Safe Cosmetic Leg Lengthening for Short Stature: Long-term Outcomes

Yasser Elbatrawy, MD; Ibrahim Mohammed A. Ragab, PhD, PT

Abstract

It is well known that limb lengthening is performed to treat limb-length discrepancies resulting from congenital anomalies and developmental problems. However, few studies discuss lengthening for cosmetic purposes. The current authors conducted a prospective study with long-term follow-up. From July 2002 through June 2007, 133 patients requested that their height be increased. Fifty-two were approved to undergo limb-lengthening surgery. Two were lost to final follow-up, leaving 50 in the study group. For all patients, the Ilizarov ring external fixator was applied with a maximum-stability technique that achieved frame stability and allowed patients to ambulate with a walker from the first week postoperatively. The method requires close follow-up for early detection of problems. Physiotherapy improved ankle function and prevented plantar flexion deformity, which can occur during lengthening. Excellent final outcomes were achieved in all patients except one, who required additional surgery. The Ilizarov device is a safe tool for limb lengthening in individuals of short stature when applied with the authors’ maximum stability technique. To the authors’ knowledge, this is the first article on this topic to report long-term results (minimum 5-year follow-up for all patients). Many factors influence the outcome of lengthening surgery performed with Ilizarov devices: the material of the rings, the use of a hybrid technique combining pins and wires, the diameter and number of pins over each bone segment, the size of the rings around the limb, the surgical technique for pin insertion, and the use of hydroxyapatite-coated pins or regular stainless pins. [Orthopedics. 2015; 38(7):e552-e560.]
The Ilizarov ring external fixator, with various techniques of application, has been useful to treat limb-length discrepancies resulting from congenital anomalies and developmental problems. However, few studies discuss its use in lengthening for short stature. Improved application techniques, advancements in device technology, increased surgeon experience, and awareness of how to prevent and manage complications render the use of the Ilizarov frame possible for cosmetic reasons.

Many individuals of short stature want to gain a few inches in height. Current lifestyles, work requirements, competition to obtain a job, and ability to perform better at a variety of tasks increase the desire to be taller. Psychological disorders that can accompany being a person of short stature can manifest during childhood. However, patients with constitutional short stature or low normal stature are not treated until they have reached skeletal maturity. When assessing distribution of height in a given population, one must consider the normal bell curve. People are divided by distribution around the mean. Normal height is considered to be ±3 SDs from the mean. Stature below 3 SDs from the mean in a person without a medical condition (such as dwarfism or growth hormone deficiency) is considered constitutional short stature. The lower limit of what we refer to as normal stature is 166 cm (5 feet 5 inches) for White men and 153 cm (5 feet 0 inches) for White women (Table 1).

Using a maximum stability technique, the current authors applied the Ilizarov frame to an approved cohort of patients for limb lengthening for cosmetic purposes. This article describes their technique and presents the results and complications.

**Materials and Methods**

This study was approved by the authors’ institutional review board. From July 2002 through June 2007, 133 patients visited the clinic requesting that their height be increased. Smokers, patients with diabetes mellitus, patients with disease or hormonal deficiency, and patients who practiced competitive sports were not candidates. The remaining patients (n=104) were interviewed by a psychologist, and based on the psychologist’s recommendations, 52 patients (36 males and 16 females; mean age, 26 years [range, 17-46 years]) were accepted to undergo the procedure (Table 2). All patients were well informed about the procedure and possible complications and were invited to discuss the technique, results, and final psychological effect with previous patients who had undergone the operation. This was accomplished via Internet communication or telephone calls after permission was obtained from the previous patients. Overall mean preoperative height was 164 cm (range, 142.5-175 cm). One device (the Ilizarov ring external fixator) and one technique (the maximum stability technique) were used for all patients.

Each patient was clinically evaluated by an orthopedic surgeon (Y.E.). Height, relation of leg length to trunk length and arm span, and range of motion of all lower limb joints were assessed and documented. Any lower limb deformities and limb-length discrepancies were evaluated by clinical and radiological assessments for possible simultaneous treatment with lengthening. Eight patients had mild varus deformity of both legs preoperatively, and 2 had moderate varus deformity with mechanical axis deviation of 3 cm. Four of the 8 patients had some degree of internal rotational deformity. One patient had a limb-length discrepancy of 8 mm preoperatively (5 mm in the tibia and 3 mm in the femur). All associated deformities and discrepancies were managed simultaneously during lengthening (Figure 1).

Single-level lengthening was performed at the junction between the metaphyseal and diaphyseal areas of the proximal part of the tibia and the junction

<table>
<thead>
<tr>
<th>Percentile</th>
<th>SD</th>
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<th>Men</th>
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<td>+3</td>
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<tr>
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<td>+2</td>
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**Table 2**

<table>
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<tr>
<td>Female</td>
<td>16</td>
</tr>
<tr>
<td>Preoperative height, mean (range), cm</td>
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<td>Comorbidities, No.</td>
<td>Lower limb deformities</td>
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<td>Limb-length discrepancies</td>
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of the distal one-third and proximal two-thirds of the fibula in all patients except one, who underwent double-level lengthening (proximal and distal).

**Surgical Technique**

Forty patients received regional epidural anesthesia, and 12 received general anesthesia.

The frame consisted of 3 Ilizarov rings connected to each other by metal rods used for distraction. The tibia and fibula were fixed proximally and distally together. In all patients, the fibula was fixed proximally to the tibia by an oblique wire (3 mm in diameter) from the center of the head of the fibula going down distally obliquely to the diaphysis of the tibia, proximal to the level of osteotomy. This wire was not a transfixing wire; it was fixed only to the medial side of the frame by connecting it with different Ilizarov components and tools. It served as a hook to the fibula, preventing downward displacement.

The frame was connected to the tibia by 6-mm-diameter pins mounted at right angles to each other for maximum stability (Figure 2). All frames used in this study were US Food and Drug Administration–approved and/or CE-certified devices. All pins were hydroxyapatite coated.

One ring was proximal and 2 were distal to the osteotomy site. The proximal ring was fixed to the proximal metaphysis of the tibia by 1 transverse wire and 3 half-pins. The most proximal pin was anterolateral and the middle pin was anteromedial, creating a 90° angle to each other for maximum stability of the proximal ring. The position of the third distal pin in the proximal ring was anteroposterior to the tibia and 1 cm proximal to the osteotomy level.

The middle ring of the device was fixed to bone with 3 to 5 pins. The number of pins used depended on the weight of the patient. In heavier patients, more pins were added for better stability. Additional pins were applied at different angles to the bone to achieve maximum stability and weight-bearing tolerance. All pins that were used to fix the rings to the bone were 6 mm in diameter.

The distal ring was fixed to both the tibia and fibula by 3 wires at different angles, considering the surrounding soft tissue structure and according to the atlas.

**Figure 1:** Preoperative clinical photograph of a patient with a bilateral proximal tibial varus deformity (A). Postoperative clinical photograph of the same patient showing the lengthening and deformity correction devices applied (B). Postoperative anteroposterior (C) and lateral (D) radiographs. Postoperative clinical photograph showing the corrected deformity and 5.8 cm of lengthening achieved (E).
Two to 3 pins were also applied proximally and distally (2 sites of wire insertion and the cross-sectional anatomy). Two to 3 pins were also applied to increase stability of the frame distally. This technique was used in 45 of the 52 patients. In the remaining 7 patients, the fibula was fixed internally to the tibia distally with 7-mm–diameter oblique positioned cannulated screws (holding both fibular and both tibial bone cortices), without adding a wire distally as usually is done, to prevent the possibility of upward migration of the fibula during lengthening. This fixation is better tolerated by patients, but it requires further minor operative interference for removal.

Percutaneous Gigli saw corticotomy was applied in both tibiae proximally in all patients except one, in whom it was applied proximally and distally (2 sites of lengthening). Hospital stays ranged from 3 to 5 days (average, 4 days). All patients were instructed regarding pin care, to be done twice per week using regular povidone-iodine solution after properly cleaning around the pin’s entrance into the skin. All patients received instructions to notify the physician of any redness or pain around a pin (early signs of pin tract infection).

Ten days postoperatively, lengthening was started in all patients by manually turning the device nuts 3 times per day (every 8 hours) to achieve 0.75 mm of lengthening daily. After 3 weeks, and according to the surgeon’s evaluation of the newly formed bone, lengthening was increased to 1 mm per day.

Clinical follow-up included evaluation of pin sites, assessment of patient complaints, and examination of joints. Radiological follow-up every 3 to 4 weeks included evaluation of regenerate bone quality, measurement of tibial and fibular lengths, and assessment for signs of pin loosening. Radiography is mandatory during the lengthening phase to define the speed of lengthening and for early detection and correction of any mechanical problem. During this stage, all patients were allowed to walk with weight bearing using a walker or crutches. Physiotherapy during the lengthening stage was concentrated on the muscle strength of the whole lower limb, maintaining knee and ankle motion, preventing contracture, and maintaining proper function.

During the lengthening stage, patients were instructed to keep the ankle joint dorsiflexed during sleep by using an elastic band that connects the foot to the frame proximally (Figure 3). This helps to prevent early development of equinus contracture, which often is encountered with tibial lengthening, and to minimize the need for tendo-Achilles lengthening.

Lengthening should be slowed down or stopped completely if the patient fails to show good knee or ankle function at any stage. Tendo-Achilles lengthening is sometimes necessary to assure good future ankle range of motion and function. Botulinum toxin injection was used in 8 limbs in 5 patients (3 bilateral and 2 unilateral) to either facilitate the physiotherapy of ankle dorsiflexion or decrease the stretching pain associated with distraction.

After distraction is discontinued, the patient is gradually allowed increased weight bearing. One month after lengthening has stopped, the patient should be able to walk using a cane. At the time of removal, after good consolidation of the fibular osteotomy has been achieved, the frame is not removed as one unit. Rather, the distal ring is removed and the middle ring is left connected to the tibial bone with at least 3 pins. The middle ring remains connected to the proximal ring by 4 rods and remains in place until full consolidation of the regenerate bone is obtained.

Consolidation Phase
After lengthening is completed, a long-film radiograph is obtained to detect any malalignment. Malalignment should be corrected before the regenerate bone is consolidated.

To lengthen the Achilles tendon, a half-ring is connected to the Ilizarov frame distally and applied to the calcaneus bone by two 5- or 6-mm–diameter pins placed perpendicular to each other. One is proximal and one is distal to the half-ring, and one transverse wire is used. Percutaneous tendo-Achilles lengthening is achieved through 2 small longitudinal surgical incisions on the posterior aspect of the leg distally. The distal frame or half-ring should be kept in place for at least 1 month until soft tissue healing is complete. During this stage, the patient is allowed partial weight bearing with a walker or crutches.
consolidation. Removing the distal ring provides the patient with earlier comfort compared with leaving all 3 rings in place.

The authors’ postoperative protocol is to closely monitor the patient to avoid complications or correct them early. The radiological criteria for success of the procedure were the presence of at least 3 cortices in the newly formed bone on both anteroposterior and lateral views. During the last 8 weeks before frame removal and every time during follow-up, some pins and/or wires were removed from the frames to increase the load to the newly formed bone and thus enhance consolidation, starting with removal of pins and wires that were closer to the lengthening site.

When consolidation is radiologically confirmed, controlled loosening of the lengthening nuts is applied. The lengthening nuts are loosened to 3 to 4 mm away from the ring and are kept in position by locking standard nuts over them to prevent migration. The frame is kept in place for a week, and walking is allowed with partial weight bearing.

After a week, additional anteroposterior and lateral view radiographs are obtained and compared with the previous images. When no difference is shown, the newly formed bones are fully consolidated and it is time for frame removal. It is also important to check for the distance between the lengthening nut and the ring for any minimal collapse or change.

Follow-up for all patients was conducted clinically, radiologically, and psychologically. Communication by e-mail, telephone calls, and clinic visits was done for all patients for at least 5 years after frame removal (range, 5-12 years). All patients were evaluated for joint range of motion and radiological quality of consolidation and alignment (measuring the mechanical axis of both lower limbs before and after the procedure).

Patients completed a questionnaire that included the following questions: How well are you able to practice activities of daily living after the procedure? Given the choice, would you again decide to do the procedure? Would you recommend this procedure to others? Has your sense of self-confidence improved? Has the procedure had a positive effect on your relations with others?

RESULTS

Two patients were lost to follow-up. Using the classification system created by Catagni et al. and based on the parameters and scores assigned by the patient and physician, the patients classified their outcomes as follows; poor (0-4 points)=0 patients; fair (5-9 points)=0 patients; good (10-14 points)=1 patient; and excellent (15-18 points)=49 patients. Average lengthening achieved in 50 patients was 6.9 cm (range, 4-11 cm) (Figure 4) over an average period of 231 days of treatment in the frame (range, 166-369 days). The external fixator index was 1.14 months/cm (range, 0.91-1.21 months/cm) (Table 3).

Associated varus deformities (mild in 8 patients and moderate in 2) were corrected simultaneously with lengthening. The patient who had a limb-length discrepancy of 8 mm before the procedure and underwent simultaneous correction had no limb-length discrepancy at the end of the procedure. It was possible to fully correct the discrepancy within the tibial bone during the lengthening procedure. The patient did not have fixed pelvic tilt or compensated scoliosis preoperatively, and no future problems are anticipated.

All patients had lost between 3° and 10° of ankle dorsiflexion as of final follow-up. No patient reported pain postoperatively because it was well controlled by the pain management team at the authors’ institution. However, 32 (62%) of 50 patients reported pain during the lengthening phase, especially after reaching an increase of 4 to 5 cm. This pain was successfully treated with orally administered pain killers and muscle relaxants. No non-steroidal anti-inflammatory drugs were administered; they are not recommended for use during the lengthening procedure, which is an inflammatory process. Physiotherapy (massage) and botulinum toxin injection were administered to relax stretched muscles at the back of the lower limb. One patient experienced intolerable stretching pain that required extensive drug therapy and hypnosis for 2 weeks.

During treatment, 8 patients (3 medical students, 2 businessmen, 2 office workers, and 1 physician) were able to practice their regular activities of daily living 1 month postoperatively. Other patients preferred not to work until the procedure was completed and the frame removed. Forty patients were from countries other than Egypt. Thirty-two of them preferred to stay near the authors’ clinic for 3 to 4 months/cm (range, 0.91-1.21 months/cm) (Table 3).

Figure 4: Bar graph showing how many patients achieved various amounts of lengthening.
months until the lengthening procedure was completed and to return for follow-up visits and frame removal. All patients were cooperative during all stages of follow-up.

Because long-film anteroposterior and lateral view radiographs were examined for every patient, from the pelvis to the ankle at the end of the lengthening stage and before full consolidation of the regenerate bone, the authors were able to address any minor misalignment before the end of the procedure. As a result, all patients had excellent alignment at the latest follow-up examination.

The patients were assessed to have marked psychological improvement and self-confidence, as determined by the psychologist who recommended them for the procedure.

**Complications**

Paley\(^3\) classified the difficulties encountered with limb lengthening into 3 categories: problems, obstacles, and complications. Problems are difficulties that require no operative intervention to resolve. Obstacles are difficulties that require operative intervention to resolve. Complications are difficulties that affect the goal of the procedure and need further operative intervention to reach the original goal.

According to this classification, the authors managed problems of pain, insomnia, psychological disorders, behavioral changes, and muscle contractures in 70\% of the patients (Table 4). All problems were resolved with medical therapy, psychotherapy, and physiotherapy, as needed, without operative intervention. The problem of superficial pin tract infection occurred in 2 patients and was resolved with repeated dressing changes and orally administered antibiotics.

The obstacles encountered included tightness of the Achilles tendon requiring operative intervention in 12 (24\%) patients, 10 bilaterally and 2 monolaterally (22 tendons) (Table 4). The 12 patients who underwent tendo-Achilles lengthening had undergone limb lengthening greater than 6 cm. No patient who underwent limb lengthening less than 6 cm required tendo-Achilles lengthening. One patient who underwent 9 cm of limb lengthening did not require tendo-Achilles lengthening because she was able to dorsiflex both ankles to 90° after extensive physiotherapy and botulinum toxin injection in the gastrocnemius and soleus muscles. Other milder forms of tightness were resolved with physiotherapy or botulinum toxin injection.

The obstacle of mild misalignment as a development of procurvatum deformity at the end of lengthening occurred in 16 patients and was resolved by applying hinges to the frame for gradual correction (Table 4). The hinges were applied on an outpatient basis with no need for return to the operating room. Hypotrophic regenerate bone presented in 4 patients, 3 of whom required low-pulsed ultrasound bone stimulation (Exogen device; Smith & Nephew, Memphis, Tennessee) and a longer period of time in the frame before full consolidation was achieved. One patient refused to wait the additional time and underwent intramedullary nail insertion (Figure 5). Cystic regenerate in the newly formed bone occurred in 1 patient and required additional time in the frame until full consolidation was achieved. A large (5×3.5-cm) cyst developed in the regenerate bone of 1 patient, requiring application of percutaneous synthetic radiopaque bone graft. Slippage of the 3-mm wire connecting the proximal tibiofibular joint occurred in 1 patient on

### Table 4

<table>
<thead>
<tr>
<th>Occurrence</th>
<th>No. (%) of Patients</th>
<th>Treatment</th>
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<tbody>
<tr>
<td>Problems</td>
<td>35 (70)</td>
<td>No operative intervention</td>
</tr>
<tr>
<td>Pain (stretching pain at end of lengthening stage)</td>
<td>35</td>
<td>Muscle relaxant, pain killers</td>
</tr>
<tr>
<td>Insomnia</td>
<td>6</td>
<td>Psychotherapy</td>
</tr>
<tr>
<td>Psychological disorders</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>Behavioral changes</td>
<td>3</td>
<td>Psychotherapy</td>
</tr>
<tr>
<td>Muscle contractures</td>
<td>14</td>
<td>Muscle relaxant, physiotherapy (n=10), botulinum toxin injection (n=4)</td>
</tr>
<tr>
<td>Superficial pin tract infection</td>
<td>2</td>
<td>Antibiotics, repeated dressings</td>
</tr>
<tr>
<td>Obstacles</td>
<td>36 (72)</td>
<td></td>
</tr>
<tr>
<td>Tightness of Achilles tendon</td>
<td>12 (24)</td>
<td>Surgical gastrocnemius soleus release (modified Strayer)</td>
</tr>
<tr>
<td>Mild misalignment</td>
<td>16 (32)</td>
<td>Hinge application, gradual correction</td>
</tr>
<tr>
<td>Hypotrophic regenerate bone</td>
<td>4 (8)</td>
<td>Low-pulsed ultrasound (n=3), elective interlocking nail insertion (n=1)</td>
</tr>
<tr>
<td>Cystic regenerate</td>
<td>1 (2)</td>
<td>Longer time in frame</td>
</tr>
<tr>
<td>Large cyst</td>
<td>1 (2)</td>
<td>Synthetic bone graft</td>
</tr>
<tr>
<td>Wire slippage</td>
<td>1 (2)</td>
<td>No treatment</td>
</tr>
<tr>
<td>Broken proximal ring</td>
<td>1 (2)</td>
<td>Frame augmentation</td>
</tr>
<tr>
<td>Complications</td>
<td>1 (2)</td>
<td></td>
</tr>
<tr>
<td>Bilateral varus deformity</td>
<td>1 (2)</td>
<td>Insertion of bilateral intramedullary nails, correction of misalignment</td>
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</table>

*Abbreviation: N/A, not applicable.*
both sides; this was the oldest patient in the series (age, 46 years). The slippage occurred at the end of lengthening and did not affect the final outcome. In another patient, the proximal ring broke. A bridge was applied using Ilizarov device accessories (Figure 6) on an outpatient basis, and the procedure was continued with no negative effect on the final outcome.

Complications of premature consolidation of the regenerate bone, joint stiffness, limb-length discrepancy, nerve palsy, neurapraxia, rotational deformity, or anterior knee pain, although reported by others,\textsuperscript{12,13} were not encountered in the current study. No deep infection occurred. However, a true complication occurred in 1 patient who gradually developed bilateral varus deformity during the month after frame removal (Table 4). This is called plastic deformation of the regenerate bone and was corrected by inserting bilateral intramedullary nails after osteotomy at another hospital. Full correction of the deformity was achieved.

At latest follow-up, all patients except one were satisfied with the final outcome and reported much higher self-confidence. All patients except 2 stated that despite the problems and obstacles, they would go through the procedure again and would recommend it. One patient was not completely satisfied because of the scars at the pin sites (Figure 7), and he could not decide whether he would do it again given the choice. Based on the parameters of patient satisfaction and all previously stated problems, obstacles, and complications, clinical results were excellent in 49 (98%) of 50 patients. The 49 patients were also satisfied with the final aesthetic results (Figure 8).

The rate for readmission to the operating room to correct an obstacle or a complication was 28% (14 of 50 patients). Twelve (24%; 12 of 50 patients) of the operations were for tendo-Achilles lengthening.

**DISCUSSION**

The authors’ success in limb lengthening to correct pathological conditions since 1996 encouraged them to perform lengthening in individuals of short stature for cosmetic reasons. They accepted patients with constitutional short stature without a minimum limit. Some patients were of average height according to the international standard but were relatively short within their communities. For example, those from Northern Europe were of taller average height than those from other countries. The lengthening procedure was helpful to patients in improving their social capabilities and self-

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**Figure 5:** Anteroposterior (A) and lateral (B) radiographs of both legs after removal of the frame and application of bilateral interlocking nails to maintain the lengthened distance and the regenerate bone until full consolidation. The nails were inserted 4 months after frame application.

**Figure 6:** A broken proximal metal ring was fixed by adding an Ilizarov accessory bridge, avoiding the need for operative interference.

**Figure 7:** Appearance of scars after bilateral frame removal.
confidence, as reported at the latest follow-up visits.

All problems, obstacles, and complications were successfully treated without adversely affecting final outcome or patient satisfaction. A patient who developed a true complication of bilateral plastic deformity of the newly formed bone after frame removal reported satisfaction after his second surgery to correct the deformity with intramedullary nails because he did not lose the height he had gained during the lengthening procedure. Nonetheless, the authors consider this late complication to be the only true complication in their series because it met the criterion of affecting the final goal of lengthening within a certain period of time.

The low rate (1%) of superficial pin tract infection in this series may be attributable to the authors’ technique of maximum stability and the use of hydroxyapatite-coated pins. Achieving these results in an average of 231 days was possible because of the limited amount of lengthening (7 cm or less in most patients; 8 cm or more in 8 patients). Of note, the amount of lengthening is not chosen by the patient, and the authors promise no specific amount of increased length before the procedure. The goal is to achieve 5 to 8 cm of length within 6 months. Lengthening more than 8 cm is associated with a higher risk of complications, including disproportion and delayed healing. The authors’ awareness of these complications based on previous experience may explain the lower rate of complications compared with reported rates. Although not statistically significant, a trend was shown toward a decreased need for tendo-Achilles lengthening with a good physiotherapy program (24% of the patients in this study compared with a reported rate of 35%; \( P =.28 \)). Work done at the authors’ institution since this study has shown further positive results of physiotherapy (only 8 of 100 patients requiring tendo-Achilles lengthening).

Resulting pin site scars were acceptable to all patients except one. Scars were minimal because of the low pin tract infection rate achieved. Others have reported patient dissatisfaction with residual skin scars. The authors attribute the lack of substantial pain in their series to the use of a single-level technique. Pain has been reported as a problem associated with double-level lengthening. This is likely because double-level lengthening increases the distraction rate for the soft tissue to almost double (1.5 to 2 mm) per day.

Compared with the study by Catagni et al, the current authors report substantially fewer patients requiring further surgery (48% vs 28%, respectively), including a smaller percentage requiring tendo-Achilles lengthening (35% vs 24%, respectively). They attribute their lower complication rate to the use of a single proximal osteotomy. Catagni et al used a double-osteotomy technique, with 1 osteotomy performed proximally and 1 per-
formed distally. It is anecdotally known that distal osteotomies are associated with increased complications. Shorter time in the frame was also likely a reason for fewer complications in the current study. For these reasons, the authors consider their technique safe.

**CONCLUSION**

Based on postoperative psychological evaluation, patients in the current study showed improvement in self-confidence and psychological status after the lengthening procedure was completed. However, some patients suffered from psychological problems during the procedure that the authors did not discover preoperatively. Therefore, they advise advanced psychological evaluation of all patients before commencing cosmetic lengthening surgery.

This study shows that assessments of patient satisfaction can be favorable in a cohort of patients undergoing leg lengthening for cosmetic reasons, even in the face of preexisting psychological issues related to short stature. The study results confirm that the Ilizarov device is a safe tool for limb lengthening in individuals of short stature when applied with the authors’ technique of maximum frame stability.

**REFERENCES**