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ORIGINAL STUDY

Results of cosmetic lower limb lengthening by the lengthening over nail technique

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We conducted a retrospective study by reviewing our results following cosmetic lengthening using the lengthening over nail technique in terms of the importance of the patient selection process, bone and soft tissue complications, and functional and subjective clinical outcomes. The study data were obtained from medical records and radiographs. A total of 32 patients, 24 males and 8 females, with constitutional short stature underwent the lengthening over nail technique for cosmetic purposes between 2000 and 2013. Lengthening was performed in the femora of 15 patients and in the tibiae of 17 patients. All patients who were accepted for cosmetic lengthening underwent a careful selection process that included a psychiatric evaluation. The mean follow-up time was 73 months (range, 12 to 163 months). Thirty-four complications were reported. Cosmetic lengthening is not without complications. Patient selection is of paramount importance. This technique is recommended for cosmetic lengthening because it is minimally-invasive and it has documented reproducible results.

Keywords : Limb lengthening; cosmetic lengthening

INTRODUCTION

People with short stature might feel dissatisfaction and relate low working performance to their height. Limb lengthening procedures have evolved over time. The procedure began with the Codivilla technique, continued with the Ilizarov external fixation technique, and then evolved into the highly improvised lengthening over nail (LON) technique described by Paley et al. (*4,10*). Currently, a self-distracting intramedullary nail can be used without the need for an external fixator (*15*). In this study, we used the LON technique to treat individuals with short stature who wanted to be taller. We compared our results with the existing literature and discussed the associated risks and benefits.

PATIENTS AND METHODS

A retrospective study was conducted by reviewing data from medical records and radiographs of 32 patients who underwent cosmetic lengthening between 2000 and 2013 using the LON technique bilaterally in their femora (*15*) or tibiae (*17*). The patients included 24 males and 8 females. All patients were physically normal but unsatisfied with their height. The mean age during the procedure was 30 years (range, 16 to 62 years). The average preoperative height was 159 cm (range, 137 to 171 cm).

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All patients underwent a psychiatric evaluation (SCL-90R test) prior to surgery (patients with a Global symptom index (GSI) above 1.02 were rejected) (*3*).

During the initial visit, all patients were asked whether they had a history of any chronic illness that might cause short stature. Heavy smokers, young people with open physes, and patients with metabolic diseases (including diabetes mellitus) were not accepted for cosmetic lengthening. Long x-rays of the lower extremities on both planes were obtained, and a physical examination was performed. If the patient was deemed suitable for cosmetic lengthening, detailed information was provided regarding the surgical procedure with its risks and possible complications. Then, the patient was advised to consider the procedure until the next office visit, when at least one accompanying member of the immediate family was required to be present.

This decision is based on the following three criteria: first, the ratio of the femur to the tibia (*14*); second, the quality of the soft tissue envelope at the corresponding segment (previous scars, atrophic soft tissue); and third, the wishes of the patient. When needed, simulations of lengthening using photo manipulation at one of the tibial segments and at one at the femoral segments were used to help the patient make the decision (Figures 1 and 2). The procedure, its risks and possible complications were explained again in detail to the candidate. The candidate was advised to consider the procedure further until the last preoperative office visit, when consent was obtained from the psychiatry department before scheduling the procedure.

The following evaluation criteria were used: the bone healing index (BHI), which represents the duration of consolidation in days per cm length gained; the external fixation index (EFI), which represents the duration of external fixation in days per cm length gained; and the post-operative lengthening.

The complications are listed in Table I. The outcome was assessed using specific questionnaires related to the procedure, which we modified from SF-36 (Appendix: Table II). The best score is 100, and the worst score is 0.

Fig. 1. — Figure 1 depicts photographic manipulation showing femoral lengthening.

Surgical technique

Femoral LON

The patients were placed supine on a radiolucent table and examined with fluoroscopy from the hip to the ankle in both planes before sterile preparation. An osteotomy was performed with a multiple-drill-hole technique in the femur for lengthening. The

Fig. 2. — Figure 2 depicts photographic manipulation showing tibial lengthening.

level of the lengthening osteotomy and the length of the intramedullary nail were selected to ensure that at least 8 cm of the nail would lie beyond the distraction gap following the lengthening.

An intramedullary guide wire was then percutaneously inserted through the piriformis fossa for antegrade insertion or through the intercondylar notch for retrograde insertion. The medullary canal was over-reamed to a size 1.5 mm larger than the diameter of the intramedullary nail to be used to allow sliding of the nail for lengthening. The nail was then inserted slowly. Interlocking screws were inserted proximally (the antegrade technique) or distally (retrograde technique), whereas the interlocking screws at the other end of the nail were not placed until the lengthening was completed. Two Schanz screws were placed perpendicular to the anatomic axis of each segment proximally and distally, with care taken to remain distant from the intramedullary nail to be inserted. An image intensifier was used to check all of the Schanz screws to ensure that they were not in contact with the intramedullary nail, and distraction testing was performed with the external fixator to confirm that distraction was occurring at the osteotomy level (Figures 3 and 4). An epidural catheter was inserted for postoperative analgesia.

Tibial LON

The patients were placed supine on a radiolucent table and evaluated from the hip to the ankle with a C- arm image intensifier in the frontal and sagittal planes prior to sterile preparation. The fibula was osteotomized at the mid-diaphyseal level through a small incision. Multiple drill holes were made at the tibial osteotomy site, which acted as internal grafting and venting (decompression) of the medullary canal. Then, the medullary canal was over-reamed at least 1.5 mm larger than the diameter of the nail to be used. The tibial osteotomy was completed at this point with an osteotome. Then, the intramedullary nail was inserted and locked proximally. To prevent lateral deviation of the proximal segment, interference screws were inserted to narrow the medullary canal if necessary. A circular external fixator consisting of three rings was applied while taking care to maintain the proper rotational alignment. The middle ring added stability; however, it was not used for fixation. To prevent dislocation of the tibio-fibular joints during lengthening, a Schanz screw was applied proximally to secure the fibula to the tibia (from the anteromedial end towards the fibular head posterolaterally) with purchase only on

Table I. — Complications

Complications	Number of occurrences	Residual deficits	Additional surgical intervention
Soft tissue-related			
Pin tract infection needing intervention	21	None	None
Scar tissue	2	None	Scar revision
Distal locking screw irritation	7	None	Screw removal
Drop foot due to compartment syndrome	1	Returned only partially	Tendon transfer
Bone-related			
Deformity of regenerate while on fixator	2	None	Deformity correction during fixator removal
Technical issues			
External fixator system not working properly	1	None	Schanz screw revision

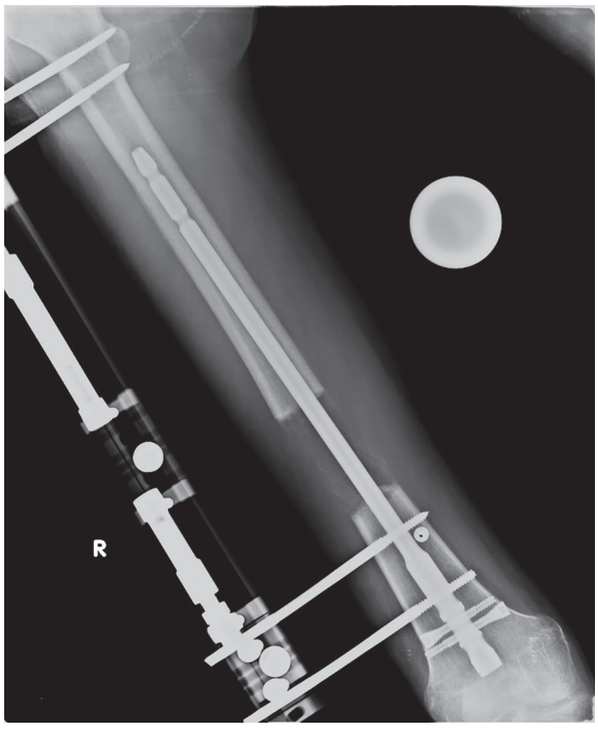

Fig. 3. — An x-ray of a patient during the lengthening period is shown. Lengthening over a retrograde intramedullary nail technique has been used (right femur). Note that a unilateral fixator is used for distraction of the femur

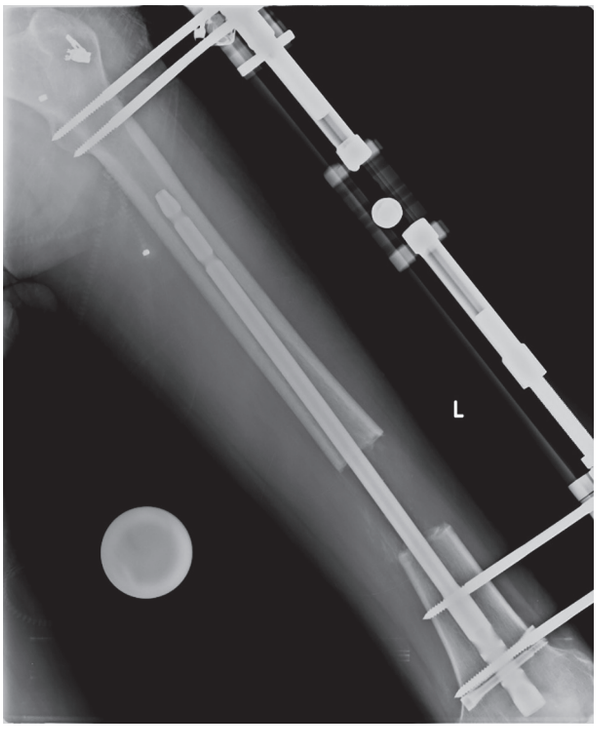

Fig. 4. — The contralateral x-ray of the same patient during the lengthening period (left femur).

Table II.— Appendix : Questionnaire modified from the SF-36

1. In general, would you say your health is ;

Excellent	1
Very good	2
Good	3
Fair	4
Poor	5

2. Compared to one year ago, how would you rate your general health now?

Much better now than one year ago	1
Somewhat better now than one year ago	2
About the same as one year ago	3
Somewhat worse now than one year ago	4
Much worse now than one year ago	5

3. The following items are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?

Activities	Yes, limited a lot	Yes, limited a little	No, not limited at all
Vigorous activities, such as running, lifting heavy objects, or participating in strenuous sports.	1	2	3
Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	1	2	3
Lifting or carrying groceries	1	2	3
Climbing several flights of stairs	1	2	3
Climbing one flight of stairs	1	2	3
Bending, kneeling, or stooping	1	2	3
Walking more than a mile	1	2	3
Walking several blocks	1	2	3
Walking one block	1	2	3
Bathing or dressing yourself	1	2	3

4. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?

	YES	NO
Reduction in the amount of time you spent on work or other activities	1	2
Accomplished less than you would like	1	2
Were limited in the type of work or other activities	1	2
Had difficulty performing work or other activities (for example, they required extra effort)	1	2

5. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?

	YES	NO
Reduction in the amount of time you spent on work or other activities	1	2
Accomplished less than you would like	1	2
Did not perform work or other activities as carefully as usual	1	2

6. During the past 4 weeks did emotional problems interfere with your normal social activities with family, friends, neighbors, or groups?

None	1
Very Mildly	2
Moderately	3
Severely	4
Very severely	5

7. How much body pain have you experienced during the past 4 weeks?

None	1
Very Mild	2
Moderate	3
Severe	4
Very severe	5

8. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?

Not at all	1
A little bit	2
Quite a bit	3
Moderately	4
Extremely	5

9. These questions are about our emotional state during the last 4 weeks. For each question, please give the answer that best represents how you have been feeling.

	All of the time	Most of the time	A good bit of the time	Some of the time	A little bit of the time	None of the time
Did you feel enthusiastic?	1	2	3	4	5	6
Have you been very nervous?	1	2	3	4	5	6
Have you felt so depressed that nothing could cheer you up?	1	2	3	4	5	6
Have you felt calm and peaceful?	1	2	3	4	5	6
Did you have a lot of energy?	1	2	3	4	5	6
Have you felt depressed?	1	2	3	4	5	6
Did you feel fatigued?	1	2	3	4	5	6
Have you been happy?	1	2	3	4	5	6
Did you feel tired?	1	2	3	4	5	6

10. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (such as visiting with friends, relatives, etc.)?

All of the time	1
Most of the time	2
Some of the time	3
A little bit of the time	4
None of the time	5

11. How true or false is each of the following statements for you?

	Definitely true	Mostly true	Do not know	Mostly false	Definitely false
I seem to get sick a little easier than other people	1	2	3	4	5
I am as healthy as anybody I know	1	2	3	4	5
I expect my health to get worse	1	2	3	4	5
My health is excellent	1	2	3	4	5

12. In your opinion, how was your appearance before the operation?
- 1- Perfect
- 2- Very good
- 3- Good
- 4- Neither good nor bad
- 5- Bad

13. In your opinion, how was your appearance after the operation?
- 1- Perfect
- 2- Very good
- 3- Good
- 4- Neither good nor bad
- 5- Bad

14. Did you have pain in your hip, knee or ankle joint before the operation?
- 1- Very severe (was present at rest and painkillers did not help)
- 2- Severe (was present at rest but could be managed with painkillers)
- 3- Moderate (was present after motion and needed painkillers at times)
- 4- Mild (was present with excessive motion but relieved after rest)
- 5- There was no pain

15. Did you have restricted motion in your hip, knee, or ankle joint before the operation? If so, to what degree did it affect your daily activities?
- 1- Could not move at all
- 2- Severely restricted (could only move inside the house)
- 3- Moderately restricted (could do my daily activities but could not exercise)
- 4- Mildly restricted (could do light exercise such as walking, jogging, and swimming)
- 5- Was not restricted

16. Do you have pain in your hip, knee, or ankle joint after the operation?
- 1- Very severe (is present at rest and painkillers do not help)
- 2- Severe (is present at rest but can be managed with painkillers)
- 3- Moderate (is present after motion and requires painkillers at times)
- 4- Mild (is present with excessive motion but relieved after rest)
- 5- There is no pain

17. Do you have restricted motion in your hip, knee, or ankle joint after the operation? If so, to what degree does it affect your daily activities?
- 1- Cannot move at all
- 2- Severely restricted (can only move inside the house)
- 3- Moderately restricted (can do my daily activities but cannot exercise)
- 4- Mildly restricted (can do light exercise such as walking, jogging, and swimming)
- 5- 5-Not restricted

18. In your opinion, was your success in your current occupation or in other areas positively affected after the operation?
    1- Yes
    2- No

19. With your experience, would you undergo the same operation again, should the need arise?
    1- Yes
    2- No

the medial cortex to prevent discomfort and skin problems, and an olive Kirschner (K)-wire was applied distally using an image intensifier (Figures 5 and 6). The Schanz screws and K-wires were checked to ensure that they were not in contact with the intramedullary nail, and a distraction test was performed using the external fixator to check the distraction at the level of the osteotomy for lengthening.

On the day of the operation, isometric quadriceps and range of movement exercises for the knee were started. On the first post-operative day, weight bearing with two crutches was allowed. The patients gradually discarded their crutches or sticks during the first month after the procedure. Distraction was initiated seven days post-operatively at a rate of 0.25 mm, four times per day. During lengthening, radiographs were taken every two weeks to monitor the distraction progress, and the patient was assessed clinically. Intravenous patient-controlled analgesia was used for postoperative pain control.

Removal of the external fixator

At the end of the lengthening period, static locking of the intramedullary nail was performed, and the external fixator was removed during an outpatient procedure. The patients were allowed to ambulate with two crutches until three cortices were detected on the anteroposterior and lateral x-rays during a follow-up visit.

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RESULTS

In total, 301 candidates were rejected for cosmetic lengthening because they did not meet our compatibility criteria during the office visits, and 4 patients were rejected because they did not meet the criteria for the psychiatry consultation (32/337 were accepted, 9.5 %). The mean follow-up time was 73 months (range, 12 to 163 months). The average lengthening was 7.5 cm. The average height following the procedure was 166 cm. The mean external fixation time was 85.9 days (range, 24 to 137 days). The mean external fixation index was 11.2 days/cm (range, 6.3 to 15.4 days/cm). The mean bone healing index was 29.96 days/cm (range, 15 to 38.66 days/cm; 30.06 days/cm for the tibia and 29.83 days/cm for the femur, on average). The mean duration of the hospital stay was 5 days (range, 4 to 8 days).

Thirty-four complications were reported. A total of 21 patients encountered superficial pin track infections, which were treated successfully with oral antibiotics and pin site care. Two patients developed a valgus deformity in the tibial regeneration, which required deformity correction during external fixator removal (*1,5,6*). Two patients required scar revision surgeries. Distal locking screws caused soft tissue irritation in 7 patients, which was resolved by removing the locking screws. The external fixator system did not work properly in one patient, which was resolved by changing the Schanz screws in the operating theatre. Compartment syndrome developed in one patient with tibial lengthening, which was masked by epidural analgesia. This patient developed drop foot and eventually underwent a fasciotomy. Drop foot returned only partially. He underwent a tendon transfer 6 years later.

The intramedullary nails were removed in 6 patients at their request.

A total of 29 of the 32 patients returned the questionnaire. One patient denied having undergone

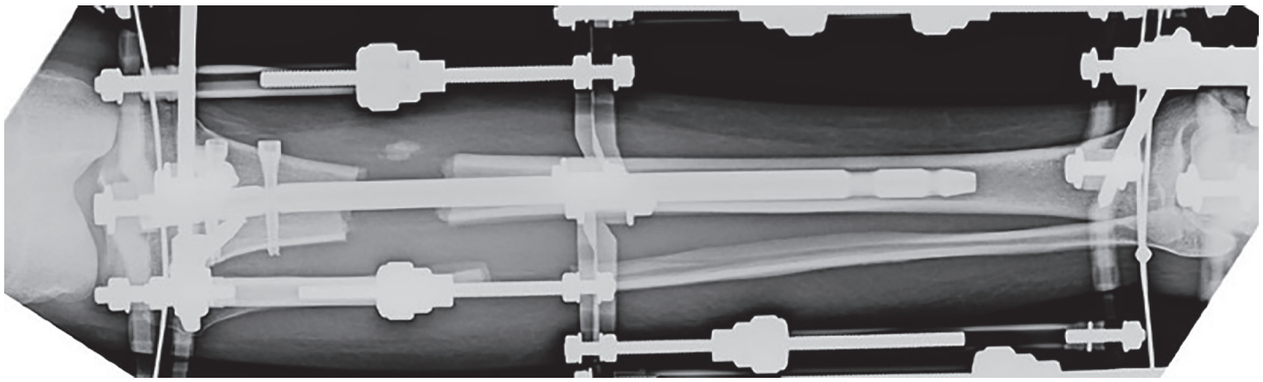

Fig. 5. — An x-ray of a patient during the lengthening period. Lengthening over an intramedullary nail technique has been used (right tibia). Note that a circular type external fixator is used for distraction of the tibia.

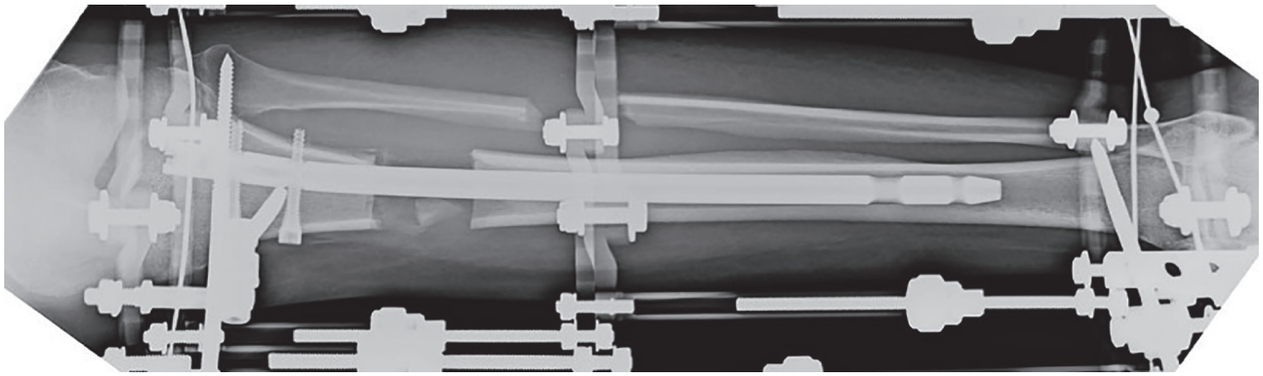

Fig. 6. — A contralateral x-ray of the same patient during the lengthening period is shown (left tibia).

the lengthening procedure. The scores are shown in Table III. X-rays taken preoperatively, during lengthening and at the latest follow-up are shown in Figures 7-10.

DISCUSSION

Bone lengthening has been performed for many decades for the reconstruction of various pathological conditions *(12)*. The development of new lengthening techniques, which are continuing to become less invasive, and the invention of internal lengthening devices have facilitated consideration of bone lengthening for cosmetic surgeries *(2,9,11)*.

The majority of the patients in our series were male. The likelihood of seeking cosmetic lengthening to reach the height of a partner appears to be much higher in males. One female patient in our series (patient no. 4), whose husband was a soccer goalkeeper, sought lengthening for this reason.

The selection process of the patients in our series was notably strict and careful, as outlined in the Patients and Methods section. The possible complications were explained in detail because we hypothesize that this knowledge is crucial for a healthy physician and patient relationship if a complication occurs, as is a preoperative psychiatric consultation. A history of dissatisfaction with multiple cosmetic procedures indicates body dysmorphic syndrome, and these patients would not be good candidates for such a complicated procedure *(13)*.

To select between the femur and the tibia as the lengthened segment, the ratio of the femur to the

tibia, the soft tissue quality over the corresponding segment and patient choice after seeing photos manipulated to simulate lengthening of either the femur or the tibia were considered as criteria. The BHI was slightly better in femoral lengthening cases than in tibial lengthening cases (29.83 versus 30.06 day/cm). We favored femoral lengthening when possible. Likewise, the ability to use a unilateral fixator during femoral lengthening versus the need to use a circular external fixator in tibial lengthening increased the preference for femoral lengthening.

We selected the LON technique, which has a shorter EFT compared to conventional external fixation lengthening techniques *(4,8,10)*. The LON technique minimizes the number of Schanz screws, which is important for the cosmetic results and for reducing limitation of the range of motion. Moreover, consistent low complication rates have been published for the LON technique *(1,6,7,8)*. Internal lengthening techniques would be preferable because they do not need an external fixator. However, the price of the implants used for this technique is 6 to 7 times higher than that of the implants used for the LON technique.

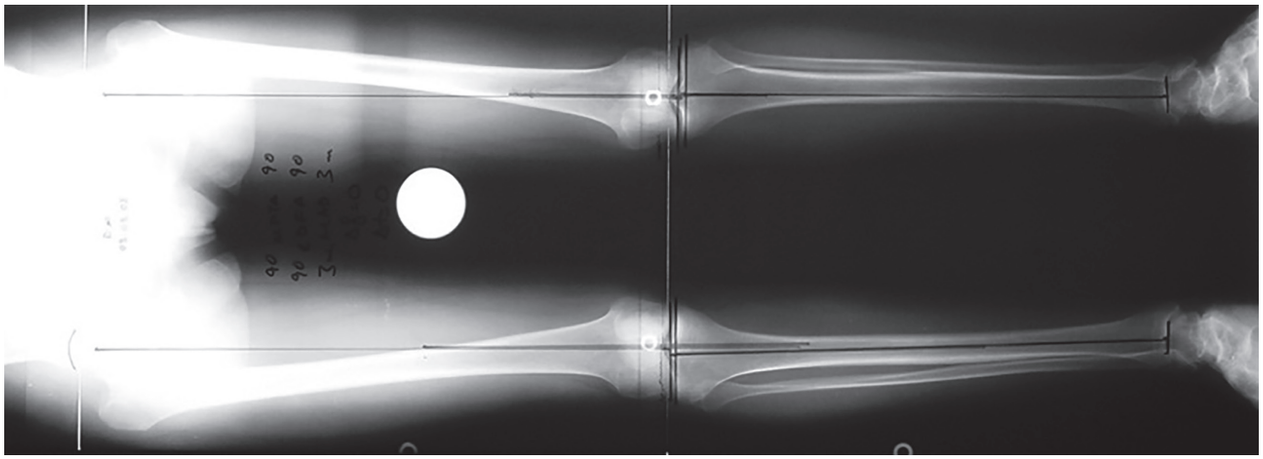

Fig. 7. — A preoperative standing orthoroentgenogram of a patient is shown.

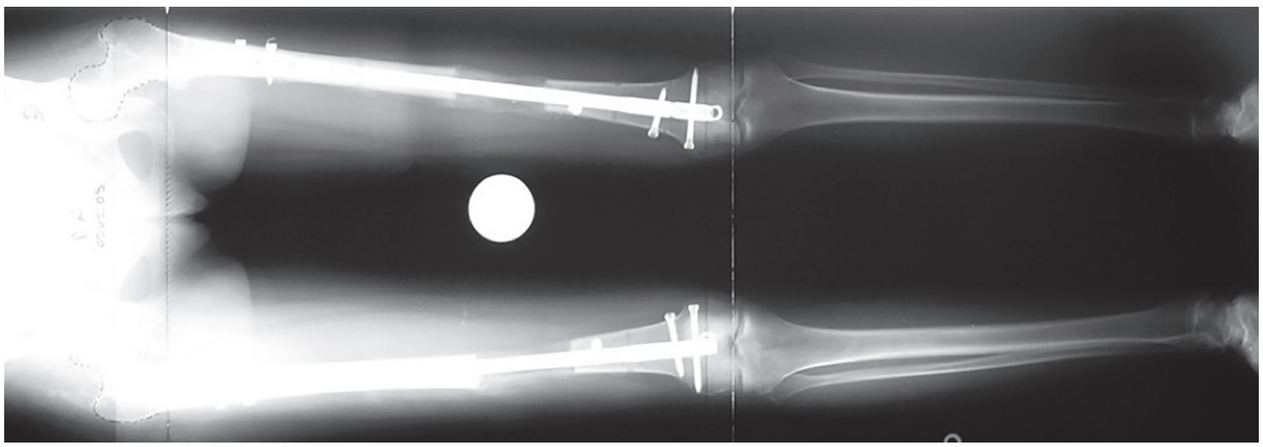

Fig. 8. — A standing orthoroentgenogram of the same patient is shown after lengthening both femora using the lengthening over nail technique.

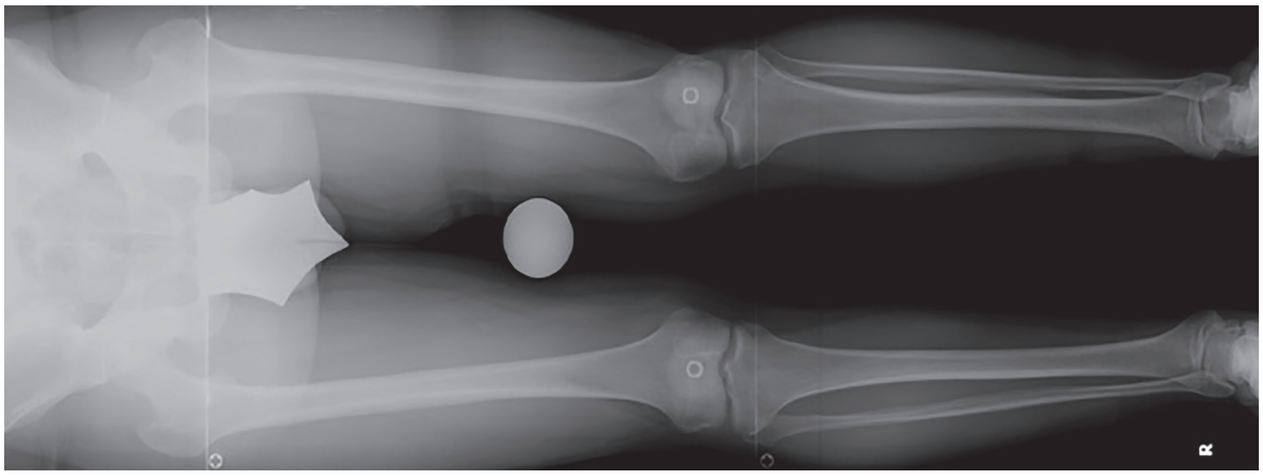

Fig. 9. — A preoperative standing orthoroentgenogram of the patient is shown.

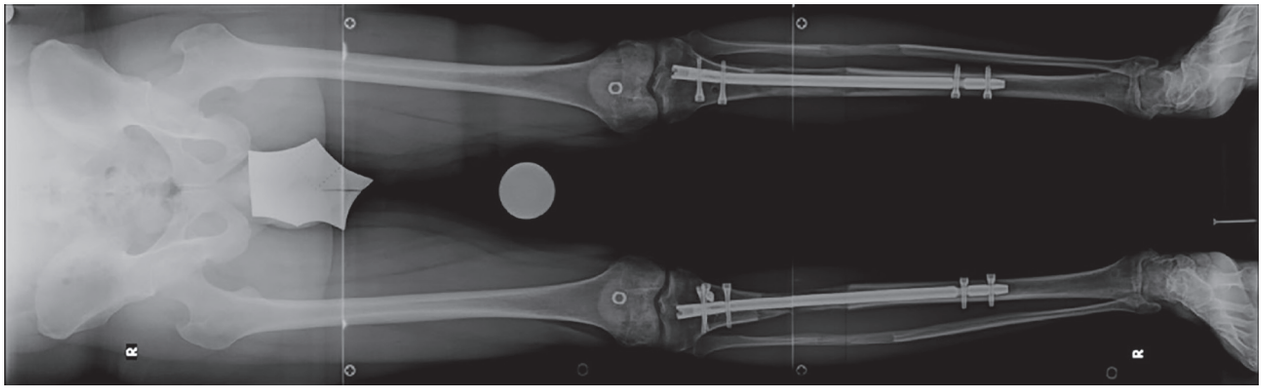

Fig. 10. — A standing orthoroentgenogram of the same patient is shown after lengthening both tibiae using the lengthening over nail technique.

Novikov et al. reported that optimal lengthening should be between 5 to 7 centimeters because more lengthening could cause a disproportionate ratio of the thigh to the leg *(9)*. Likewise, we do not recommend more than 8 cm of lengthening at the tibia or at the femur for cosmetic reasons. Additionally, increased lengthening has been associated with increased complication rates in LON procedures *(7)*.

Crossed contralateral lengthening of the femur and tibia has been reported *(9)*. We do not recommend crossed contralateral lengthening because some cosmetic lengthening patients tend to stop the treatment earlier than planned, which might leave the knees at different levels and create a significant cosmetic problem.

None of the treatment costs were covered by insurance, and the patients paid for their surgeries.

The 29 patients in our study reported on the questionnaire that they were very satisfied with their appearance and did not encounter any joint-related problems, such as pain or stiffness. In addition, the patients affirmed that this procedure affected their lives positively, and most of the patients stated that they would undergo this procedure again based on their experience. It is a weakness of our study that we administered this questionnaire only after the treatment. It would have been better to have also administered it prior to the treatment.

Despite our careful selection criteria, one patient in our series displayed poor cooperation (patient no. 23). He increased the recommended distraction

Table III. — Data obtained from the questionnaire

	Average score	Range (min-max)
Physical functioning	87.25	75-100
Role limitations due to physical health	77.45	0-100
Role limitations due to emotional problems	87.87	0-100
Energy/fatigue	59.00	12.5-85
Emotional well being	68.72	32-88
Social functioning	76.00	12.5-100
Pain	75.50	25-100
General health	76.26	60-95

rate and gained 4 cm in 16 days, which caused significant pain and a temporary unilateral drop foot. This patient did not comply with the recommended physical therapy. Therefore, we decided to stop the treatment because of a lack of compliance by the patient. Thus, we locked the IM nail and removed the external fixator.

Epidural analgesia might mask pain due to compartment syndrome and thus delay both diagnosis and treatment. When we encountered this complication, we discontinued epidural analgesia during tibial lengthening and recommended patient-controlled intravenous analgesia instead.

Cosmetic lengthening is not without complications. Patient selection is of paramount importance, as is a detailed preoperative discussion of the procedure and the possible complications. Surgeons should be aware of possible complications related to uncooperative patients. The LON technique is recommended for cosmetic lengthening because it is a minimally invasive technique that provides high patient comfort during lengthening and because it has documented reproducible results. We recommend that cosmetic LON be performed in selected centers because it requires a high level of experience in internal and external fixation techniques.

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