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To Observe Changes in Callus Features Pre and Post Infection During Lengthening Over an Intramedullary Device.

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Research Article

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ABSTRACT

Limb lengthening was described by Codivilla in the 19 century as a preferred procedure for limb-length discrepancies and has evolved greatly over the past 60 years(1,2).It is indicated when the discrepancy in length is greater than 5 to 6 cm(3,4). Lengthening over an intra-medullary device maintains alignment both during the distraction and consolidation phase. Thus reducing the number of percutaneous tracts and regenerate fractures. The device is removed when the desired length is achieved .We conducted a study on 62 patients over a period of four years. They were treated with limb lengthening over an intramedulary device. We compared changes in callus features in terms of shape, pattern and density both before and after infection. Limb lengthening over an intramedullary nail/rush pin was performed on 62 patients from 2004 to 2008 in our institution. The mean age was 20.34 years (3-48years) at the time of index procedure. We used UTN-AO nail and rush pins for lengthening .Circular external fixator was applied using both wires and half pins for tibial lengthening. All the radiographs were analyzed retrospectively by three different observers. The types and shapes were classified according to Ru Li et al.'s classification system. In infected cases changes in the callus pattern, shape and density were observed by serial radiographs every four weeks. And they were compared with the noninfected segments. We excluded patients who had a history of previous bone infection, open fracture, cases treated with bone transport, double level lengthening and severe bone deformity requiring gradual deformity correction and femoral segments were also excluded. All the patients were followed up for a minimum of two years post operatively62 patients (116 segments) were divided into three groups (Group A-noninfected, group B -superficial pin site infection, group C -deep intra-medullary infection). From 18 segments of (group B and C) staphylococcus aureus was recovered by culture. Group C differed significantly in its callus pattern ($P<0.05$) and density ($P=0.0001$) from both group (A and B). The callus shape and pattern follows a particular path during distraction osteogenesis. This pathway may get disturbed due to infection. Thus early radiographic changes like lucency, progressive heterogenousity and deficiency of the cortex can point towards underlying deep intra-medullary infection. Early recognition of these callus features along with other constitutional symptoms can help in early intervention. Thus, leading to timely diagnoses and appropriate treatment.

INTRODUCTION

Limb lengthening was described by Codivilla in the 19th century as a preferred procedure for limb-length discrepancies and has greatly evolved over the past 60 years [1,2]. It is indicated when the discrepancy is more than 5 to 6 cm [3,4]. Many methods and procedures are used often confining the patient to periods of bed rest followed by bone grafting and plating. But by succession of modern devices the ease and success of lengthening procedures

has increased manifold. Commonly performed procedures include low-energy corticotomy, preserving the periosteum, device positioning, and gradual lengthenin. *Circular external-fixator (Ilizarov) method*, which was originally popularized by Ilizarov has a circular external fixator which allows incremental lengthening while supplying angular, rotational and translational control. It uses tensioned transosseous wires or half-pins attached to the circumferential or partial fixator rings [5,6]. Which bolsters the support of regenerating bone, and decreases the time for which the external fixator is applied. Paley [7] started lengthening over an intra-medullary nail. Kim and colleagues [8] have successfully used this method with lesser complications and performed tibial lengthening up to 5.5 cm. However, this technique remains controversial as it cannot control the anatomical and mechanical axes of the segment being lengthened which creates a route for intra-medullary infection. Gordon and colleague [9,10] reported osteomyelitis in 2 of 9 cases while lengthening the femur of preadolescents over an intra-medullary nail.
It was a retrospective study on 62 patients treated with the technique of lengthening over an intramedulary device. To evaluate the changes in callus shape, pattern and density both before and after infection.

MATERIALS AND METHOD

Lengthening over an intramedullary nail/rush pin was performed on 62 patients (116 segments) between 2004 and 2008 in our institution for limb length discrepancies. The mean age of 62 patients (116 segments) was 20.34 years (3ys-48yrs) at the time of index procedure. The causes for short limbs were Familial short stature (54 segments), Idiopathic short stature (21segments), Hypochondroplasia (10 segments), Osteogenesis imperfecta (4 segments),Vitamin D resistant rickets (6 segments), Trauma resulting in epiphyseal injury(4 segments), Russell silver syndrome (2 segments), Achondroplasia (2 segments), Spondyloepiphyseal dysplasia (2 segments),Short stature due to nephrotic syndrome (2 segments), Short stature due to adrenal hypertrophy (2 segments),Turners syndrome (2 segments), congenital hemihypertrophy (2 segments), pseudoarthrosis (2 segments) and tibial dysostosis (1segment). We excluded patients with history of previous bone infection, open fracture, cases treated with bone transport, double level lengthening, bone deformity of the severity that required gradual deformity correction and femoral segment lengthening cases. UTN-AO nail and rush pins were used for lengthening procedure. Nails were used in 84 segments and rush pin in 30 segments. Rush pin was used in young patients who had narrow medullary canal .Osteotomy of tibia was performed at proximal metaphyseo-diaphysial junction and fibula was osteotomized at junction of middle and distal one-third. Circular external-fixator was applied using both wires and half pins for tibial lengthening. Gap of 3-5 mm was kept between intra-medullary device and wires/half pins. Distraction was started on the 7th post operative day at a rate 1mm/day (0.25mm x 4 times). Fixator was removed when the desired length was achieved and the intramedullary nail was locked. In case of rush pin locking procedure was not performed. All radiographs were taken digitally (StarPACS, Infinitt, PiView Star, 5.0.6.0). Full range of motion of knee and partial weight bearing with two crutches was started on the 1st post operative day. After removal of the fixator weight bearing was increased depending upon the quality of the regenerate observed on serial radiographs. Full weight bearing was started when at least 3 cortices were seen on the radiograph. All the radiographs were analyzed retrospectively by three observers. Types and shapes were classified according to Ru Li et al.'s classification system[16]. They classified the regenerate area based on the shape and type of callus (table 1, 2).The shapes were classified as fusiform, cylindrical, lateral, concave, and central depending upon the width compared to the original osteotomy site. The types are based on four patterns of distraction osteogenesis (Sparse, Homogenous, Heterogeneous, and Lucent) and three densities (low, intermediate, and normal).The density was compared to the adjacent soft tissue and cortex. And matched with three treatment periods (distraction, early consolidation and late consolidation).The callus width was measured at the center of the callus and compared with the original width of the tibia at the osteotomy site. Patients were observed for the signs of infection during the post operative period and follow up visits. In the infected cases changes in the callus pattern, shape and density both pre and post infection were observed every four weeks by serial radiographs. And compared with the noninfected segments. The patients were followed for a minimum of two years post operatively.

Table 1: Classification of callus as proposed by Ru Li et al. (shape)

Shape	Description
Fusiform	Regenerate wider than the original bone
cylindrical	Regenerate same width as the original bone
concave	Regenerate narrower than the original bone
lateral	Regenerate mainly on one side of the distraction gap
central	Regenerate is a thin pillar

Table 2: Classification of callus as proposed by Ru Li et al (Types)

Type	Low density	Intermediate density	Normal density
sparse	Type 1 (soft)	Type 5 (half tone)	
homogeneous	Type 2 (stripe)	Type 6 (uniform)	Type 9 (solid)
heterogeneous	Type 3 (speckled)	Type 7 (irregular)	Type 10 (cyst defects)
lucent	Type 4 (adjacent)	Type 8 (saw tooth)	

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Statistical analysis

We used following parameters to evaluate results in present study: Callus features which included shape, Pattern and density in infected and non-infected patients. Among the three group comparisons for categorical variables (callus shape, pattern and density), we employed Fisher's exact test. p <0.05 was regarded as statistically significant.

RESULTS

The three groups (A, B and C) were comparable in age (P=0.316) and sex (P=0.472). The mean age of patients in group A was 20.7 years (range 3-47 years) with 32 males and 13 females, Mean age of patients in group B was 22.15 years (range14-39 years) with 9 male patients and 4 females . Mean age of patients in group C was 18.8 years (range 13-24 years) with 3 female and 2 males. *Bacteriology*: 18 segments had infection in (group B & C). A single organism was recovered from the discharge. In group B the organism was MSSA (methicillin sensitive staphylococcus aureus) in six segments, and MRSA (methicillin resistant staphylococcus aureus) in one segment and six segments had negative culture. In group C- MSSA was recovered from four segments and MRSA from one segment. *Callus shape, pattern & density:* In Group A -32 segments had fusiform (F), 59 had cylindrical (Cyl) and 5 had concave (Con) shape. None of the segments had central or lateral callus shapes. Regarding density 79 segments were homogenous (HOM), 19 were heterogeneous (HET). In callus pattern 95 segments were of normal (NOR) did density and 2 have callus deficient medially (NOR-DM) at the final follow- up. In Group B - 8 segments had cylindrical shaped callus, 5 had fusiform, and none had concave, lateral or central shaped callus.We found 11 segments with homogenous callus pattern and 2 with heterogeneous callus pattern. There were 11 segments with normal density, one with normal density callus deficient medially (NOR-DM) and one with normal density callus deficient anteriorly (NOR-DA). Group C did not differ significantly in its callus shape but differed significantly in its pattern and density from the other two groups (A & B). This group passed through lucent stage in two segments which later followed heterogeneous callus pathway after successful treatment (table 3).In this group five segments had cylindrical shape, one segment had homogenous callus pattern and four segments had heterogeneous callus pattern (P<0.05). One segment had normal density callus while three segments had normal density callus deficient anteriorly and medially (NOR-DAM). One segment had normal density callus deficient anteriorly (NOR-DA) at the final follow up (P =0.0001) in this group.

Table 3: Groups A, B and C: Callus Shape, Pattern and Density.

	Group A	Group B	Group C	P value
Callus shape[b]	34(F), 59(Cyl), 5(Con)	5 (F), 8(Cyl)	5 (Cyl)	0.426
Callus pattern[b]	79(HOM), 19(HET)	11(HOM), 2(HET)	1(HOM), 4(HET)	<0.05
Density[b]	96(NOR), 1(NOR-DM), 1(NOR-DA)	11(NOR),1(NOR-DM),1(NOR-DA)	1(NOR),1(NOR-DA), 3(NOR-DAM)	0.0001

P value<0.05 was considered significant. The results show significant differences.
[b]Comparison of three groups (A, B and C) by Fisher's exact test.

Treatment of infection

Eighteen infected segments in this series were treated by variety of methods. Factors that influenced the treatment of infection included type of infection, primary disease, type of organism and its antibiotic sensitivity, integrity of the soft tissue, anatomical location, and to a large extent the patient's attitude and desires. Despite these variables the methods of treatment can be divided into three groups. Group 1 consisted of six patients in whom the infection was considered to be amenable to conservative management and who were treated with antibiotics, aspiration, and incision and drainage, and without removal of the infected pin, wire or nail/rush pin. Group 2 comprised ten patients in whom the infected implant like half pin or wire or nail was removed. Incision & Drainage done and the length of the limb was maintained by thes external-fixator and appropriate antibiotics were administered for 7-14 days. Group 3 consisted of two patients in whom removal of infected implant and further infection control by antibiotic impregnated polymethylmethacrylate beads was done (fig 1), Antibiotics were then administered for 7-14 days either by intravenous or oral route. In our series we found that all the patients responded to the treatment and there was effective control of infection after above treatment.

DISCUSSION

During lengthening over an intra-medullary device, rod serves to maintain the alignment in both distraction and consolidation phases. The external devices are used to achieve length. There has been some hesitation in use of this approach because of the risk of producing a serious intra-medullary infection. As the intra-medullary foreign material is in continuity with the exterior through the pin tracts. Some studies reported a low infection rate and recommended the technique [11,12,13].

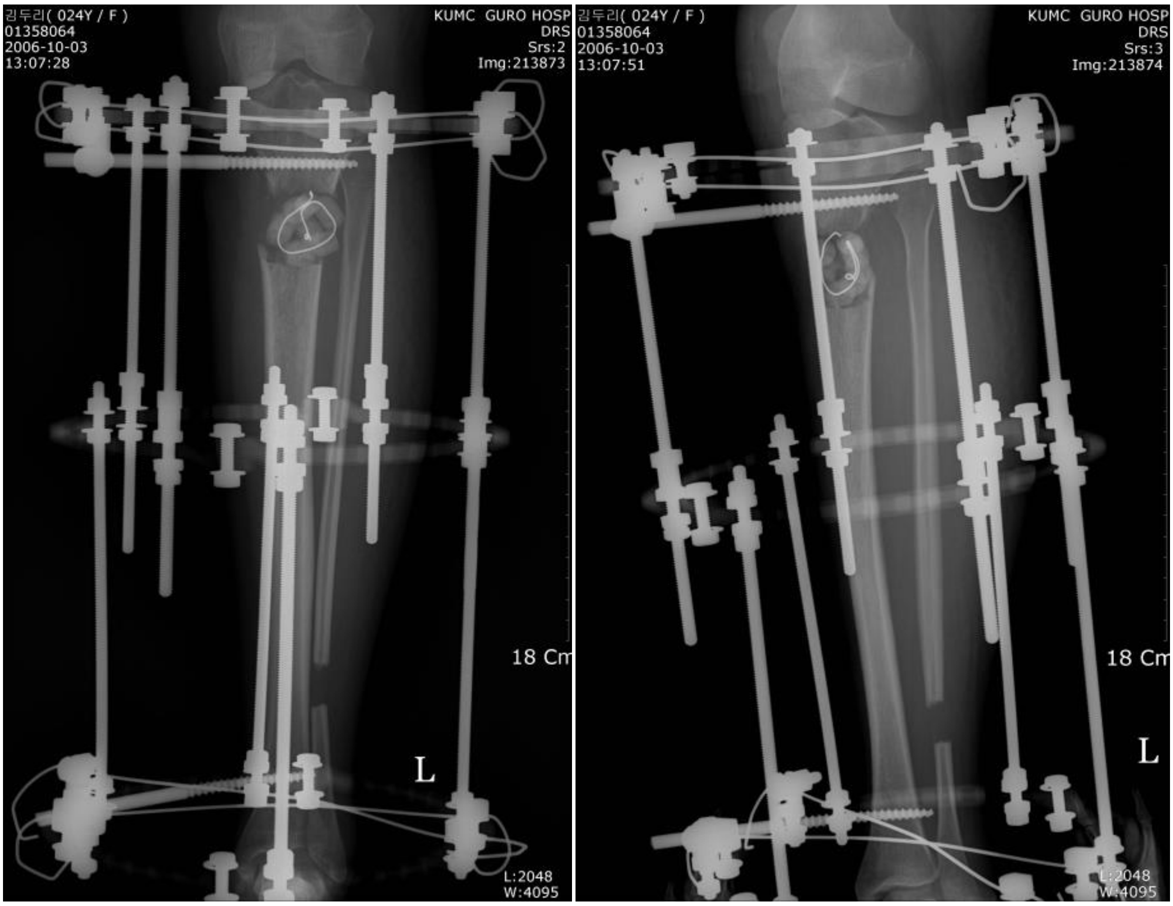

Figure 1: showing antibiotic beads application after intra-medullary nail removal in infected case (deep intra-medullary infection group)

Paley et al. reported deep infection in 1 of 29 patients. He recommended that contact between the nail and half pins of the external fixator should be avoided. But others are less enthusiastic, about the approach because of the significant rate of infection [14,15,16]. In our study (following Paley's recommendations) there was 15.7% infection rate (including superficial pin site and deep intra-medullary infection).Deep intra-medullary infection in 5 segments and superficial Pin site infection in 13 segments. Over all rate of superficial pin site infection was 11.4% and that for deep intra-medullary infection was 4.3%. Rate of deep intra-medullary infection is same (3%- 5%) as reported by Paley et al and Silberg et al [17]. And less than 15% as reported by Simpson et al [18]. The present concept of callus formation is that during distraction, the hematoma at the osteotomy site metaplases into a zone of longitudinally well vascularized fibrous tissue [19]. This area is radiolucent in appearance and is flanked by advancing fronts of ossification from both ends. New trabeculae are formed from fibrous tissue, which have a central radiolucent zone of rapid remodeling. When the distraction phase is complete, the zone is obliterated by the advancing zone and coalesces to make the bone structurally continuous. Ru Li et al gave importance to these temporal changes and proposed different pathways that callus may take on its course from the time of distraction to the period of consolidation and finally corticalization. There has been apprehension that the callus in the regenerate of the infected groups can be of abnormal shape and pattern. Which can cause delayed healing and refracture of the regenerate upon weight bearing. In our study we found that the regenerate of the non-infected (group A) and superficial pin site infection group (group B) did not differ significantly, the most predominant pathway in this group was homogenous pathway. According to Ru Li et al., the homogenous pathway is an indicator of good outcome[3]and fusiform shape is advantageous. On review of literature, a fusiform regeneration has a rapid bone healing index and cylindrical shape shows a satisfactory regeneration. The concave shape regenerations are associated with poor bone response to lengthening and vigorous distraction rate.Lateral shape regenerations are due to difference in circulation and amount of soft tissue cover over the bone . The central shape was reported by Kojimoto et al [20] where only the endosteum seems to participate in the callus formatiom [21]. The callus shape in the regenerate of group C did not differ significantly from the group A and B (P=0.497). Our study showed a significant difference in callus pattern of deep intra-medullary infection group (group C) from the other two groups (groups A & B) ($p<0.010$).The predominant pathway was lucent pathway; it can be an indication of delayed healing or nonunion. The callus in the deep infection group was lucent in three segments due to intra-medullary infection which resolved into heterogeneous callus pattern after proper intervention. We observed medial and anterior deficiency in the density of the regenerates in group C and the difference was highly significant (p=0.0001) when compared with the other two groups. The deficiency was due to superficial location of medial and anterior border of tibia. As it has poor circulation and deficient muscle mass, and infectious discharge finds its way through this least resistant area. It is also used for interventions like incision-drainage and antibiotic beads application. Thus, this area becomes deficient due to drainage of infectious discharge and surgical intervention, this deficiency persists even after consolidation of the regenerate. The observation of callus shape and pattern gives a clue towards the healing and consolidation of the regenerate. Lucency, progressive heterogenousity, deficiency of the callus medially or anteriorly along with other constitutional signs should alert the surgeon of underlying deep intra-medullary infection. And if recognized earlier can be treated effectively. In our study we removed the intra-medullary device in the deep infection cases; in 2 cases (two segments) we used antibiotic beads after incision and drainage. All our deep infection cases resolved but in most of them there was deficiency of callus anteriorly and medially at the final follow up (Figs: 2a,v2b).

Figure 2(a): Showing deficient callus anteriorly at final follow-up in deep intra-medullary infection case.

Figure 2(b): Showing deficient callus medially at final follow-up in the same case.

In summary, the callus shape and pattern follows a particular pathway during distraction osteogenesis and this pathway can get disturbed by infection. Thus early changes like lucency, progressive heterogenousity and deficiency of the cortex can give a clue towards underlying deep intra-medullary infection. Early recognition of these callus features along with other constitutional symptoms can make surgeon to intervene in these cases. Thus timely diagnoses and appropriate treatment can be done to prevent catastrophic complications of deep intra-medullary infection.

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