Distraction osteogenesis using a longitudinal corticotomy

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Abstract

Purpose The purpose of this study was to evaluate whether the use of a longitudinal corticotomy (S-Z osteotomy) results in more rapid consolidation following distraction osteogenesis of short tibiae.

Methods Sixty-seven lengthening procedures were performed in 51 patients ranging in age from nine to 38 (mean 25) years.

Diagnoses included short stature (32 tibiae), postpolio limb deformity (22 tibiae), osteomyelitis (three tibiae), trauma (two tibiae) and other diagnoses (eight tibiae). Forty-five lengthenings were performed via a longitudinal corticotomy, and 22 were performed via a transverse corticotomy. Patients were followed until consolidation of the regenerated bone was noted radiographically (consolidation time). The healing index (consolidation time per centimetre of lengthening) was calculated for each patient and compared between groups.

Results The healing index was significantly lower in the S-Z group (30.8 ± 9.6 days/cm) than in the transverse corticotomy group (46.8 ± 20.2 days/cm) ($p < 0.0001$). Mean lengthening was 6.6 (range 2.5–12.5) cm in the S-Z group and 5.8 (range 2.0–12.0) cm in the transverse group ($p = 0.28$). Mean consolidation time was 6.3 ± 2.8 (range 3–16) months in the S-Z group and 8.1 ± 3.8 (range 3–13.5) months in the transverse group ($p = 0.03$).

Conclusion The S-Z osteotomy safely reduces consolidation time of regenerative bone during distraction osteogenesis in the tibia relative to a transverse corticotomy.

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Introduction

It has long been recognised that significant and longstanding bony shortening cannot be immediately corrected following osteotomy: gradual stretching of soft tissue is required [4]. Early treatment techniques had high complication rates, and optimal results were rare [3, 17]. In the 1950s, Ilizarov describe distraction osteogenesis, a technique based on the biology of bone regeneration [7, 8]. The procedure began with a transverse corticotomy, followed by gradual distraction of the bone segments. During this distraction phase, immature bone forms in the gap between the two bones [1]. When the desired length is reached, distraction halted and a consolidation phase begins. During this consolidation period, mechanical strength of the newly formed bone is minimal

[13]. Following consolidation, external support is removed and loading of the limb begins. Essentially, the same procedure is used to this day to lengthen long bones [19].

One disadvantage of distraction osteogenesis is the need to wait for a long consolidation period. Prolonged use of an external fixation device and delay of weight-bearing is not ideal due to high infection risk [2] and frustration experienced by patients. One reason for prolonged consolidation is the lack of cortical apposition following bone lengthening with a traditional transverse corticotomy. In 1996, we developed at our centre a novel technique of bone lengthening (S-Z osteotomy) based on a longitudinal corticotomy that increases cortical contact in order to accelerate bony consolidation. We hypothesise that the use of a longitudinal corticotomy (S-Z osteotomy) results in more rapid consolidation following distraction osteogenesis of shortened tibiae, without increased complications when compared to traditional transverse corticotomy.

Materials and methods

Sixty-seven tibial-lengthening procedures performed in 51 consecutive patients at our institution between 1994 and 2007 were retrospectively identified. The patients ranged in age from nine to 38 (mean 24.7) years. Diagnoses included short stature (32 tibiae), postpolio limb deformity (22 tibiae), osteomyelitis (three tibiae), trauma (two tibiae), and other diagnoses (eight tibiae). Over this time period, the senior author abandoned the transverse corticotomy in favour of a longitudinal corticotomy in the shape of an S (left tibia) or a Z (right tibia) (S-Z osteotomy) for tibial lengthening. In total, 45 lengthenings were performed via longitudinal corticotomy, and 22 were performed via transverse corticotomy. Preoperative demographics and diagnoses of the two groups were similar (Table 1).

Surgical technique

All surgery was performed by the senior author (FA). Patients were placed in the supine position with a sand bag positioned

to support the affected extremity. The procedure began with placement of proximal and distal pins for external fixator application, spanning the site of the osteotomy. We prefer to use fluoroscopy to ensure that pins are perpendicular to the long axis of the tibia. Following pin placement, a corticotomy was performed. In 22 limbs in 17 patients, the corticotomy was performed using the traditional Ilizarov technique [7, 20]. A small midshaft incision was made, and a transverse corticotomy was performed with a mallet and osteotome.

In 45 limbs in 34 patients, the corticotomy was performed using the S-Z technique. Through a small incision at the proximal end of the desired osteotomy site, an osteotome was used to osteotomise the lateral tibial cortex, taking care that the medial cortex was not violated. Then, through a separate small incision approximately 5- to 7-cm distal, a similar osteotomy of the medial tibial cortex was performed. The osteotome was then used subcutaneously to make a longitudinal corticotomy of the anterior tibial cortex, connecting the two prior corticotomies. An osteotomy of the fibula was then performed through a 2-cm lateral incision with a bone cutter. The two ends of the tibia were then rotated in opposite directions, fracturing the posterior tibial cortex and completing the osteotomy. The completed osteotomy resembles a “Z” if performed in the right tibia and an “S” if performed in the left tibia (Fig. 1).

Following the corticotomy performed by either technique, an external fixator was applied for lengthening. Between 1994 and 1996, an Ilizarov frame was used. From 1997 onward, an Orthofix external fixator (Verona, Italy) was used. Prophylactic antibiotics i.v. were used intraoperatively, and oral antibiotics were continued for the duration of lengthening. Lengthening was initiated intraoperatively and proceeded at a rate of 0.25 mm every six hours. Full weight bearing with a walker was initiated on the first postoperative day. During the lengthening phase, patients attended regular physical therapy sessions, with weekly follow-up in the orthopaedic clinic. To avoid equinus contracture of the ankle, a percutaneous tenotomy of the Achilles tendon was performed after three to four weeks of lengthening. Radiographs of the treated limb were obtained at two week intervals until bony consolidation was confirmed. The follow-up

Table 1 Patients' preoperative characteristics

	Transverse corticotomy	Longitudinal corticotomy (S-Z)	Significance (<i>p</i>)
Mean patient age (years)	25.3±5.5	24.3±6.5	0.54
Gender	10 Female 7 Male	19 Female 15 Male	0.84
Diagnosis for each tibia	Short stature 10 (45%) Postpolio 7 (32%) Osteomyelitis 1 (5%) Trauma 1 (4%) Other 3 (14%)	Short stature 22 (49%) Post-polio 15 (33%) Osteomyelitis 2 (5%) Trauma 1 (2%) Other 5 (11%)	0.98

Fig. 1 S-Z osteotomy in a right tibia. **a** Lateral view demonstrates the proximal osteotomy of the medial tibial cortex as well as the transverse osteotomy of the fibula (black lines). Distal osteotomy of the lateral cortex on the opposite side of the limb (gray line). **b** A medial view demonstrates the distal osteotomy of the lateral tibial cortex and the transverse osteotomy of the fibula (black lines). Proximal osteotomy of the medial cortex on the opposite side of the limb (gray line). **c** Anterior view demonstrates the longitudinal corticotomy of the anterior tibial cortex that connects the two osteotomies (forming a Z) and the transverse osteotomy of the fibula. **d** An anterior view of the same type of osteotomy in a left tibia (forming an S)

interval decreased to every two months until one year after consolidation, then annually after that.

Assessment of healing

Following the lengthening period, external support was left in place until bony consolidation was seen on plain radiographs. To decrease the amount of time the external fixator was in place, it was often exchanged for a cast prior to complete consolidation. Healing duration was defined as time from the beginning of lengthening until bony consolidation, which was defined by formation of complete cortices at least 2 mm in diameter (three mm for lengthenings under ten centimetres and four mm for lengthening over ten centimetres), as previously described [16, 18]. The healing index (healing duration per centimetre of lengthening) was calculated for each patient, and any complications were noted. Mean healing index was compared between the two groups.

Statistical analysis

Continuous variables were compared between the two groups using unpaired *t* tests. Categorical variables including gender and diagnosis were compared using Fisher exact tests.

Statistical significance was defined as a *p* value <0.05. A power analysis determined that a minimum sample size of 20 tibiae in each group was required to identify a clinically significant difference of ten days/cm in the healing index between the two groups, with $\alpha=0.05$ and a statistical power of 80%.

Results

Mean lengthening of all tibiae in the series was 6.3 ± 2.8 cm and was not significantly different between the two osteotomy groups (Table 2). Mean time from surgery to bony consolidation (healing duration) was 6.9 ± 3.2 months, and was significantly shorter in the longitudinal corticotomy (S-Z) group (Table 2). Mean healing index was 36.0 ± 15.8 days/cm, and was significantly lower (more rapid healing) in the S-Z group (Table 2) (Fig. 2).

Mean surgical time for both transverse and S-Z osteotomies was 30 minutes for unilateral tibial lengthening and 60 minutes for bilateral tibial lengthening. Mean follow-up in both groups was three (range one to five) years. Complications were rare with both procedures. One patient in the transverse osteotomy group showed no evidence of bony consolidation six months following a four centimetre lengthening. He was treated with bone grafting and open reduction and internal fixation and went on to heal three months later. One patient in the transverse osteotomy group developed a varus deformity, which was addressed with a subsequent high tibial osteotomy. One patient in the S-Z osteotomy group fractured through one of the distal screw holes from the external fixator following its removal. This patient was treated in a cast and healed uneventfully. None of the patients developed pin-track infections requiring antibiotic treatment, and no neurovascular complications were noted. No ankle or knee stiffness was reported.

Discussion

The most significant finding of our study is that the use of a longitudinal rather than a transverse corticotomy results in

Table 2 Lengthening and healing rates

	Transverse corticotomy	Longitudinal corticotomy (S-Z)	Significance (<i>p</i>)
Mean lengthening (cm)	5.8 ± 2.9	6.6 ± 2.7	0.28
Mean healing duration (months)	8.1 ± 3.8	6.3 ± 2.8	0.03
Mean healing index (days/cm)	46.8 ± 20.2	30.8 ± 9.6	<0.0001

Fig. 2 Plan radiographs of a patient in whom a transverse osteotomy was performed on the right tibia and an S-Z osteotomy performed on the left tibia. **a** During the lengthening period following 4 cm of lengthening. **b** Ten weeks following completion of lengthening. The external fixator was removed from the left leg and a cast could be applied. Note the increased bony consolidation in the left leg (S-Z osteotomy) compared with the right (transverse osteotomy)

more rapid healing following tibial lengthening. This increased healing rate is advantageous for several reasons. Primarily, it allows patients a faster recovery from a significant operation. In addition, less time with an external fixator in place decreases infection risk, which has been shown to be quite high in cases of prolonged external fixation [2]. Finally, a more rapid return to weightbearing and normal limb mobility decreases functional loss and stiffness that can be associated with long-term external fixator usage [5]. We believe the reasons for the more rapid healing are increased cortical contact between the two bony segments and larger exposure of the new regenerative bone to the cancellous bone of the tibial shaft. These factors effectively decrease the amount of new bone formation required to re-establish stability in the tibia. Another key factor in reducing healing duration in both groups is the use of an osteotome rather than a motorised saw to create the corticotomy. This method reduces injury to both the bone and surrounding periosteum, potentially increases the number of healthy cells available for healing [10].

We demonstrated the healing index of the S-Z technique (30.8 days/cm) was significantly faster than that observed following a traditional transverse corticotomy (46.9 days/cm). The healing index for distraction osteogenesis following a transverse corticotomy has been noted by several authors to be between 31 and 64 days/cm (Table 3).

Several techniques have been described that aim to shorten the healing index following corticotomy. Kristiansen et al demonstrated reduced healing index from 52 days/cm to 30 days/cm by performing two separate transverse osteotomies and distracting in both locations [12]. However, they noted a significant increase in complications with their technique. Oh et al placed a locking plate over the distraction site and secured one end of the plate with screws [15]. They then performed the distraction and locked the

plate with screws on the other end. This technique allowed them to remove the external fixator early, but healing still occurred at 48 days/cm. Healing rates following lengthening over an intramedullary nail are reported between 37 and 48 days/cm [9, 11]. Future comparative studies are necessary to evaluate outcomes of these techniques relative to the longitudinal corticotomy technique described in the our study.

We are unaware of any previous description of the use of a longitudinal corticotomy for distraction osteogenesis. Longitudinal osteotomies have a long history of use in correcting rotational deformities. Haas [6] in 1929 and Nicholson [14] in 1957 both cited the major advantage of such a technique over a transverse osteotomy in providing increased cortical contact for both postoperative stability and increased healing rates. These same benefits can be extended to distraction osteogenesis as described above.

There are several limitations to this study. The first is lack of comparisons of outcome data between the two groups. Rather, the focus is on healing time with the two different techniques. The second is the retrospective nature of data collection, due to which bony consolidation was

Table 3 Healing index of distraction osteogenesis with a transverse corticotomy

Study	Healing Index (days/cm)
Garcua-Cimbrelo et al ¹⁹	31
Antoci et al ²⁰	33
Lie et al ²¹	48
Oh et al ¹⁴	48
Kristiansen et al ¹³	52
Kristiansen et al ²²	64
This study	46.8

determined by a single surgeon in the course of his clinical practice. This assessment was made based on a standardised technique, as noted in the “Methods” section, but assessment by a single, unblinded observer introduces potential bias. Finally, findings are primarily applicable to patients who are similar to the population reviewed in this series. A majority of patients was treated for short stature or postpolio deformities, with a significantly fewer patients treated for congenital deformities. Results of this lengthening technique require further study in these challenging situations.

Conclusions

The S-Z osteotomy safely reduces consolidation time of regenerative bone during distraction osteogenesis in the tibia relative to a transverse corticotomy.

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