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ORIGINAL PAPER

Tibial lengthening over humeral and tibial intramedullary nails in patients with sequelae of poliomyelitis: a comparative study

Daoyun Chen · Jianmin Chen · Yao Jiang · Fanggang Liu

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Abstract Leg discrepancy is common after poliomyelitis. Tibial lengthening is an effective way to solve this problem. It is believed lengthening over a tibial intramedullary nail can provide a more comfortable lengthening process than by the conventional technique. However, patients with sequelae of poliomyelitis typically have narrow intramedullary canals allowing limited space for inserting a tibial intramedullary nail and Kirschner wires. To overcome this problem, we tried using humeral nails instead of tibial nails in the lengthening procedure. In this study, we used humeral nails in 20 tibial lengthening procedures and compared the results with another group of patients who were treated with tibial lengthening over tibial intramedullary nails. The mean consolidation index, percentage of increase and external fixation index did not show significant differences between the two groups. However, less blood loss and shorter operating time were noted in the humeral nail group. More patients encountered difficulty with the inserted intramedullary nail in the tibial nail group procedure. The complications did not show a statistically significant difference between the two techniques on follow-up. In conclusion, we found the humeral nail lengthening technique was more suitable in leg discrepancy patients with sequelae of poliomyelitis.

The authors claim that none of the material in the paper has been published or is under consideration for publication elsewhere.

D. Chen · J. Chen · Y. Jiang (✉) · F. Liu
Department of Orthopaedics, Shanghai 6th People's Hospital,
Shanghai Jiaotong University,
Shanghai 200233, People's Republic of China
e-mail: jiangyaosjtu@sina.com

Introduction

Leg lengthening by distraction osteogenesis is widely used both in children and adults to solve serious problems associated with leg length discrepancy, short stature, axial deformities and combinations of these conditions [1–5]. This technique was originally described by Ilizarov, using an external ring fixator to perform distraction osteogenesis; it is well known and widely used. However, this technique is associated with a high rate of complications, and the time for external fixation is very long. The consolidation phase is approximately twice as long as the distraction phase in children and up to four times as long in adults [6]. Patients often tolerate the consolidation periods poorly, and the complications such as pin-tract infections, axial deviation and stiffness of the joint may develop. On the other hand, if the external fixator is removed too early, regenerated bone fracture may result in one or more complications including deformity, shortening and nonunion [7, 8]. It would be beneficial if the period of external fixation could be reduced without increasing the risks.

It is believed that lengthening over a tibial intramedullary nail can provide a more comfortable lengthening process, shorten the external fixation period, and support the regenerated bone internally [9]. This technique is gaining wider acceptance because of the improvement in patient comfort and fewer incidences of complications [10–12]. However, leg discrepancy after poliomyelitis is associated with a narrow intramedullary canal, and there is usually difficulty attaching the external fixator because of the small amount of space available for inserting Kirschner wires after tibial intramedullary nailing. In the early stage, we treated tibial lengthening with tibial nails in 21 patients. We found that the tibial nail was not suitable for all lengthening procedures because of intramedullary canals which were

Table 1 Patient clinical and demographic data

Parameter	Humeral nail group	Tibial nail group	*P* value
Age (years)	24.15±4.46	23.90±4.53	0.862
Gender (female/male)	14/6	13/8	0.58
Limb length discrepancy (cm)	4.74±0.61	4.80±0.47	0.705

relatively narrow in patients following poliomyelitis. Therefore, we tried using a humeral nail combined with a single plane external fixator for the tibial lengthening procedure in these patients.

In this study we retrospectively compared a group of poliomyelitis patients treated with tibial lengthening over a humeral nail with another group of cases treated with tibial lengthening over a tibial intramedullary nail.

Patients and methods

During the period of November 2000 through September 2006, 41 patients underwent a tibial lengthening procedure using an intramedullary nail combined with a single plane external fixator in our department (Table 1). Among those patients, 20 were treated with a humeral intramedullary nail and 21 with a tibial intramedullary nail. All the aetiologies of limb-length discrepancy were attributed to poliomyelitis. We excluded patients who had a history of previous bone infection, were skeletally immature, had an open fracture, soft tissue compromise, antineoplastic chemotherapy, or bone deformity of a severity that required gradual deformity correction. We also did not include cases treated with double-level lengthening.

Two types of intramedullary nail were used in this study (Fig. 1).The humeral intramedullary nail (Kanhui company, China) with a diameter of 7 mm (diameter 8 mm and 55 mm proximal section at an angle of 6° with the main nail) was used in the humeral nail group. The tibial intramedullary nail (Kanhui company, China) with diameter of 8–9 mm (diameter 10 mm and 70 mm proximal section at an angle of 11.5° with the main nail; 8 mm and 9 mm tibial nails share the same diameter in the proximal part) was used in the tibial nail group. The single plane external fixator (Jinglu company, China) was used in all patients of both groups. The frame was constructed with two straight shafts, which allow transverse insertion of four to five Kirschner wires (we usually use four Kirschner wires with diameter of 3.5 mm). Each shaft consists of a fixed part and a lengthening part, the lengthening ranged from 2–8 cm (Fig. 2).

Under regional anaesthesia, the proximal inlet for insertion of the intramedullary nail was created, then progressive reaming was done to enlarge the tibial cavity. After drilling multiple wire holes at the planned osteotomy site to prevent fat embolism related to intramedullary nailing, we inserted the intramedullary nail with proximal interlocking screws. The osteotomy was completed with an osteotome using multiple wire holes. We ensured that at least 8 cm of the intramedullary nail was on the distal side of the distraction gap at the end of lengthening. With the nail in situ, a single plane frame was mounted with four to five 3.5-mm Kirschner wires. All external fixation wires were inserted without contact with the intramedullary nail. Lengthening was initiated on an average of seven days postoperatively at a rate of 0.25 mm, four times a day, at the distraction site. The distraction rate was adjusted according to the efficiency of new bone formation or to patients' tolerance. During lengthening, radiographs were obtained weekly to monitor the distraction progress. After the desired limb-length had been achieved, distal interlocking screws were inserted and the external fixator was removed. It was important to insert these distal locking screws before removing the fixation to prevent loss of length. After radiographs showed remodelling of two cortices, full weight-bearing was permitted. After completion of bone

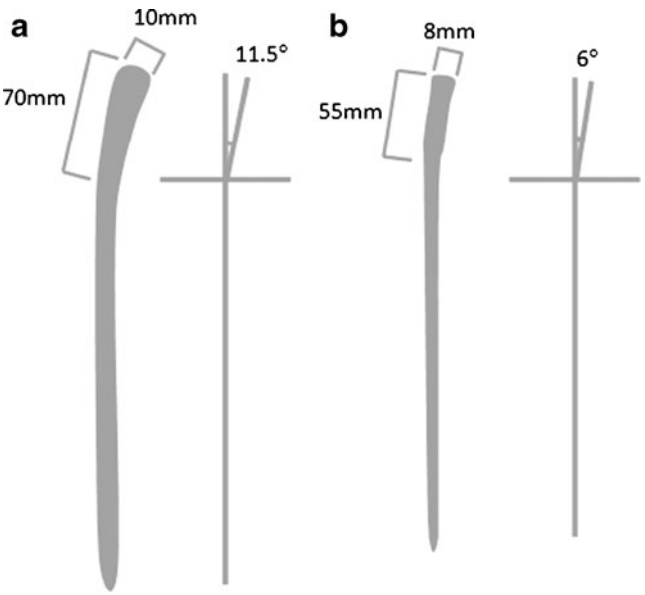

Fig. 1 The proximal part of the two types of intramedullary nail. **a** Tibial intramedullary nail; diameter 10 mm and proximal 70 mm at an angle of 11.5° with the main nail (8 mm and 9 mm nail share the same diameter in the proximal part). **b** Humeral intramedullary nail; diameter 8 mm and 55 mm proximal part at an angle of 6° with the main nail

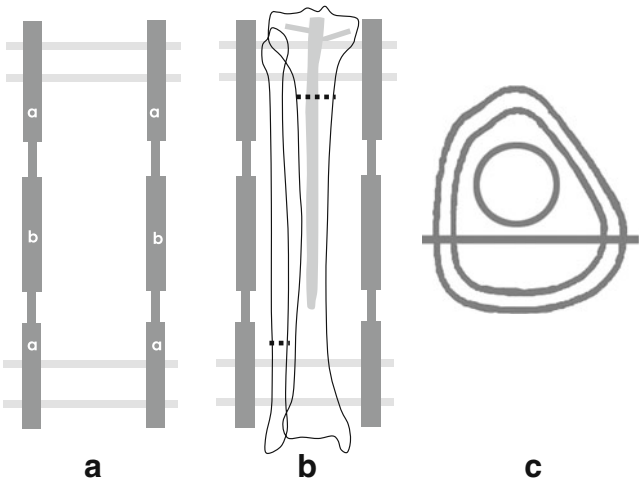

Fig. 2 **a** The single plane fixator (*a* fixed part; *b* lengthening part). **b** Tibial lengthening using intramedullary nail with a single plane fixator. **c** The Kirschner wires and the intramedullary nail configuration on the coronal plane of the medullary cavity

remodelling, the intramedullary nail was removed at the patient's request (Fig. 3).

We used the distraction index, the consolidation index, the external fixation index, operating time and blood loss to evaluate the results. The distraction index was obtained by dividing the duration of lengthening by the length gained; the consolidation index was calculated by dividing the duration of consolidation (measured from application of external fixation to radiographic consolidation of regenerated bone) by the length gained; and the external fixation index was defined as the entire duration of external fixation divided by the length gained. Some tibial lengthening complications such as pin-tract infection, refracture, delayed consolidation, the axial deviation, the joint contracture and the additional surgical interventions were compared between the two groups.

Results

The average tibial lengthening of 4.27±0.51 cm in the humeral nail group was not significantly different (P= 0.705) from the tibial nail group, which had a mean tibial lengthening of 4.23±0.43 cm. The duration of external fixation was much lower in the humeral nail group (P= 0.043) with 53.90±6.80 days in the humeral nail group verus 58.67±7.72 days in the tibial nail group. The mean consolidation periods did not differ significantly between the two groups (P=0.354), i.e. 161±11.93 days in the humeral nail group and 164.19±9.81 days in the tibial nail group. The mean consolidation index was 38.05± 3.95 days/cm in the humeral nail group versus 39.01± 3.43 days/cm in the tibial nail group (no significant difference; P=0.410). The mean percentage of increase did not differ significantly between the two groups, i.e. 0.113±0.018 in the humeral nail group versus 0.108±0.012 in the tibial nail group (P=0.312). The mean external fixation index was significantly lower in the humeral nail group (P<0.01), with 12.66±1.13 days/cm in the humeral nail group versus 13.85±1.352 days/cm in the tibial nail group. The mean operating time for the tibial nail procedure was approximately 25 minutes longer than for the humeral nail group, i.e. 167.28±17.55 min for the tibial nail group versus 142.45±19.96 for the humeral nail group (P<0.01). The mean blood loss recorded in the anaesthetic operative record was 168.75±44.18 ml in the humeral nail group

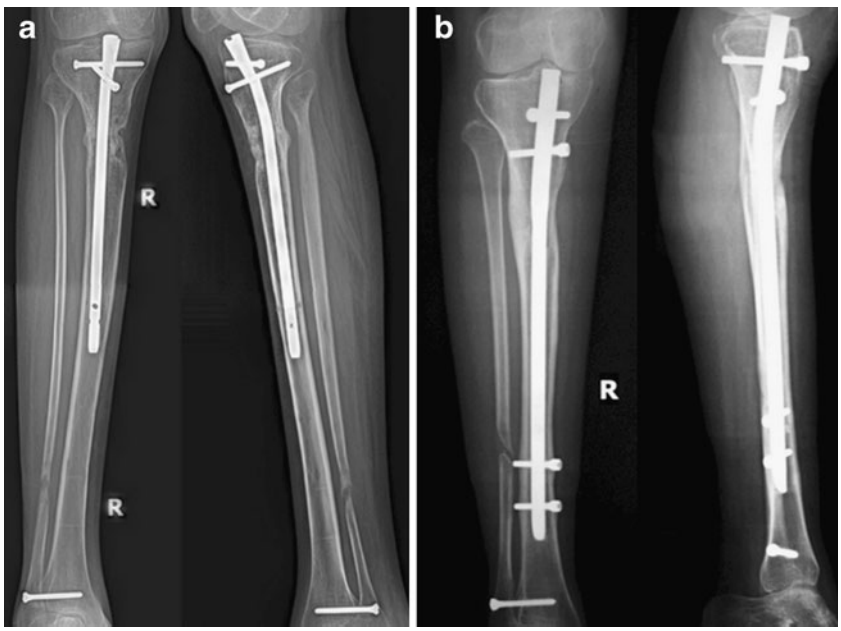

Fig. 3 **a** Tibial lengthening over a humeral intramedullary nail. **b** Tibial lengthening over a tibial intramedullary nail

Table 2 Outcomes of both procedures

Parameter	Humeral nail group	Tibial nail group	*P* value
Tibial lengthening (cm)	4.27±0.51	4.23±0.43	0.705
Duration of external fixation (days)	53.90±6.80	58.67±7.72	0.043
Consolidation period (days)	161±11.93	164.19±9.81	0.354
PI (%)	0.113±0.018	0.108±0.012	0.312
EFI (days)	12.66±1.13	13.85±1.352	<0.01
CI (days)	38.05±3.95	39.01±3.43	0.410
Operating time (min)	142.45±19.96	167.28±17.55	<0.01
Blood loss (ml)	168.75±44.18	212.85±35.51	<0.01

PI percentage of increase, *EFI* external fixation index, *CI* consolidation index

versus 212.85±35.51 ml in the tibial nail group (significant difference, $P<0.01$). We used an air tourniquet during the operation in both groups. No patient required blood transfusion intraoperatively or postoperatively in either group (Table 2).

The complications in tibial lengthening were evaluated in this study (Table 3). The incidence of pin-tract infection, peroneal nerve injury and equinus deformity did not shown significant differences between the two groups. Axial deviation during lengthening occurred in three patients in the humeral nail group versus one patient in the tibial nail group (no significant difference, $P=0.56$). But all the deviations were less than five degrees and no patient needed corrective surgery in either group. Four delayed unions were noted in the humeral nail group and three were found in the tibial nail group ($P=0.87$), all of the cases were treated with cancellous bone grafting. Even though we tested the ability of the osteotomy site to separate intra-operatively, one case of premature consolidation occurred in the humeral nail group and three cases occurred in the tibial nail group. We treated the complication by another osteotomy. In six patients intraoperative difficulty in inserting the intramedullary nail was encountered in the tibial nail group, and we had to adjust the location of the external fixator pins. However, no difficulties were encountered in the humeral nail group (significant difference, $P=0.031$). There were no statistically significant differences found in complications of deep-vein thrombosis, severe pain, and wound dehiscence in either group. No intramedullary nail or screw breakage occurred in either group.

Discussion

Complications are the major risk of tibial lengthening. Lengthy application of the external fixation is associated with many complications, such as loss of motion at the knee or ankle and pin-tract infections in addition to interference with activities of daily living. It is reported that lengthening with a tibial intramedullary nail can decrease the incidence of lengthening complications and provide a more comfortable procedure [10]. However, in

Table 3 Complications of tibial lengthening in both groups

Complication	Humeral nail group ($N=20$)	Tibial nail group ($N=21$)	*P* value
Pin tract infection	13	12	0.60
Deep intramedullary infection	0	0	
Peroneal nerve injury	2	3	0.67
Osteomyelitis	0	0	
Equinus deformity	16	12	0.11
Joint contracture requiring surgery	8	7	0.66
Axial deformity	3	1	0.56
Axial deformity requiring surgery	0	0	
Premature consolidation	1	3	0.32
Delayed union	4	3	0.87
Delayed union requiring bone graft	4	3	0.62
Difficulty with intramedullary nail	0	6	0.031
Deep-vein thrombosis	2	1	0.96
Severe pain	6	5	0.65
Wound dehiscence	6	8	0.58

poliomyelitis leg discrepancy is associated with a narrow intramedullary canal, and there is usually difficulty attaching the external fixator because of the small amount of space available for inserting 3.5-mm Kirschner wires after tibial intramedullary nailing. The most common difficulty in inserting Kirschner wires occurs in the proximal tibia, since the nail is relatively fixed in the proximal cavity and limited space is left for inserting the wires. As the length of nail can be selected preoperatively, this problem rarely occurs on the distal side of the osteotomy gap. Although there is only 1–2 mm difference in diameter between the two nail types, the proximal volume of the humeral nail is much less than the tibial nail, while there is no difference in proximal volume between the 8-mm and 9-mm diameter tibial nails. After inserting the intramedullary nail, enough space is available in the proximal tibial cavity in the humeral nail procedure, whereas only a small space remains when tibial nail is used. In this study, we inserted a humeral nail and tibial nail respectively in two groups. We did not encounter difficulties in inserting Kirschner wires in the humeral nail group, but six cases of difficulty occurred in the tibial nail group. Consequently, shorter operating time and less blood loss were observed in the humeral nail group than in the tibial nail group.

It is believed that the longer the duration of the external fixation, the worse the joint contracture becomes. We used an intramedullary nail to maintain the lengthening gained after the external fixator is removed, which significantly reduces the duration of external fixation. Therefore, patients can recover their daily living and exercise their ankle joint early. In this study, some patients encountered ankle contracture in both groups; however, the majority of them recovered nonoperatively. Another critical complication in tibial lengthening is axial deviation, where the intramedullary nail acts as an internal fixation after the external fixator is removed, and maintains better axial alignment until complete bone remodelling. In this study, there were three cases of axial deviation in the humeral nail group versus one case in the tibial nail group. Although it seems that humeral nail is less stable than tibial nail, there was no statistical difference between the two groups. In the humeral nail group, two cases of axial deviation occurred with a humeral nail of 240 mm in length, and one case by using a humeral nail of 260 mm, while axial deviation was not found in patients lengthening with a humeral nail of 280 mm in length. This indicated that humeral nail of 280 mm in length could support enough axial stability for the lengthening procedure. Based on those findings, we recommend tibial lengthening using a humeral nail of 280 mm in length. We also noticed that all the deviations were less than five degrees, no patient needed an additional corrective operation, and no lengthening was interrupted by this small deviation. Thus, we had similar results in consolidation periods, percentage of increase as well as consolidation index between the two groups.

Some authors believe that intramedullary nail may impede endosteal blood supply of diaphyseal bone and thus affect the quality of newly formed bone during lengthening procedures. However, it has been demonstrated that the periosteum and surrounding soft tissue still can support osteogenic cells to permit new bone formation [9, 11, 13, 14]. Fat embolism is a major concern of combined intramedullary nail and external fixator, especially with simultaneous bilateral procedures [9]. To prevent this complication, we drilled multiple wire holes at the planned osteotomy site before reaming and decompressing the medullary canal, furthermore we did not perform bilateral lengthening with intramedullary nails. In our cases, no patient suffered a fat embolism. Deep infection was also a cause for concern. Paley et al. recommend avoiding contact between the pins of the external fixator and the intramedullary nail [9]. We took this precaution, and no patient developed a deep intramedullary infection in our series.

In summary, satisfactory lengthening gain can be achieved by either a humeral intramedullary nail or a tibial intramedullary nail combined with an external fixator. Both methods can be recommended as a good technique for tibial lengthening in patients with leg length discrepancy. Lengthening by humeral nail is a relatively simple operation and can reduce the difficulty in Kirschner wire insertion as well as reduce the operating time, which is an ideal choice in the leg discrepancy patients with the sequelae of poliomyelitis.

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