evaluated according to postoperative measurements; MAD within 10 mm excellent, MAD within 20 mm good, within 30 mm fair, and MAD greater than 30 mm poor. Same for LDFA and MPTA: 85–90 excellent; 80–84 or 91–95 good; 96–100 or 75–79 fair, and >100 or <75 poor. For PPTA; 77–84 excellent, 71–77 good, 65–70 fair, and <65 poor (Table 3).

Table 2 Clinical data of the circular external fixator-ilizarov group

Ilizarov		Etiology	Age	Def.	MAD pre/post	MPTA pre/post	mLDFA pre/post	FR	Comp.	Paley bone/function
1.	R tibia	Rickets	13	Fem. vara	60/2	95/96	127/92	8	(−)	Poor/Good
2.	R tibia	Rickets	16	Tibia vara	35/20	83/89	97/97	5	(−)	Good/Exc
	L tibia			Tibia vara	43/24	89/91	100/100	5	(−)	Good/Exc
3.	R tibia	Rickets	22	Tibia vara	60/41	85/87	103/103	6	(−)	Good/Good
4.	R femur	Rickets	13	Fem. vara	60/23	80/84	103/91	6	(−)	Exc./Exc.
	L femur			Fem. vara	42/4	79/91	98/90	6	(−)	
	R tibia			Tibia vara	60/23	80/84	103/91	6	(−)	
	L tibia			Tibia vara	42/4	79/91	98/90	6	(−)	
5.	R tibia	Rickets	19	Tibia vara	55/62	82/90	103/101	11	Premature fibula consolidation	Exc./Exc.
	L tibia			Tibia vara	70/46	80/87	88/89	12	(−)	
6.	R tibia	Rickets	14	Tibia valga	57/20	110/93	78/84	5	(−)	Exc./Exc.
	L tibia			Tibia valga	15/11	95/88	101/96	5	(−)	
7.	R tibia	Rickets	17	Tibia vara	75/14	78/88	105/104	6	(−)	Exc./Exc.
	L tibia			Tibia vara	97/39	74/87	95/94	6	(−)	
8.	R tibia	Rickets	20	Tibia valga	112/5	97/87	56/85	5	(−)	Exc./Exc.

Def deformity; *ND* nail duration in month; *Compl* complication; *Pin loos* pin loosening; *corr loss* correction loss; *FR* frame removal time in month; *Exc* excellent; *pre* preoperative; *post* postoperative

Table 3 Results table according to postoperative measurements of MAD, mLDFA and MPTA

	FAN				SEF			
	Excellent	Good	Fair	Poor	Excellent	Good	Fair	Poor
MAD	9	7	2	6	4	3	4	4
mLDFA	6	10	4	4	5	4	3	3
MPTA	14	8	0	0	8	6	1	0

Nearly all patients complained of pain, limping, instability, and walking problems at their first preoperative visit. When we checked all the patients' ROM for the study, there were no marked deficits. Also they were asked if they were satisfied with the operation; except two who had complications, all of them specified that they were satisfied and they were ready for that experience again.

According to those criteria, we had 2 good and 13 excellent functional results in the circular ring fixator group. In the FAN group we had 6 good and 18 excellent functional results. Range of motion was used to assess any postoperative joint stiffness adding further compromise to the first three criteria.

The statistical analysis revealed significant correction levels in both of groups. Comparing preoperative and postoperative MAD values using McNemar test, p was <0.05 in both groups (Ilizarov group $p = 0.016$, FAN group $p = 0.001$). The difference between MAD correction ratios between these two groups were statistically not significant (Pearson Chi Square test, $p = 0.332$).

For LDFA, in the Ilizarov group from 13 patients who had poor-fair values preoperatively six of them turn into excellent-good; in FAN group from 22 patients 14 of them had become excellent-good which was found statistically significant (Ilizarov $p = 0.016$ FAN $p < 0.05$). On the other hand, there were no significant results between correction ratios of Ilizarov and FAN groups (Pearson Chi Square $p = 0.477$).

For MPTA, in the Ilizarov group all of 6 patients who had poor-fair values preoperatively had become excellent-good postoperatively and 5 of 5 FAN poor-fair patients had become excellent-good which were not found statistically significant (Ilizarov $p = 0.016$ FAN $p < 0.05$).

According to Paley functional classification no statistically significant difference was found (Fisher exact $p = 0.684$).

Discussion

Metabolic bone diseases frequently result in skeletal deformities, especially in the lower weight bearing limbs due to physeal growth disturbances or defective mineralization in children before puberty [1–3]. Among these disorders, hypophosphatemic rickets, hypophosphatasia, and renal osteodystrophy are the most frequent ones [1–3].

Deformities observed in metabolic bone diseases are either discrete angular deformities, or long bowing (or multiapical) deformities [2–4]. Angular deformities originate from or adjacent to growth plate and a single osteotomy can correct the deformity. Multiapical deformities generally result from bowing of the entire long bone. These require more than one osteotomy to correct and achieve a straight bone thereby avoiding secondary iatrogenic deformity [3, 4].

Deformities due to metabolic bone diseases usually occur in multiple limb segments. If the disease is not under control metabolically, deformities tend to recur after corrective osteotomies [5]. In addition, operative correction of deformities in metabolic bone diseases tend to heal in a prolonged time [1, 3, 4] with increased potential for non-union and recurrence. Price [13] is of the opinion that stable fixation is necessary for early mobilization in these patients to prevent calcium imbalance interfering with the medical management of the underlying disease.

Rubinovitch et al. [6] reported their experience in a patient series with vitamin D-resistant rickets. They observed a recurrence of corrected deformities exceeding 10°, in 27% of the limb segments after an average of 25 months following surgery. Besides, about one-third of their patients developed metabolic decompensation, although they were under metabolic control in the early perioperative period. In this study there was no recurrence of any deformity due to metabolic decompensation.

As we have also previously described, the intramedullary nail facilitates a stable protection against recurrence of deformities, even if they develop metabolic decompensation in the postoperative period [8, 14].

Correction of all deformities only by external fixators at one operation causes great patient discomfort. Sequential operations performed after healing of the former one increases the total treatment time and decreases the patient compliance.

Osteotomy and stabilization with Ilizarov-type external fixators allow gradual, controllable deformity correction with advantages of high union and low infection rate due to a low-energy osteotomy and osteosynthesis utilizing minimal intraosseous hardware. The Ilizarov technique allows postoperative adjustments and correction of limb length inequality, though it has some disadvantages like pin tract infections, discomfort, and bulkiness [3–6].

Song et al. [15] are of the opinion that in multiapical deformity correction and fixation with an IM nail early ambulation is not possible because of limited stability afforded and is associated with high risk of complications if used alone. Their study also points out that IM fixation helps to prevent progressive diaphyseal deformity but has no control over a deformity developing in the metaphysis in the remaining growth period, as it lacks fixation in this region. They favor a combination of external fixator-assisted gradual correction and later fixation with an IM device for better results and prevention of fixator-related complications. In this study, the deformity reoccurred in one patient. In that patient treated with retrograde femoral nailing the proximal femur was left unblocked, and deformity reoccurred in that region due to metabolic imbalance.

We had some difficulties in comparing techniques of the groups. We did not compare them according to correction percentage due to inequalities in preoperative values of MAD, LDFA, and mPTA. So we based on the normal values at the last.

While comparing the EFI between two techniques, Ilizarov group had prolonged healing time, whereas for FAN group it was shorter. Stanitski [1] determined in her series of patients treated with Ilizarov frame, for metabolic bone disease, that the duration of EFI was double the amount for femoral lengthening from normal and 25% more for the single level tibial lengthening. There was no problem with the union of the osteotomies. The complications included mild pin-track infections managed locally and mechanical axis translational of inconsiderable amount having no effect on the final outcome.

Gugenheim and Brinker [8] are of the view that the FAN has limitations when there is shortening, the magnitude of angular and rotational deformity near the joint limiting the correction that can be achieved by angular-translational osteotomy and still be fixed with an IM nail. These factors in the open growth plate also limit the use of FAN, especially if retrograde nailing through the knee is to be used.

Conclusion

In deformity correction procedures the fixation technique determines healing time, complications, and patient comfort. Internal fixation techniques provide high patient comfort but lack corrective accuracy. External fixation techniques allow per- and postoperative adjustment and thus a high accuracy, but they lack patient comfort. Fixator-assisted nailing carries deformity correction accuracy comparable with Ilizarov type external fixators.

In patients with metabolic bone diseases the retained IM nail further provides protection against recurrence even if the metabolic pathology reoccurs.

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