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Original Research Article

FEMORAL LENGTHENING IN CHILDREN: A PROSPECTIVE STUDY

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Abstract

Introduction: We evaluated the outcomes following femoral lengthening by distraction osteogenesis in children. Additionally, we determined the incidence and nature of complications, the management thereof and factors associated with the development of complications.

Materials and Methods: A Prospective study done at Dept. Of Orthopaedics ,Vels medical college and hospital ,was performed of all patients who underwent femoral lengthening as an isolated procedure at our institution. Data regarding presenting details and clinical course were collected and X-rays analysed. The healing index (HI) and the percentage lengthened were calculated. Complications were defined as deep sepsis, joint contracture, fracture and neurological injury.

Results: Fifteen patients underwent 16 femoral lengthenings from 2008–2018. Nine patients had congenital short femur or proximal focal femoral deficiency, three patients had sequelae of meningococcaemia and four had various other pathologies. The median age at time of surgery was 9 years (6–13). Median follow-up was 1.6 years.The median HI was 32 days/cm (20–60). Leg lengths were equalised to ≤2.5 cm in 11 patients; length achieved was as planned in all but three patients. Eight patients sustained fractures on average six days (2–57) after frame removal, five through the regenerate. Four required surgery. Thirteen patients developed joint contractures of which six required additional procedures to address this. Two deep infections required surgery. Two patients developed neurological symptoms of which one recovered fully. Higher percentage length gained (>20%) was associated with increased fracture and joint contracture rate. Diaphyseal osteotomy, as opposed to metaphyseal, was associated with increased risk of fracture (71% vs 25%). A diagnosis of congenital short femur was associated with increased fracture rate. Spanning the knee did not prevent joint stiffness in 4/5 patients but did prevent subluxation.

Conclusion: Femoral lengthening using external fixation can be successful in achieving leg length equality, but complications are common and often require additional surgery. Limiting lengthening to less than 20% of the original bone length and performing the osteotomy through the metaphysis decreases the risk of fracture and joint contracture.

Keywords: femoral lengthening, distraction osteogenesis, leg length discrepancy

Introduction

Distraction osteogenesis using external fixation is a well-recognized technique for limb lengthening. Ex- ternal fixators provide versatile, reproducible, relatively cheap, and effective options for bone lengthening. External fixators allow joint spanning when required.[1] However, external fixators are associated with many complications. These complications include pin site infections, joint contractures, subluxation, and

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regenerationproblems (delayed union, nonunion, early consolidation).[2,3] The prolonged treatment time of external fixators was reported to cause significant limitations to children's activities and lifestyles.[4] The increased emphasis on improving the quality of life of children and their families during treatment stimulated the development of motorized lengthening nails. PRECICE lengthening nails (Nuvasive Specialized Orthopedics Inc., Aliso Viejo, CA) have become very popular in limb lengthening. PRECICE nails are magnetic telescopic titanium intramedullary lengthening nails. The rate of distraction is controlled with external remote control. This is thought to be more convenient for the patients than the traditional methods of lengthening.[5] There are different designs of PRECICE nails, including antegrade and retrograde as well as straight and trochanteric entry, which adds to the versatility of the system. Magnetic lengthening nails were reported to have more effectiveness and fewer complications than external fixators in adult populations.[6,7] However, there is limited evidence to support the use in the pediatric population. That evidence includes reports from noncomparative research[8,9]

Materials and Methods:

A Prospective study done at Dept. Of Orthopaedics ,Vels medical college and hospital ,was performed of all patients who underwent femoral lengthening as an isolated procedure at our institution. Data regarding presenting details and clinical course were collected and X-rays analysed. The healing index (HI) and the percentage lengthened were calculated. For each patient the ratio between the amount of length obtained and the total length of the bone, measured from the tip of the greater trochanter to the intercondylar notch, was calculated and expressed as a percentage. The healing index (HI) was calculated by determining the amount of time spent in the external device for the amount lengthened using the units days/cm.

Table I: Simpson classification of fractures following distraction osteogenesis[13]

Fracture type		Description
Type I		Regenerate fracture
	Type Ia	Acute collapse
	Type Ib	Gradual collapse
Type II		Fracture at junction of regenerate and normal bone
Type III		Fracture through pin fixation site
Type IV		Fracture at peripheral site

Results

Following exclusions, we identified 15 patients that underwent 16 femoral lengthenings for various aetiologies. The presenting details, as well as the details of surgery and healing are summarised in *Table II*. The median age at surgery was 9 years (6–13 years). Median follow-up was 1.6 years.The most common cause for femoral shortening was congenital short femur followed by the sequelae of meningococcal septicaemia. An Orthofix Limb Reconstruction System (LRS) was used in all patients except patient 5 in whom a TSF was used. The knee was spanned in six patients and the hip in one. Mean length obtainedwas 54 mm (range 35–80).

The mean percentage lengthened was 20% (range 8–32%). The mean HI was 32 days/cm (range 20–60). Lengthening was abandoned prior to the desired length being obtained in four patients due to knee stiffness or knee/hip subluxation. Complications encountered and

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outcome following femoral lengthening is summarised in *Table III*. Leg length equality was achieved in five patients. Six patients had residual discrepancies at latest follow-up of ≤2.5 cm which was managed with an orthosis and well tolerated (*Figure 2*). In four patients, a significant LLD remains. One patient is still awaiting tibial lengthening (pt 10), two patients have residual discrepancies of 5 cm and 12 cm respectively (pts 14 and 7) but are functioning well and do not desire any further surgery. Patient 5 has ongoing neurological pain and LLD as well as contracture of the knee and ankle. Amputation was offered but the family refused any further surgery.Our patients developed many complications. Nine patients (50%) sustained fractures of which seven were through the regenerate (*Figure 3*). Fracture occurred on average six days (range 2–57) following removal of the distracting device. Four patients required additional procedures to manage the fracture. Thirteen patients developed joint contractures and six required additional procedures including one quadricepsplasty, one distal femoral extension osteotomy and one guided growth procedure for a fixed flexion deformity of the knee Eight of our patients developed superficial pin-site infections requiring oral antibiotics and pin-site care only. Two patients developed deep infections requiring surgery. Two patients developed neurological symptoms, of which one recovered fully. There was no difference in age between patients who sustained fractures (11.4 years) and those who did not (11.3 years).

The diagnosis of congenital short femur was associated with an increased rate of fracture following lengthening. Five out of seven patients with this diagnosis sustained a fracture. Patient 15 lost all the length gained due to the regenerate fracture; the other fractures did not result in any significant loss of length. The development of a fracture was associated with a higher average percentage lengthened (21.4% vs 16.9%). The incidence of fracture in patients who had ≥20% lengthened was 62.5% compared to 37.5% in those with <20% lengthened. Regenerate fractures occurred in six out of seven patients in whom the osteotomy was performed in the mid-diaphysis. There was no clear association between the HI and the development of fractures. The median HI was 30 days/cm (20–38) and 28 days/cm (22–60) for those that sustained fractures and those that did not, respectively.Nearly all patients developed loss of range of motion in either the knee or the hip. There was no association between the percentage length gained and the need for secondary procedure for joint stiffness. Spanning of the knee did not prevent joint stiffness but did prevent joint subluxation. Only one patient, patient 7, developed a knee subluxation during his second lengthening. The fixator was subsequently extended to cross the knee joint. The same patient, and one other (patient 13) developed hip subluxation. Patient 7 underwent a shelf acetabuloplasty to address the subluxation; patient 13 still had a subluxed hip at last follow-up but refused further surgery.There were no cases of premature consolidation. Delayed consolidation was not documented but no patients underwent bone graft or cyst aspiration during the consolidation phase.

Table II: Demographic and surgical details

Patient	Sex	Age (years)	Side	Diagnosis	Osteotomysite	Adjacent joint spanned	Original length (mm)	Length obtained (mm)	Percentage lengthened (%)	Time spentin frame (days)	Healing index (days/cm)
1	Male	8	Left	Meningococcal septicaemia	Distal	No	275	50	18	120	24
2	Female	13	Left	Hemiplegic cerebral palsy, previous varus osteotomy	Distal	No	390	32.5	8	196	60
3	Female	13	Right	Congenital short femur	Midshaft	Knee	280	55	20	163	30
4	Male	6	Right	Femoral malunion	Distal	No	412	49	12	119	24
5	Male	8	Right	Congenital short femur Fibular hemimelia	Distal	Knee	250	43	17	230	53

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6	Male	8	Left	Congenital short femur	Midshaft	No	245	60	24	118	20
7	Male	8 13*	Right	Proximal focal femoral deficiency	Distal Midshaft	Knee Knee	177 288	35 80	20 29	118 224	33 28
8	Male	9	Left	Tom Smith'sarthritis	Midshaft	Hip	320	85	27	230	27
9	Female	11	Left	Congenital short femur Fibular hemimelia	Midshaft	Knee	310	65	21	174	27
10	Male	9	Right	Congenital short femur	Midshaft	No	280	50	18	181	36
11	Female	10	Left	Meningococcal septicaemia	Distal	No	320	35	11	134	38
12	Male	13	Left	Post-traumaticdistal femoral physeal bar	Midshaft	Knee	250	80	32	184	23
13	Female	11	Right	Congenital short femur	Distal	No	285	57	20	159	28
14	Female	6	Left	Congenital short femur	Midshaft	No	208	50	24	153	31
15	Male	12	Right	Meningococcal septicaemia	Midshaft	No	334	45	13	100	22

Table III: Complications, subsequent surgeries and outcome

Patient	Complications	Subsequent surgeries	Outcome
1	Knee flexion deformity	Distal femoral extension osteotomy	Residual 2 cm LLD
2	Knee extension contracture	MUA knee Quadricepsplasty	Residual 2 cm LLD
3	Regenerate fractureSimpson Ib	None	Asymptomatic residual deformity atsite of fracture; 2 cm LLD
4	Fracture Simpson III	ORIF	Leg lengths equalised
5	Deep infection Sciatic nerve neuropraxiaKnee FFD	Revision of half-pin MUA knee	Ongoing neurological pain and knee FFD
6	Regenerate fractureSimpson Ib	None	Leg lengths equalised
7(1st lengthening)	Fracture Simpson III	None	Residual LLD 20 cm
7 (2nd lengthening)	Peroneal nerve palsyKnee subluxation Hip subluxation Implant fracture	Revision of distractors MUA knee Spanning of knee for subluxation Adductor release Shelf acetabuloplasty	12 cm LLD, stiff knee Mobile and pain-free
8	Regenerate fractureSimpson Ia	ORIF Washout for sepsis ×2Removal of plate	Leg lengths equalised Sepsis resolved
9	Regenerate fractureSimpson Ia	None	Desired length achieved Awaiting tibial lengthening
10	Regenerate fracture Simpson Ia	ORIF femur	Leg lengths equalised
11	Knee stiffness Regenerate fracture Simpson Ib	MUA knee Corrective osteotomy	Desired length achieved
12	Deep infection	Washout	2.5 cm LLDSatisfied
13	Knee FFD Hip subluxation	Anterior distal femur stapling	2.5 cm LLD Hip subluxed
14	Regenerate fracture Simpson Ib Periprosthetic fracture	Spica External fixation for fractureRemoval of external fixator	Residual distal femoral deformity and5 cm LLD
15	Knee stiffness	None	Leg lengths equalised

Discussion

There are many conditions that can result in an LLD requiring limb lengthening. The majority of cases in our study were congenital shortening, with the rest consisting of post-traumatic, post-infectious and neurological causes. A similar spectrum of disease is described in other published

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series.[11,12] The HI for our patients was on average 30 days/cm. This is quite low when compared to the literature. Launay *et al.*,[11] and Aston *et al.*[10] reported HI in their series of 45.1 days/cm and 39.97 days/cm respectively. It is likely that our high fracture rate may be ascribed to premature removal of the fixator device, although there was no difference in the HI between those that fractured and those that did not. Fracture following removal of the lengthening device was the most common complication in our series (8/16 segments). Fracture rates described in the literature vary from 9.3% to 56%.[10] In our series we found an association between the percentage of bone lengthened and the incidence of fractures, with an increased rate of fracture in those lengthened more than 20%. Aston *et al.* found an increased rate of delayed consolidation in patients lengthened more than 6 cm and an increased rate of fracture in those lengthened more than 20%.[10] Launay *et al.* reports a more conservative upper limit for percentage lengthened of 15%.[11] Simpson *et al.*, in a large series of 157 adults and adolescents, demonstrated no association between the length of the regenerate and fracture rate.[11] We had an increased rate of fracture in patients with congenital deficiencies (five out of seven limbs lengthened). Patients with congenital shortening are known to develop poor regenerate and to be more prone to fractures through the regenerate, with rates of up to 56% reported.[14,10] Efforts have been made to reduce the rate of fracture by lengthening over an intramedullary nail. A significant decrease in fracture rate is reported with this modification, as well as reduced time before removal of the fixator.[10,14] Superficial pin-site infection developed in 50% of our patients and is regarded as a problem, not a complication.[15] All superficial infections responded well to oral antibiotics and pin-site care. Deep pin-site infection requiring surgical revision occurred in two patients (13%). These rates are comparable to the published literature.[15,10] We had no pin breakages but one fracture of the distracting device requiring revision. Seven patients developed joint stiffness or subluxation requiring a surgical intervention, often in the form of a manipulation under anaesthesia. We found no association between the amount lengthened or the underlying diagnosis and the incidence of stiffness/subluxation. Higher rates of stiffness and subluxation have been reported in patients with congenital deficiencies, possibly due to inherent instability of the knee.[15,10] Two of our patients developed sciatic and peroneal nerve injury, of which one resolved. The patient in whom the neurological injury did not resolve underwent simultaneous femoral and tibial lengthening. Aston *et al.* reports a 10% rate of neurological injury, all of which resolved spontaneously and were more common in ipsilateral tibial and femoral lengthening.[10] Despite the high rate of complications, we had satisfactory outcomes in 80% of our patients in whom leg lengths were equalised (five patients) or insignificant discrepancy remained (six patients), and joint mobility was restored to a functional range. The use of intramedullary lengthening nails, particularly the new generation magnetic lengthening nails, has offered a less invasive and more acceptable option for lengthening in the absence of significant deformity. These devices reduce the rate of device- related complications such as pin-site sepsis, muscle tethering and scarring, but do not reduce the rate of complications inherent to the distraction procedure such as premature or delayed consolidation, neurological injury and joint stiffness or subluxation.[16] The use of these devices is mostly limited by their excessive cost, and limb lengthening using an external fixator remains the gold standard, especially in small paediatric bones and in the presence of significant deformity.

Conclusion

We present a small series of patients undergoing femoral lengthening for the treatment of LLD due to a variety of aetiologies. Our complication rate, though high, is comparable to the existing literature and our outcomes satisfactory in 80% of patients. More complications are

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encountered when distracting more than 20% of the initial length of the bone and when performing osteotomies in the mid-diaphysis. It is advisable to span the adjacent joint if a long lengthening is planned.

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