Case Report

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Multidisciplinary team approach to residual limb lengthening using the Ilizarov technique: A case study

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Abstract

Background and aim: A 47-year-old male suffered a traumatic transtibial amputation; initial limb use was unsuccessful and the short tibial length was thought to be the cause of failure.
Case description and methods: The patient underwent gradual tibia lengthening using the Ilizarov technique and utilised a weight-bearing prosthesis to expedite bone growth and repair.
Findings and outcomes: The patient is now able to use his prosthesis successfully without aids.
Conclusion: This case study demonstrates that combining a scientifically based surgical technique with a tailored rehabilitation approach had an improved outcome for the patient.

Clinical relevance

This study reports one case where tibial lengthening using the Ilizarov technique combined with a collaborative team approach has enabled a patient to return to successful prosthetic limb use.

Keywords

Residual limb lengthening, Ilizarov technique

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Background

Despite considerable advances in prosthetic manufacturing and technology, the residual limb condition and subsequent socket fit remain crucial to the success of prosthetic rehabilitation. There is a clear understanding among limb reconstruction surgeons that transtibial amputation is preferred over transfemoral amputation; this is because energy consumption for the transtibial amputee, due to preservation of the knee joint, is far less than for amputees with a transfemoral level. The relative ease of transtibial versus transfemoral gait is born out of several studies of prosthesis usage.[1] Limb salvage, particularly salvage of the knee joint, is therefore always a priority. In the case of traumatic amputations, 'ideal' residual limb conditions cannot always be achieved initially. This case follows a traumatic transtibial amputation and how residual limb lengthening utilising the Ilizarov technique along with a collaborative team approach achieved a more acceptable outcome for the patient.

Case description and methods

Patient history: a 47-year-old male who was involved in a road traffic accident when his motorcycle collided with a car sustained an open fracture to the lower end of his left tibia and fibula with severe de-gloving injury of the soft tissues. Due to the severity of the injuries, limb salvage was not possible and the patient underwent a transtibial amputation.

Initial tibial bone length was measured at 86 mm, which was considered suitable for a trial of transtibial prosthesis. Prosthetic limb use was attempted but was unsuccessful as the patient was experiencing considerable residual limb pain, left knee-joint pain and significant

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phantom limb pain. A magnetic resonance imaging (MRI) scan of the knee joint confirmed a patella femoral injury. Arthroscopic debridement of his joint resulted in a reduction in the pain levels but there was no improvement to mobility when using a prosthesis. The patient abandoned limb wearing. (Special Interest Group in Amputee Medicine (SIGAM) Score[2] pre-lengthening: A.)

During a multidisciplinary case clinic discussion, it was felt that the length of his stump was too short to support a prosthetic limb, and a bone-lengthening procedure using the Ilizarov external fixator was proposed with an aim to increase the tibial bone length by 50 mm. It was imperative when assessing whether the patient was suitable for a procedure of this kind that the whole team were aware of both the long-term nature of the bone-remodelling treatment that the patient would endure and the social and psychological impact of the process. The surgical risks were discussed with the patient, who confirmed that he understood the risk of transfemoral amputation should an infection of the bone develop.

The patient was under the care of a clinical psychologist who monitored anxiety and depression levels using the Hospital Anxiety and Depression Scale[3] (HADS; HADS pre–leg-lengthening procedure: Anxiety = 17, Depression = 18).

Surgical procedure

The lengthening method involved the Ilizarov procedure with distraction osteogenesis, which included a diaphyseal corticotomy performed on the residual tibia. Distraction commenced after a latency period of 10 days, and the aim was to complete a daily rate of 1 mm per day in four increments of 0.25 mm per turn. Initially, distraction was undertaken in an inpatient setting.

For the reasons described below, distraction was stopped after 23 mm lengthening was obtained. Distraction continued over 70 days, and a 23 mm increase in tibial bone length was measured radiographically (26.7% increase in tibial length). The Ilizarov frame was removed in clinic after 136 days.

Following surgery, the patient required continued comprehensive educational support and follow-up care to maximise his long-term success. During distraction, newly formed bone rapidly remodels to conform to the bone's natural structure, but it usually takes a year before the structure of newly formed bony tissue is comparable to that of the pre-existing bone.[4]

Ilizarov fixator apparatus

To facilitate transtibial bone lengthening and distal attachment of the prosthesis, the Ilizarov fixator design incorporated four full standard stainless steel rings. The top two rings were applied to the stump using one full ring at the proximal section of the tibia, and a second ring was placed at the distal section of the tibia to allow the production of new bone when the corticotomy site is separated by gradual distraction (Figure 1(a)).

The second ring wires were positioned through the muscular myoplasty site to ensure first that the distal section of the tibia would remain enclosed post lengthening (to aid comfortable prosthetic limb wearing) and second that the musculature would lengthen at a similar rate to the tibia and help prevent knee-flexion contractures.

The second ring also acted as a transport ring: its design enabled it to travel down the external frame while distraction/lengthening of the residual limb took place, thereby negating the need to alter the length of the distal prosthesis. This had the advantage of minimising the number of outpatient appointments the patient had to attend as well as prosthetic component costs. The third ring was a mounting ring and the fourth was stable to allow the fixed-length prosthesis to be attached (Figure 1(b)).

Prosthetic attachment

The distal prosthetic device was attached to the external fixator via the fourth stable full ring 12 days after application of the Ilizarov frame. This standard Ilizarov ring was attached to the prosthetic limb (patient's own prosthesis as used prior to lengthening procedure) by means of an aluminium footplate from a CAPS 2 seating system. The footplate was attached to the ring and then to the external frame by surgical external frame bolts and was also bolted centrally to the prosthesis endoskeletal housing, from which the shin tube, foot and ankle were attached (Figure 2).

The aim of the distal prosthetic attachment was to

1. Facilitate hospital discharge;
2. Permit full weight-bearing through the prosthetic device to stimulate new bone growth and to expedite a positive healing index score similar to non-amputee patients who have undergone a limb-lengthening procedure;
3. Introduce a longer lever arm to enable the patient to maintain knee extension and help reduce the risk of developing a flexor contracture;
4. Allow functional activities, a normal efficient gait cycle and to re-educate balance and proprioception;
5. Enable completion of the physiotherapy exercises to reduce muscle wastage and improve stamina.

A risk assessment was completed by the senior rehabilitation engineer who highlighted potential risks and failure of the device, but deemed the procedure safe for patient use under these specific circumstances. Regular safety appointments were made to check the prosthetic device and further minimise risks.

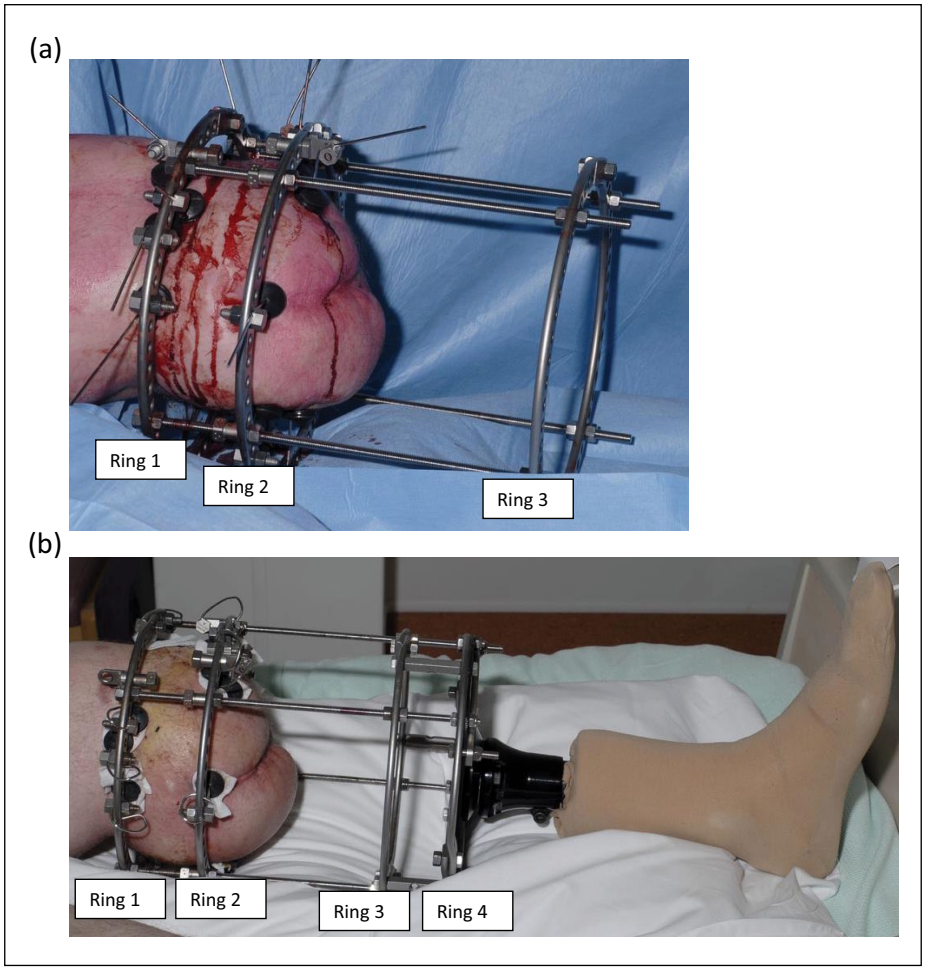

Figure 1. (a) Ilizarov fixator design used to complete distraction osteogenesis and (b) Ilizarov fixator apparatus attached to the distal endoskeletal prosthesis.

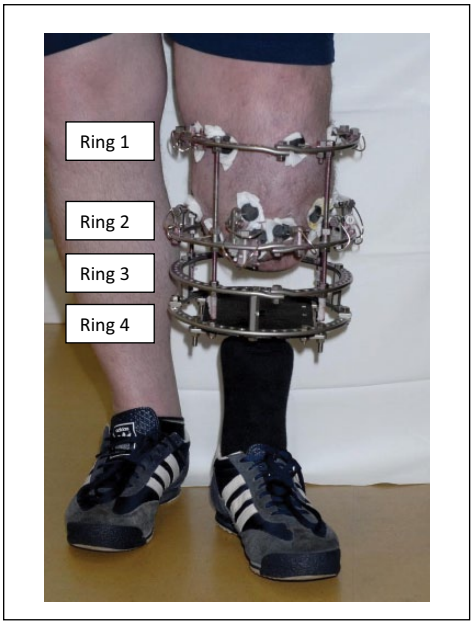

Figure 2. Patient using distal prosthesis to bear weight.

Post-operative rehabilitation and prevention of complications

A number of complications were documented relating to this procedure, including pin-site infections and soft tissue problems,[5] range of motion of adjacent joints and pain.[6] During the lengthening procedure, the patient attended numerous outpatient appointments, which included the surgical team, clinical specialist, limb lengthening physiotherapist, clinical psychologist, pain management team and prosthetist. This intensive, co-ordinated rehabilitation programme was tailored for the patient to monitor any complications and reduce associated risks, assess compliance, educate, reassure and problem-solve where necessary.

1. *Pin-site/tract infections*: weekly pin-site dressings and patient education were completed throughout the treatment to reduce the risk of infections developing. No surgical incisions were required to split the skin surrounding the pin sites while lengthening

Table 1. Results of limb-lengthening procedure.

Tibial bone length			Functional limb length			Latency (days)	Distraction (days)	Consolidation time (days)	Healing index	Fixation time (days)
Original (mm)	Increase (mm)	Percentage increase (%)	Original (mm)	Increase (mm)	Percentage increase (%)					
86	23	26.7	145	25	17.2	10	70	56	30.4 days/cm or 1 month/cm	136

Tibial bone length: measured by radiographs pre- and post-lengthening procedure.
Functional limb length: measured from Mid-patella tendon (MPT) to distal aspect of the residual limb pre- and post-lengthening procedure.
Latency period: after corticotomy procedure and before distraction.
Distraction period (introduction of new bone formation between the osseous surfaces that are gradually pulled apart): initially completed at a rate of 1 mm per day in four daily increments of 0.25 mm, reduced to 1/2 mm to prevent a knee-flexion contracture developing.
Consolidation time: time between the end of the distraction period and the removal of the fixator.
Healing index: defined as the time needed for consolidation per centimetre of distracted osteotomy site.
Fixation time: total number of days the patient was in the fixator.

occurred, even at the skin-graft sites which are an area for concern.[7]

2. *Proximal joint contractures*: a loss of mobility due to muscle contractures is not uncommon during lengthening procedures. Intensive active and passive mobilisation is necessary to avoid the development of muscle contracture and to prevent any loss of knee extension or flexion.[7] The patient was scheduled to attend physiotherapist session twice weekly. The patient progressed to using two elbow crutches with the external frame and was able to weight-bear, with the prosthesis taking approximately 80% of his weight. This was limited by the pain he felt in his pin sites. The patient lengthening rate was reduced to 1/2 mm per day 2 months after initial surgery as he had started to develop a flexion contracture at the knee.
3. *Pain* was a limiting factor in the patient's rehabilitation, due to tension in the soft tissues and wire position. This was managed through a variety of analgesics, which included fentanyl patches prescribed by the clinical nurse specialist within the pain management team.
4. *Further surgical intervention* was required on one occasion during the lengthening procedure when a wire attached to the second ring came loose and the distal fragment lost grip. Additional surgery was required 20 days after the initial surgery to attach more wires to ensure lengthening could continue. The original wire remained in situ as it worked to keep the posterior myoplasty site in place. The patient ceased lengthening and weight-bearing on the prosthesis for 19 days.

Findings and outcomes

The distraction period was 70 days with 136 days spent in the external fixator, from the date of the operation to the removal of the frame. Pain and irritation from the wires along with poor knee extension contributed to early cessation of the distraction period, causing it to cease completely when 23 mm tibial length increase had been achieved. There were no signs of protrusion of the bone through the skin. A significant complication towards the end of the distraction phase was synovial fluid leakage from wires near his knee with associated swelling of the knee. This was addressed by a course of antibiotics and early removal of the frame, as the risk of developing an infection or septic arthritis was deemed too high. This resulted in a reduced consolidation period of 56 days (consolidation period is usually 60 days for each centimetre of distraction[8]). The healing index was 30.4 days/cm, which is comparable to other limb-lengthening statistics,[9] whose healing index ranged between 26 and 35 days/cm (Table 1).

Tibial bone lengthening and functional limb lengthening were achieved with increases of 26.7% and 17.2%, respectively. Bone length was measured radiographically from the superior edge of the medial intercondylar tubercle to the end of the tibia. Limb length was measured from the mid-patella tendon to the end of the limb's soft tissue. These lengths are equally important with regard to facilitating prosthetic limb use, as the skeletal tibia supports the residual limb, which controls the prosthesis and the soft tissues surrounding the bone and aids prosthetic suspension (Figure 3(a)).[6]

Proximal joint contracture can be a serious complication during treatment. This was minimised by preoperative planning and physiotherapy during the fixation period. The patient developed a flexor contracture (approximately 15° off full extension) of his left knee, which was resolved post treatment. This was confirmed by clinical examination and three-dimensional (3D) gait analysis (Figure 3(b)).

The patient received his new prosthesis 3 months post Ilizarov frame removal. Post-lengthening physiotherapy rehabilitation commenced with his new socket. The time from the start of the procedure to prosthetic fitting was 239 days. The patient subjectively reported a reduction in pain in his stump including phantom limb pain and an

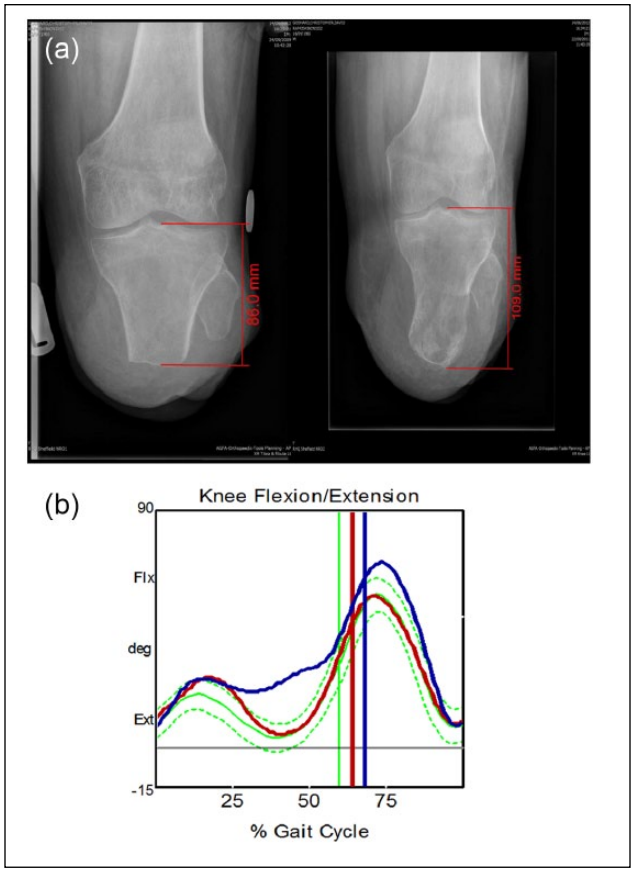

Figure 3. (a) X-rays showing tibia length pre- and post-lengthening procedure and (b) knee flexion/extension in the sagittal plane during gait. Red line indicates left knee which is generally within normal limits compared to average adult sample which is indicated by green line. Blue line indicates patients' knee flexion/extension following the procedure.

improvement in the fit of the socket and walking when using the prosthesis post lengthening. The patient reported greater socket tolerance, decreased knee pain and increased wear time. At the most recent follow-up, the patient was still able to use his prosthesis comfortably and unaided and maintained grade E on the SIGAM scale.

The patient is readily able to use his prosthesis 8 months post lengthening, and while his depression and anxiety issues have not been completely resolved, there has been significant improvement with continued psychological support (HADS: 6 months post leg-lengthening procedure: Anxiety = 10, Depression = 7).

Conclusion

Limb lengthening is a complex and prolonged procedure that extends well beyond the operating room.[9] Managing our patient's holistic needs required the unique skills that each allied health professional brought to the rehabilitation team. This case study demonstrates that combining a scientifically based surgical technique with a tailored rehabilitation approach can achieve an improved outcome for the patient, by enabling him to return successfully to prosthetic limb use and resume his everyday activities with renewed enthusiasm.

This study was completed with full informed consent from the patient including the use of all relevant details and images. Ethical approval was not required.

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Author contribution

All authors contributed equally in the preparation of this manuscript.

Conflict of interest

The authors declare that there is no conflict of interest.

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