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Original article

Correction of axial deformity during lengthening in fibular hypoplasia: Hexapodal versus monorail external fixation

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ABSTRACT

Introduction: Childhood fibular hypoplasia is a rare pathology which may or may not involve limb-length discrepancy and axial deformity in one or more dimensions. The objective of the present study was to compare the quality of the axial correction achieved in lengthening procedures by hexapodal versus monorail external fixators. The hypothesis was that the hexapodal fixator provides more precise correction.
Material and methods: A retrospective multicenter study included 52 children with fibular hypoplasia. Seventy-two tibias were analyzed, in 2 groups: 52 using a hexapodal fixator, and 20 using a monorail fixator. Mean age was 10.2 years. Mean lengthening was 5.7 cm. Deformities were analyzed and measured in 3 dimensions and classified in 4 preoperative types and 4 post-lengthening types according to residual deformity.
Results: Complete correction was achieved in 26 tibias in the hexapodal group (50%) and 2 tibias in the monorail group (10%). Mean post-correction mechanical axis deviation was smaller in the hexapodal group: 12.83 mm, versus 14.29 mm in the monorail group. Mean post-correction mechanical lateral distal femoral angle was 87.5° in the hexapodal group, versus 84.3° in the monorail group (P = 0.002), and mean mechanical medial proximal tibial angle 86.9° versus 89.5°, respectively (P = 0.015).
Discussion: No previous studies focused on this congenital pathology in lengthening and axial correction programs for childhood lower-limb deformity. The present study found the hexapodal fixator to be more effective in conserving or restoring mechanical axes during progressive bone lengthening for fibular hypoplasia.
Conclusion: The hexapodal fixator met the requirements of limb-length equalization in childhood congenital lower-limb hypoplasia, providing better axial correction than the monorail fixator.
Level of evidence: IV.

1. Introduction

Fibular hypoplasia is a rare pathology which may or may not involve limb-length discrepancy and axial deformity in one or more dimensions.

Treatment may consist in a limb-length equalization program, sometimes comprising several lengthening phases. The treatment objective is to lengthen a bone segment while conserving the mechanical axes if they are normal or else correcting any axial deformity.

Lengthening is more difficult in congenital deformity than in acquired pathology [1,2], as all structures (bone, but also muscles, ligaments and joints) are abnormal, leading to more frequent complications: dislocation, stiffening, progressive deformity.

Lengthening, based on callus distraction (callotasis) [3], is achieved by an external fixator, which may be monolateral, such as the Orthofix MiniRail®, or circular. In 1994, Charles Taylor developed a hexapodal external fixator, the Taylor Spatial Frame (TSF®, Smith & Nephew), using Ilizarov's principles of osteogenesis in distraction [4,5]. Its originality lies in associating telescopic struts, hexapodally distributed between the rings, to computer-assisted planning, enabling length and all axes to be corrected during the lengthening program, including in the horizontal plane. Such progressive correction of the deformity is not achievable with a monorail fixator, where correction is extemporary.

The interest of the TSF was shown in several series [6–10], which, however, did not focus specifically on congenital or on acquired pathology. We therefore thought it would be useful to

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Table 1
Distribution of patients according to number of lengthening procedures and type of external fixator.

Number of lengthenings	*n*	Fixator		
		Hexapodal	Monorail	
1	35	33	2	
		2 hexapodals	1 monorail + 1 hexapodal	
2	14	8	6	
		3 hexapodals	3 monorail	2 monorail + 1 hexapodal
3	3	1	1	1

compare a homogeneous series of lengthenings for congenital hypoplasia managed by monorail versus hexapodal fixator.

The objective of this two-center retrospective study was to compare the quality of axial correction during sometimes iterative lengthening in children with congenital lower-limb hypoplasia between a monorail versus a hexapodal fixator. The study hypothesis was that the hexapodal fixator provides more precise correction in this pathology.

2. Patients and methods

2.1. Series characteristics

The retrospective series comprised 52 patients with fibular hypoplasia requiring isolated limb lengthening or lengthening associated to axial correction, managed in the university hospital of Nantes and the Timone hospital of Marseille (France) between June 1986 and March 2014.

Mean age at lengthening was 10.2 years (range: 2–23 years). Sex-ratio was 1.7: 33 males, 19 females.

Mean follow-up was 47.44 months in the hexapodal group and 165.8 months in the monorail group.

Mean pre-treatment length discrepancy was 50.8 mm in the hexapodal group and 64.3 mm in the monorail group ($P = 0.629$).

The equalization program was fully adhered to in all cases.

The 72 tibial lengthenings were distributed between 2 groups: 52 hexapodal and 20 monorail fixations. Several patients underwent iterative lengthening (Fig. 1); Table 1 shows distribution according to type of fixator.

All patients presented with fibular hypoplasia; on the Kalamchi-Achterman classification [11], there were 30 type Ia, 3 type Ib and 19 type II.

2.2. Correction program

All patients underwent pre- and postoperative AP and lateral lower-limb telemetry to analyze the deformity and measure the axes. Postoperative X-rays were taken at fixator ablation. Correction was progressive in the hexapodal group, and extemporary in the monorail group. Each deformity was analyzed and measured in the frontal and sagittal planes; analysis in the horizontal plane was clinical.

MAD (mechanical axis deviation) was measured in mm, to identify genu varum or valgum; mLDFA (mechanical lateral distal femoral angle) and mMPTA (mechanical medial proximal tibial angle) were measured, specifying the femoral or tibial origin of fontal axial joint disorder. In the sagittal plane, tibial and femoral slope were measured to identify deformity in flexion contracture or genu recurvatum.

All deformities were classified ahead of treatment into 4 types on Manner's classification [8]. Type I is limb-length discrepancy without associated axial deformity; type II, single-plane axial deformity and limb-length discrepancy; type III, axial deformity in 2 planes and limb-length discrepancy; and type IV, axial deformity in 3 planes and limb-length discrepancy. Tables 2 and 3 detail the present deformities.

Table 2
Characteristics of preoperative deformities in the 2 groups.

	Hexapodal	Monorail
Discrepancy		
Mean (SD)	5.08 cm (1.24)	6.43 cm (3.18)
Frontal		
Mean (SD)	12.17° (5.65)	9.5° (3.7)
Sagittal		
Mean (SD)	13.37° (6.12)	16° (6.56)
Horizontal		
Mean (SD)	30° (10)	17.5° (3.54)

Table 3
Distribution of preoperative deformities on Manner's classification and by type of external fixator.

Type of deformity	Total	Hexapodal	Monorail
Type I	23	12	11
Type II	30	22	8
Frontal	13	10	3
Sagittal	12	10	2
Horizontal	5	2	3
Type III	18	18	0
Frontal and sagittal	18	18	0
Type IV	1	0	1

Residual deformity persisting at fixator ablation was also assessed 3-dimensionally and classified in 4 groups on Manner's criteria [8]:

- group 1, with no post-lengthening deformity;
- group 2, with residual deformity ≤ 5°;
- group 3, with at least 1 persisting deformity of 6–10°;
- group 4, with residual deformity > 10°.

Statistical analysis used R software, version 3.0.2. The non-parametric Mann-Whitney test was used for quantitative variables, the Fisher test for binary variables, and the Wilcoxon test for matched pairs.

3. Results

Axes were better conserved in the hexapodal group: lengthening was completed without onset of deformity in type 1 deformities (simple lengthening) in 10 of the 12 tibias in the hexapodal group (83%), versus 2 out of 11 in the monorail group (18%) (Table 4).

Axes were also better restored in the hexapodal group: complete type II correction was achieved in 10 of the 22 tibias in the hexapodal group (45%), versus none in the monorail group; complete type III correction was achieved in 6 of the 18 tibias in the hexapodal group (33%); the type IV deformity was not completely corrected (1 patient, in the monorail group) (Table 4).

There was no residual deformity in 28 tibias (39%), taking both groups together. Minor (< 5°) residual deformity was found in 3 tibias (4%), moderate (6°–10°) deformity in 13 (18%), and severe (> 10°) deformity in 28 (39%). Fig. 2 shows distribution according to fixator type.

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