International Orthopaedics (SICOT) (2013) 37:1995–2000
DOI 10.1007/s00264-013-1962-x

ORIGINAL PAPER

S-osteotomy with lengthening and then nailing compared with traditional Ilizarov method

Xia Lan · Lihai Zhang · Peifu Tang · Hetao Xia · Gang Li · Aiming Peng · Yilian Han · Bangtuo Yuan · Wenpeng Xu

Received: 27 April 2013 / Accepted: 30 May 2013 / Published online: 17 July 2013

Abstract
Purpose The purpose of this study was to explore the clinical effect of the novel method combined longitudinal S-osteotomy and Lengthen And Then Nail (LATN) technique for leg lengthening and compare with the classic Ilizarov method.
Methods This retrospective study was performed from March 2008 to April 2012. A total of 176 leg lengthenings (88 consecutive patients) were performed at our institution. The mean duration of follow-up was 2.2 years (range, one to four years). In group A, 78 tibial lengthenings were performed with longitudinal S-osteotomy and LATN technique. In group B, 98 tibial lengthenings were performed with the classic method. The final gain in length, mean surgical time for bilateral tibial osteotomy, the external fixation index and the radiographic consolidation index were calculated and compared. The complications encountered during operation and follow-up were documented.
Results There was no significant difference in the final gain in length between the two groups. Mean surgical time in group A (130.05±6.60 min) was significantly longer than that in group B (91.4±6.61 min; $P<0.05$). External fixation index in group A (21.02±3.16 days/cm) was significantly lower than that in group B (76.19±8.32 days/cm; $P<0.05$). Consolidation index was significantly lower (more rapid healing) in group A (43.38±5.35 days/cm) than that in group B (76.19±8.32-days/cm; $P<0.05$). There was a significant difference in pin-tract problems and axial deviation between the two groups.
Conclusion The novel method combined longitudinal S-corticotomy and LATN technique safely reduces the consolidation time, rate of pin-tract problems and axial deviation during leg lengthening, compared with the classic Ilizarov method.

Keywords S-corticotomy and lengthening and then nailing · Ilizarov · Pin-tract problems · Axial deviation · Leg lengthening · Tibial osteotomy

Introduction

In the 1950s, Professor Gavril Abramovich Ilizarov described distraction osteogenesis, a technique based on the biology of bone regeneration. Nowadays the technique has been widely used for limb lengthening, deformity correction and reconstruction of nonunions and bone defects [1–4]. The widely used procedure began with a transverse osteotomy, followed by lengthening over an external fixator (the classic Ilizarov method) or a nail. The classic method confers several disadvantages such as prolonged time in a frame and high risk of fracture of the new bone after frame removal [5–7]. During the latter procedure, an intramedullary nail was inserted concomitantly with the external fixator [8, 9]. At the end of the distraction phase, the nail was locked by inserting two distal screws and the external fixator was removed. Lengthening over a nail confers many advantages, such as reduced consolidation phase and frame time. However, serious complications such as deep pin-tract infection, breakage of nails and locking screws have been reported [8, 9]. Therefore, it is a demanding challenge for doctors to acquire more rapid consolidation following distraction osteogenesis without increased complications.

Xia Lan and Lihai Zhang are both co-first authors.

X. Lan · L. Zhang · P. Tang (✉) · B. Yuan · W. Xu
Department of Orthopaedics, Chinese People's Liberation Army General Hospital, 28 Fuxing Road, Haidian District, Beijing 100853, China
e-mail: pftang301@126.com

X. Lan
e-mail: lanxjxh@126.com

G. Li
Department of Orthopaedics and Traumatology, The Chinese University of Hong Kong, Clinical Science Building, Prince of Wales Hospital, Shatin, 999077 Hong Kong, SAR, People's Republic of China

H. Xia (✉) · A. Peng · Y. Han
Beijing Institute of External Skeletal Fixation Technology, 169 Fengtai East Road, Fengtai District, Beijing 100071, China
e-mail: info@leg-lengthening.com

Al-Saati et al. [10] described the clinical application of a longitudinal corticotomy (S-Z osteotomy) and lengthening over an external fixator. The study showed that the healing index was significantly lower in the S-Z group than in the transverse corticotomy group. Rozbruc et al. [11] described a lengthening and then nailing (LATN) technique. The procedure began with a transverse osteotomy using a multiple-drill-hole technique. External fixation is used for lengthening during the distraction phase. Once length has been achieved, a reamed locked intramedullary nail is inserted across the regenerate bone and the frame is removed. The intramedullary nail supports the bone during the consolidation phase allowing removal of the external fixator after the distraction phase of lengthening. The study showed that LATN confers advantages over the classic method including shorter times needed in external fixation, quicker bone healing, and protection against refracture. However, no study has reported the combination of the longitudinal corticotomy and LATN technique.

In 2008, we developed a novel method which combines longitudinal S-osteotomy and the LATN technique for leg lengthening. In this retrospective study, we describe our clinical experience and make a case-match comparison between the novel method and the classic Ilizarov method.

Materials and methods

This retrospective study was performed from March 2008 to April 2012. A total of 176 leg lengthenings (88 consecutive patients) were performed at our institution. All cases were taken from our IRB-approved limb lengthening database. All patients were skeletally mature at the time of the procedure. There was an absence of active or history of infection or trauma at the site of lengthening and area of subsequent nailing. Patients with severe bone deformity that require gradual deformity were excluded. The indication for surgery in all patients was constitutional short stature. An Ilizarov external fixator (Beijing Institute of External Skeletal Fixation Technology, China) was used in both groups, and an intramedullary nail (Beijing Institute of External Skeletal Fixation Technology, China) was used in group A. The mean duration of follow-up was 2.2 years (range, one to four years).

Patients were grouped according to different procedures. There were 39 patients in group A; 78 tibial lengthenings were performed via longitudinal S-osteotomy and LATN technique. There were 49 patients in group B; 98 tibial lengthenings were performed with the classic method. Preoperative demographics and tibial lengthenings of the two groups were similar (Table 1).

Surgical technique

All operations were performed by the same senior surgeon. Under general anaesthesia, the patient was placed in the supine position. A tourniquet was used. In both groups, the tibial and fibula osteotomy was performed using a multiple-drill-hole technique. The fibula osteotomy was performed at the distal one third junction of the fibula. In group A, the S-shape of osteotomy can be divided into four parts (Fig. 1): (1) the medial part close to the metaphysis in the proximal, (2) the longitudinal part in the proximal, (3) the longitudinal part in the distal, and (4) the lateral part in the distal. Through a small incision (0.8–1cm) at the proximal end of the desired osteotomy site, osteotomy of the medial and the longitudinal parts in the proximal were performed. Then, through the other separate incision (0.8–1 cm) in the distal, osteotomy of the longitudinal and lateral parts in the distal were carried out. The longitudinal length of the osteotomy was approximately 2 cm more than the desired length. In group B, the transverse corticotomy was performed at the proximal meta-diaphyseal junction of tibia.

The tourniquet was deflated during the following surgery. The Ilizarov frame was composed of three full rings, two 3/4 rings and one half ring. Both the proximal and distal rings were stabilized with a 2.5-mm tensioned transverse wire and 2.5-mm tibia-fibula wire. Both the proximal 3/4 ring and middle ring were stabilized with a 4-mm half-pin. The half ring was stabilized with a 2.5-mm tensioned transverse wire and two 2.5-mm half-pins (one in the medial and the other in the lateral) in the calcaneus. The pins were placed peripherally within the proximal tibia to allow future insertion of a nail without any contact with each other [11, 12].

Three to five weeks after the distraction phase ended, an intramedullary nail with full-length was inserted across the regenerate bone, and then the apparatus was removed. The

Table 1 Patients' preoperative characteristics

Characteristic	Group A (novel procedure)	Group B (classical Ilizarov method)	Significance(*P*)
Number of cases (tibiae)	39 (78)	49 (98)	
Mean patient age in years (range)	26.82±6.69 (18–46)	25.71±5.34 (18–45)	0.40>0.05
Gender	28 male, 11 female	32 male, 17 female	0.52>0.05
Mean preoperative height in cm (range)	152.6±4.3 (145–158)	151.0±4.23 (145–159)	0.07>0.05

A *p*-value of≤0.05 was taken to indicate statistical significance

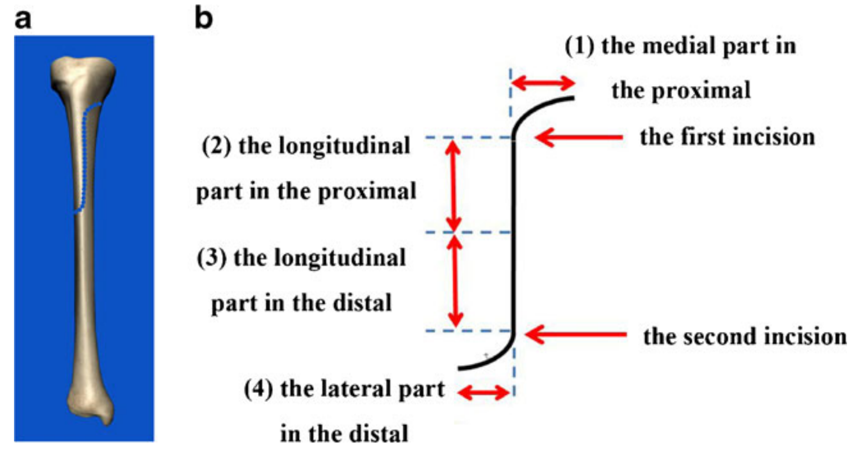

Fig. 1 **a** Anterior view demonstrates the longitudinal S-osteotomy. **b** Four parts of the longitudinal S-osteotomy. Through the first incision, osteotomy of the medial and the longitudinal parts in the proximal were performed. Then, through the second incision in the distal portion, osteotomy of the longitudinal and lateral parts in the distal were carried out

medullary canal was enlarged to 2 mm larger than the nail's diameter. This allowed easy insertion of the nail without force and avoided bending moments that could interfere with the new bone. The nail was locked using three screws in the proximal end with the aid of a jig and two in the distal end. To prevent tibial displacement or shortening, it was important to insert the nail and the locking screws before apparatus removal [11, 12] (typical bilateral leg lengthening combined S-osteotomy and LATN technique shown in Fig. 2).

Postoperative protocol

The surgical wounds were covered with a dry sterile. The pin sites were cleaned with sterile saline and alcohol daily.

Prophylactic intravenous antibiotic was administered for 48 hours after surgery. Distraction was carried out seven to ten days postoperatively at 1.0 mm/day. One week later, distraction was continued at 0.67 mm/day. The rate of lengthening was adjusted according to the radiographs made

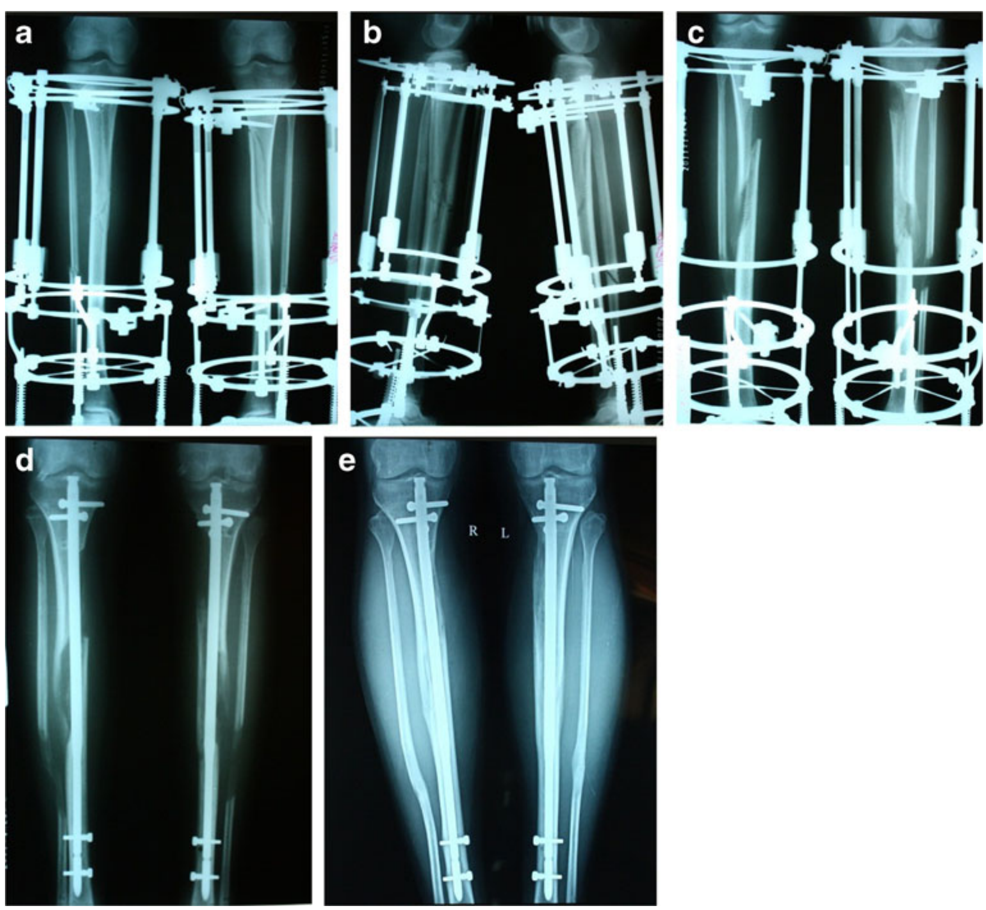

Fig. 2 **a** The anterioposterior (AP) radiograph ten days after osteotomy showing the external fixation had been applied. **b** The lateral radiograph ten days after osteotomy showing the external fixation had been applied. **c** AP radiograph taken ten weeks after operation, 4 cm of lengthening has been achieved. **d** Eighteen weeks after operation, 8 cm of lengthening has been achieved. AP radiograph taken three weeks later, the nail had been applied and the apparatus had been removed. **e** Five months after apparatus removal, there was complete consolidation

Table 2 Clinical results

Results	Group A	Group B	Significance (*P*)	95 % confidence interval
Final gain in length	8.49±1.71 (6–13)	9.25±2.22 (5–13.3)	0.07	−1.59～0.08
Mean surgical time (min)	130.05±6.60 (120–140)	91.4±6.61 (80–100)	0.00	35.8–41.4
External fixation index (EFI, days/cm)	21.02±3.16 (16–25.3)	76.19±8.32 (65–95.6)	0.00	−57.7～−52.6
Consolidation index (CI, days/cm)	43.38±5.35 (35–55.43)	76.19±8.32 (65–95.6)	0.00	135.7～−29.9

Values for groups A and B are given as mean ± standard deviation with range in parentheses. A *p*-value of≤0.05 was taken to indicate statistical significance

every two weeks. Radiographs were made monthly throughout the consolidation phase and at least every three to six-months after consolidation had been completed. The patients were allowed full weight-bearing after operation and walking less than ten steps at a time for a maximum of 50 steps per day in both groups. In group A, after frame removal, partial weight-bearing with a brace and two crutches were allowed. Full weight-bearing with a brace was allowed when there were two intact cortices seen on radiographs. Full weight bearing without brace was allowed when there were at least three intact cortices on the anteroposterior and lateral radiographs. In group B, the fixators were removed when complete radiographic consolidation was confirmed.

Outcome measures

The final gain in length, mean surgical time for bilateral tibial osteotomy, and the appropriate indices (the external fixation index and the radiographic consolidation index) were calculated and compared. The external fixation index was defined as the time in external fixation in days divided by the length gained in centimetres. Consolidation was considered to be complete when anteroposterior and lateral radiographs confirmed at least three of four cortices were intact [13]. The consolidation were measured by two of the authors. If they had different opinions, another senior doctor was invited to make a decision. The radiographic consolidation index was defined as the time until bony union in days divided by the amount of lengthening in centimetres. The complications encountered during operation and follow-up were documented according to the Paley's classification. Complications were differentiated as problems, obstacles, and true complications [14].

Statistical analysis

Descriptive statistics were obtained on all variables. Data are given as means and range. The independent Student's t-test was used to analyse the differences with regard to mean preoperative height, final gain in length, mean surgical time for bilateral osteotomy, external fixation index and consolidation index age, and Pearson's χ^2 test was used to assess the differences in the number of complications and sex. A *P* value of <0.05 was regarded as significant.

Results

There was no significant difference in the final gain in length between the two groups. Mean surgical time in group A was significantly longer than that in group B ($P<0.05$). External fixation index in group A was significantly lower than that in group B ($P<0.05$). Consolidation index was significantly lower (more rapid healing) in group A ($P<0.05$) (Table 2).

The rate of pin-tract problems was 2.56 % in group A and 11.22 % in group B. Grade 1 pin-tract problems were treated with local antiseptic or antibiotic. Grade 2 soft-tissue infection was treated with removal, curettage, and administration of one week of intravenous antibiotics. No axial deviation was observed in group A and eight problems were observed in group B. There were significant differences in pin-tract problems and axial deviation between the two groups (Table 3).

Six problems of ankle flexion contractures were observed in group A and eight in group B during the distraction period, and were gradually corrected by splint and physiotherapy. Full range of movement was regained. These problems were noted early and were treated with adjusting the fixator. Six limbs had

Table 3 Complications encountered during operation and follow-up in both groups

Complication	Group A (78 tibiae)	Group B (98 tibiae)	Significance (*P*)
Pin-tract problems			
Grade 1 (soft-tissue inflammation)	2	9	
Grade 2 (soft-tissue infection)	0	2	
Total	2	11	0.03<0.05
Ankle contracture problems	6	8	0.9>0.05
Axial deviation problems	0	8	0.02<0.05
Delayed consolidation			
True complication	0	6	0.07>0.05

A *p*-value of≤0.05 was taken to indicate statistical significance obstacles of delayed consolidation and required auto-iliac bone graft in group B. No fracture occurred after nail removal in group A and apparatus removal in group B. There were no significant differences in ankle contracture and delayed consolidation between the two groups (Table 3).

There were no neurologic and vascular injuries, joint luxation and stiffness in either group.

Discussion

The lengthening procedure began with osteotomy, followed by two distinct stages of treatment: distraction and consolidation. One disadvantage of distraction osteogenesis is the need to wait for a long consolidation phase which is approximately four times as long as the distraction phase in adults [12]. Patients often tolerate the consolidation period poorly. The most significant finding of our study was that the longitudinal S-osteotomy combined with LATN technique (group A) is more favourable for bone regeneration than the classic method (group B), and no delayed consolidation occurred in group A. The results showed significantly lower consolidation index in group A. According to our opinion, there are three major reasons for the more rapid healing in group A.

First, we believe one of the reasons is the larger surface area of cortical contact between the two bone segments at the site of longitudinal S-osteotomy. Furthermore, the larger the surface area of contact at the site of bone interruption, the better the stability. These factors effectively decrease the amount of new bone formation required to reestablish stability in the tibia. Haas [15] and Nicholson [16] both cited the major advantage of a longitudinal corticotomy over a transverse osteotomy in providing increased cortical contract for both postoperative stability and increased healing rates. These same benefits can be extended to distraction osteogenesis as described above.

Second, the stability in distraction osteogenesis was very important [2]. We speculate that the reason for the increasing healing rates in group A was that the application of full-length and large-diameter nail could provide good stability for the newly-formed bone after apparatus removal. Furthermore, the longitudinal length of S-osteotomy was 2 cm more than the tibial lengthening, so there was overlap between the distal and proximal bone segments at the end of distraction. Moreover, the risk for axial deviation or refracture of the regenerated bone due to the lack of internal stabilization after apparatus removal could be decreased. O'Carrigan et al. [5] reported an 8 % fracture rate after frame removal in a review of 650 patients with 986 lengthening segments. In our study, no fracture and no axial deviation were observed in group A.

Third, the reaming nail may confer a certain degree of jeopardization to the intramedullary circulation. However, many studies have showed that the periosteal blood flow returned to normal and even supernormal levels in a few days after reaming [17]. The increased blood flow stimulates periosteal new bone formation [17]. The products of reaming, which contain osteoblasts and multipotent stem cells, also serve as local bone graft that stimulates medullary healing [18]. The nail applied in group A may effectively improve bone regeneration and consolidation.

Deep infection is a major concern of combined intramedullary nailing and external fixation [12]. In our study, the rate of pin-tract problems was 2.56 % and no deep infection occurred in group A. Pin sites may become colonized with bacteria. The significantly reduced duration required for external fixation may contribute to the lower rate of pin-tract problems in group A. In lengthening over a nail, the pin tract infection may spread over the nail and become a deep infection. Brewster et al. reported a 1.4 % rate of pin tract infection and a 5.5 % rate of deep infection in the group lengthening over a nail in a literature review [19]. Rates of infection have ranged between 1.7 % and 21 % and bony union rates were high when an intramedullary nail is inserted after initial use of external fixation for high-energy and open tibial fractures [20–22]. However, all the tibiae in our study were healthy and well-vascularized. Moreover, if there were superficial pin-tract problems, the insertion of intramedullary nail can be delayed until the pin tract infection is controlled in the LATN technique. To prevent this complication in our cases, all pins and wires were inserted without their coming into contact with the intramedullary nail [11].

In our study, the mean surgical time for bilateral tibial osteotomy in group A was significantly longer than that in group B ($P<0.05$). According to our opinion, the reason may be that S-osteotomy was more complicated than the transverse osteotomy. Therefore, the doctors need to grasp more operating techniques for the novel procedure.

In conclusion, this novel method which combined the longitudinal S-corticotomy and LATN technique safely reduces the consolidation time, rate of pin-tract problems and axial deviation during leg lengthening, compared with the classic Ilizarov method.

References

1. Ilizarov GA (1992) Tranosseous osteosynthesis, 1st edn. Springer, Berlin
2. Ilizarov GA (1990) Clinical application of the tension-stress effect for limb lengthening. Clin Orthop Relat Res 250:8–26
3. Nho SJ, Helfet DL, Rozbruch SR (2006) Temporary intentional leg shortening and deformation to facilitate wound closure using the Ilizarov/Taylor spatial frame. J Orthop Trauma 20:419–424
4. Rozbruch SR, Weitzman AM, Watson JT, Freudigman P, Katz HV, Ilizarov S (2006) Simultaneous treatment of tibial bone and soft-tissue defects with the Ilizarov method. J Orthop Trauma 20:197–205
5. O'Carrigan T, Paley D, Herzenberg JE (2007) Obstacles in limb lengthening: Fractures. In: Rozbruch SR, Ilizarov S (eds) Limb

lengthening and reconstruction surgery. Informa Healthcare, New York, pp 675–679

6. Simpson AH, Kenwright J (2000) Fracture after distraction osteogenesis. J Bone Joint Surg Br 82:659–665
7. Danziger MB, Kumar A, DeWeese J (1995) Fractures after femoral lengthening using the Ilizarov method. J Pediatr Orthop 15:220–223
8. Watanabe K, Tsuchiya H, Sakurakichi K, Yamamoto N, Kabata T, Tomita K (2005) Tibial lengthening over an intramedullary nail. J Orthop Sci 10:480–485
9. Kristiansen LP, Steen H (1999) Lengthening of the tibia over an intramedullary nail, using the Ilizarov external fixator. Major complications and slow consolidation in 9 lengthenings. Acta Orthop Scan 70(3):271–274
10. Al-Saati MF, Magnussen RA, Lustig S, Testa R, Al-Saati G, Al-Saati F (2012) Distraction osteogenesis using a longitudinal corticotomy. Int Orthop 36(5):1073–1077
11. Rozbruch SR, Kleinman D, Fragomen AT, Ilizarov S (2008) Limb lengthening and then insertion of an intramedullary nail: a case-matched comparison. Clin Orthop Relat Res 466(12):2923–2932
12. Paley D, Herzenberg J, Paremain G, Bhave A (1997) Femoral lengthening over an intramedullary nail. A matched-case comparison with Ilizarov femoral lengthening. J Bone Jt Surg Am 79:1464–1480
13. Zhao L, Fan Q, Venkatesh KP, Park MS, Song HR (2009) Objective guidelines for removing an external fixator after tibial lengthening using pixel value ratio: a pilot study. Clin Orthop Relat Res 467(12):3321–3326
14. Paley D (1990) Problems, obstacles, and complications of limb lengthening by the Ilizarov technique. Clin Orthop Relat Res 250:81–104
15. Haas SL (1929) Longitudinal osteotomy. J Am Med Assoc 92:1656–1658
16. Nicholson OR (1957) Longitudinal osteotomy of the tibia (the “Reed” osteotomy). J Bone Joint Surg Br 39-B:738–741
17. Danckwardt-Lilliestrom G (1969) Reaming of the medullary cavity and its effect on diaphyseal bone. A fluorochromic, microangiographic and histologic study on the rabbit tibia and dog femur. Acta Orthop Scand Suppl 128:1–153
18. Brinker MR, O’Connor DP (2007) Exchange nailing of ununited fractures. J Bone Joint Surg Am 89:177–188
19. Brewster MBS, Mauffrey C, Lewis AC, Hull P (2010) Lower limb lengthening: is there a difference in the lengthening index and infection rates of lengthening with external fixators, external fixators with intramedullary nails or intramedullary nailing alone? A systematic review of the literature. Eur J Orthop Surg Traumatol 20:103–108
20. Maurer DJ, Merkow RL, Gustilo RB (1989) Infection after intramedullary nailing of severe open tibial fractures initially treated with external fixation. J Bone Joint Surg Am 71:835–838
21. Nowotarski PJ, Turen CH, Brumback RJ, Scarboro JM (2000) Conversion of external fixation to intramedullary nailing for fractures of the shaft of the femur in multiply injured patients. J Bone Joint Surg Am 82:781–788
22. Siebenrock KA, Schillig B, Jakob RP (1993) Treatment of complex tibial shaft fractures. Arguments for early secondary intramedullary nailing. Clin Orthop Relat Res 290:269–274