International Orthopaedics (2019) 43:1473–1478
https://doi.org/10.1007/s00264-018-4072-y

ORIGINAL PAPER

Minimally invasive treatment for fractures of lower extremity amputees using a rapid reductor

Shilun Li [1] · Yingchao Yin [1] · Ruipeng Zhang [1] · Wei Chen [1] · Yingze Zhang [1]

Received: 6 June 2018 / Accepted: 23 July 2018 / Published online: 30 July 2018

Abstract

Purpose A traction table is recommended for lower limb fractures, while it is unavailable for amputees to immobilize the ipsilateral foot to remain stationary and reduce the fracture. For these patients, our rapid reductor can be applied to guarantee stable fixation and optimal reduction, allowing satisfactory implant positioning. This study aims to evaluate the prognosis of amputee patients with lower limb fractures treated by minimally invasive techniques that employ a rapid reductor to reduce the fracture.

Methods Between 2013 and 2014, 11 cases of amputees suffering from a lower limb fracture were enrolled in the study, including four transtibial amputees with a tibial plateau fracture, three transtibial amputees with a femoral shaft fracture, and four transfemoral amputees with a femoral neck fracture. All fractures involved the amputated ipsilateral lower limbs, which were all reduced in a closed fashion using a rapid reductor. During the operation, the rapid reductor was connected to the injured limb for skeleton traction to reduce the fracture and then used to maintain the reduction for subsequent minimally invasive fixation. The operation time, reduction time, fluoroscopy time, and intra-operative blood loss were recorded. Follow-ups were conducted to evaluate the union of the fractures and the functional recovery.

Results All 11 cases were treated successfully using this minimally invasive technique, with anatomical or nearly anatomical reduction reached in all fractures. The average operative time, reduction time, fluoroscopy time, and intra-operative blood loss were 60 minutes (range, 46–90 minutes), 13.2 minutes (range, 7–20 minutes), 19.8 seconds (range, 6–65 seconds), and 95 mL (range, 80–170 mL), respectively. No incidents of reductor-induced complications occurred during the operation. Patients were followed up for an average of 20.8 months (range, 18–24 months). All fractures healed well on an average of six months. At the latest follow-up, all 11 cases reported satisfactory functional recovery of the fixed limbs, which were similar to that before the fractures.

Conclusions The rapid reductor can be used to efficiently reduce and maintain ipsilateral fractures of the amputated lower extremity in a closed fashion, which can facilitate minimally invasive fixation of the fractures. The patients can achieve excellent outcomes.

Keywords Lower limb amputees · Lower limb fractures · Traction reduction · Skeletal traction · Closed reduction · Internal fixation

✉ Yingze Zhang
dryzzhang@126.com

Shilun Li
lshilun@163.com

Yingchao Yin
dryingchao@gmail.com

Ruipeng Zhang
zhangruipengdoctor@126.com

Wei Chen
drchenwei@qq.com

1 Department of Orthopaedic Surgery, Third Hospital of Hebei Medical University, Shijiazhuang 050051, Hebei, China

Introduction

Fractures of the lower extremity are common. In cases suitable for internal fixation, the outcome is affected by patient-related factors, type of fracture, reduction technique, operation time, and rehabilitation. The ability to manipulate the fracture to realize anatomical or nearly anatomical reduction is a vital part of achieving excellent recovery among the factors above [1]. In the process, the setup should provide satisfactory reduction of the fracture through stable traction and specific surgical methods and also obtain intra-operative image-taking of the fracture [2]. Non-amputee lower limb fracture is usually manipulated on a traction table where the patient is positioned supine and the foot of the affected side is immobilized in a boot or a similar device to assist with reduction through traction [3]. However, in cases of amputees with an ipsilateral fracture, using a normal traction table is not possible, and a special instrument should be considered in the meantime.

To provide an appropriate reduction for lower limb amputees, the rapid reductor comes into service. Meanwhile, a matched technique of obtaining and maintaining reduction has been employed as a method to promote closed reduction and minimally invasive internal fixation of lower extremity fractures in amputees. This article evaluates the prognosis of leg amputees with lower limb fractures treated by closed reduction and minimally invasive internal fixation with the adoption of a rapid reductor.

Patients and methods

All amputee patients treated for lower limb fractures in the Department of Orthopaedic Surgery of our Hospital between 2013 and 2014 were collected in this study. Operators were all experienced orthopaedic doctors who had reduced lower limb fractures of non-amputees using the rapid reductor.

In total, 11 patients (11 fractures) complying with the inclusive criteria, including ten males and one female with an average age of 36 years (range, 29–52 years). Fracture patterns included four transtibial amputees with a tibial plateau fracture (Fig. 1), three transtibial amputees with a femoral shaft fracture (Fig. 2), and four transfemoral amputees with a femoral neck fracture (Fig. 3). At the time of hospitalization, pre-operative examination and preparation were given to patients. Surgery was performed two to five days after fracture.

The Institutional Review Board of the local hospital approved this study after a thorough examination. Signed informed consent was obtained from all patients. The study was performed in accordance with the ethical standards of the Declaration of Helsinki from 1964.

Surgical technique

The rapid reductor is primarily composed of a reduction scaffold, traction bow, traction pin, connecting rod, auxiliary reduction pin (Schantz pin or Kirschner wire), and proximal connecting device (Fig. 4a). Under spinal anesthesia, the patient was placed supine on the operating table with a soft cushion under them. Disinfection was prepared according to the surgical site.

The proximal traction site was ipsilateral femoral condyle for tibial plateau fractures, where traction with tension was conducted using a 2.5-mm Kirschner wire and traction bow. The distal traction pin was made into the distal stump in the same way. The connecting rod was designed adjustable to suit different patients and fixed into proper length during operation. The proximal end of the rod was connected to the proximal traction pin via a cardan shaft, and the distal end was connected to the reduction scaffold with height-adjustable legs straddling the stump. Traction was eventually performed by a rotary screw via the traction position on the scaffold to distal pin through traction bow (Fig. 1c). Once the connection of the reductor was secured, a closed-loop mechanical traction system was formed by connecting the proximal body and distal stump to the reductor. The reduction is performed by the rapid reductor under fluoroscopic guidance of the C-arm on anteroposterior (AP) and lateral views. The crossbeam on the end of the scaffold, together with the reductor screw attached to, could rotate around its long axis and pull the stump distally to reduce the overlapping displacement of the fracture and provide traction and rotational control of the reduction.

In cases of the other two types of fractures for lower limb amputees, the proximal traction site was ipsilateral anterior superior iliac spine (ASIS) (Fig. 2d). For transfemoral amputees, the distal traction site was the distal stump (Fig. 3c), and for femoral shaft fractures in transtibial amputees, condyles of the femur could also be chosen to avoid extension of the knee joint in some higher shaft fractures (Fig. 2c).

There were stationary vertically drilled holes and sliding bilateral frames on the connecting rod. Anterior-posterior displacement could be reduced by accommodating a lag screw or Kirschner wire through the holes on the rod. A Schantz pin or Kirschner wire was inserted through a tapped hole on the lateral frame into the femur to reduce lateral displacement with a "joy stick" technique (Fig. 4b). For fractures with rotational deformities, the traction bow could be rotated accordingly to facilitate reduction.

After satisfactory reduction revealed by the examination of the C-arm, internal fixation via minimally invasive approaches was performed to reduce the fractures. Femoral neck fractures were managed with cannulated screws. Suitable intramedullary (IM) nails were implanted to fix femoral shaft fractures. Tibial plateau fractures were treated with minimally invasive bone tamp reduction, allograft, and percutaneous screw fixation. The operative time, reduction time, fluoroscopy time, and intra-operative blood loss were recorded.

Post-operative management

Patients received postoperative antibiotics and anticoagulant therapy after surgery. The evaluations of the reduction and fixation quality of the fractured limb depended on reviews of the X-ray. Isometric quadriceps exercises were suggested on the first day, and crutch or prosthesis assisted walking without burden on the second day. Weight-bearing of the affected leg began six weeks post-operatively after callus formation, gradually from partly to fully.

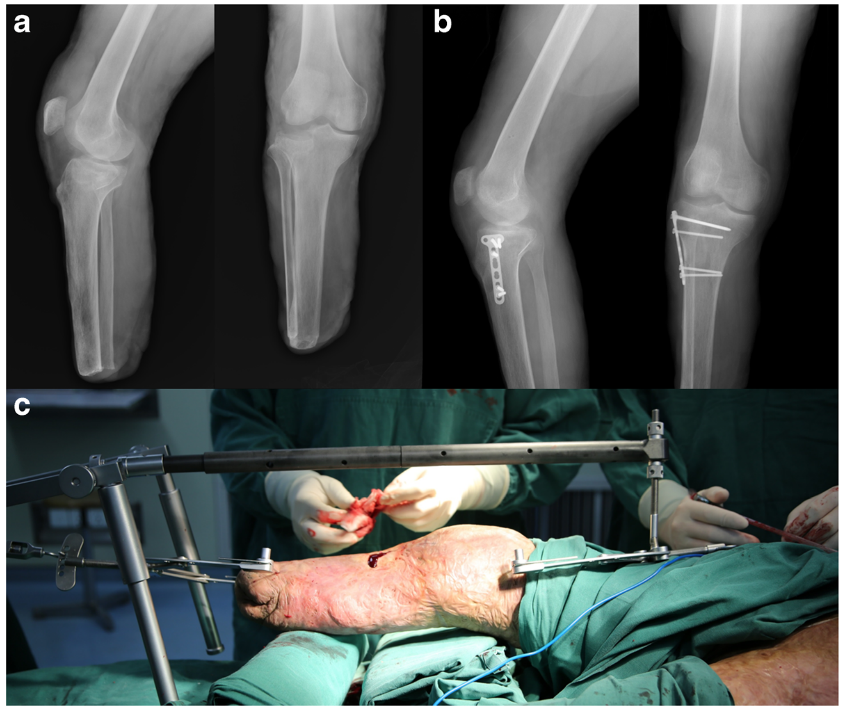

Fig. 1 A 29-year-old male transtibial amputee with a right tibial plateau fracture. **a** Pre-operative AP and lateral view. **b** Postoperative AP and lateral view. **c** The connection of the rapid reductor during operation

Full weight-bearing was usually allowed 3 months postoperatively, according to radiographic assessment. Patients were followed up at one, three and six months after surgery and every half year since then. Radiological and clinical evaluations were performed at each follow-up.

Results

With no case turning to open reduction, closed minimally invasive reduction and fixation were performed in 11 patients with the use of the rapid reductor. For amputee patients with

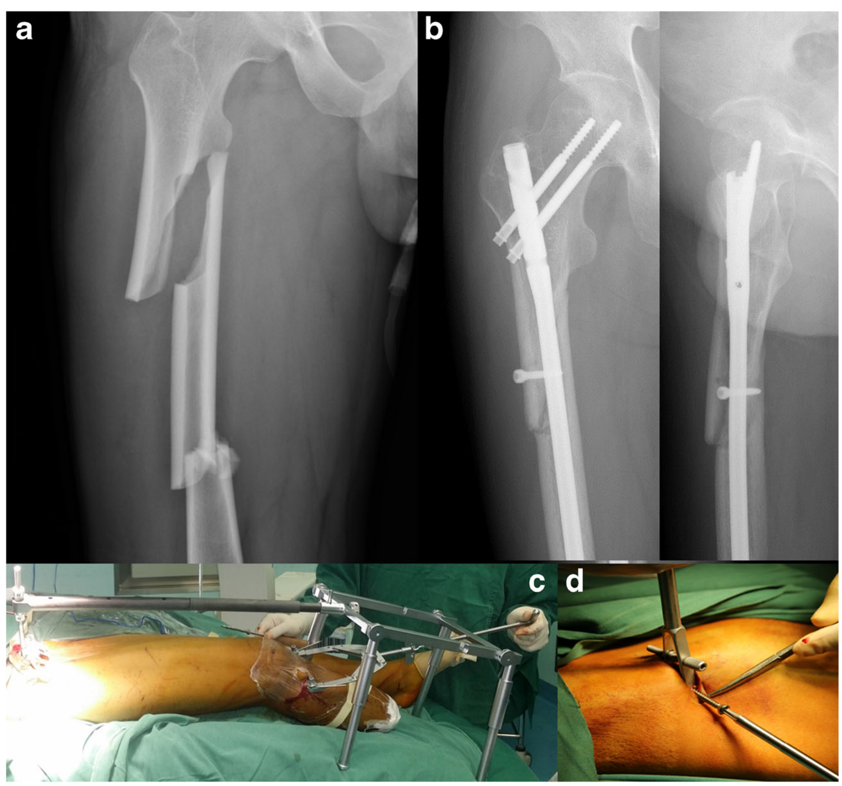

Fig. 2 A 35-year-old male transtibial amputee with a right femoral shaft fracture. **a** Pre-operative AP view. **b** Post-operative AP and lateral view. **c** The connection of the rapid reductor during operation. **d** The proximal traction site was ASIS for femoral shaft fractures

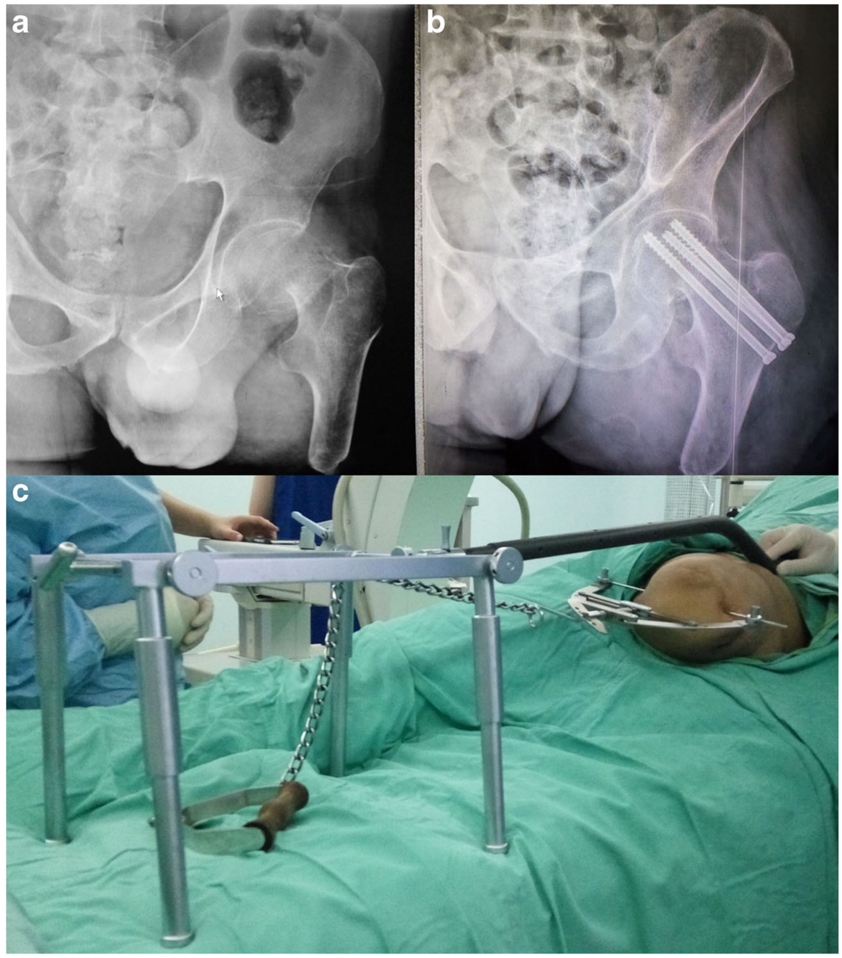

Fig. 3 A 52-year-old male transfemoral amputee with a left femoral neck fracture. **a** Pre-operative AP view. **b** Post-operative AP view. **c** The connection of the rapid reductor during operation

ipsilateral lower limb fractures, the rapid reductor can provide reduction maintenance during the corresponding minimally invasive internal fixation procedure. Afterwards, excellent alignment was exhibited on the affected side, and no inadequate reduction or angular deformity was shown on the fluoroscopic images. Anatomical or nearly anatomical reduction was reached in all 11 cases, with AP and lateral radiographs revealing excellent reduction and fixation. No clinical

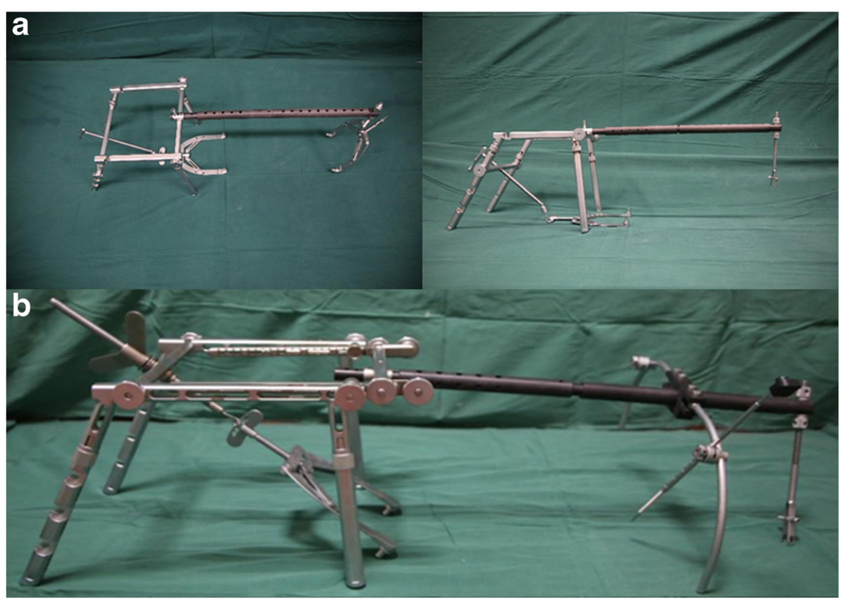

Fig. 4 The rapid reductor. **a** Overlooking and lateral view. **b** Rapid reductor with a lateral frame to reduce lateral displacement

complications occurred in any of the cases. The average operative time, reduction time, fluoroscopy time, and intra-operative blood loss were 60 minutes (range, 46–90 minutes), 13.2 minutes (range, 7–20 minutes), 19.8 seconds (range, 6–65 seconds), and 95 mL (range, 80–170 mL), respectively. All operations were performed without reductor-induced complications, such as neurovascular injury or ilium splitting caused by Schantz pin.

Eleven patients were followed up for an average of 20.8 months (range, 18–24 months). All fractures healed well on an average of six months (range,four to nine months). Deep vein thrombosis was found in the thigh of one transtibial patient. Neither superficial incision infection nor deep tissue infection occurred. No patients suffered malunion or non-union post-operatively. None requested further treatment or operation.

Discussion

We have used the rapid reductor to successfully treat four transtibial amputees with a tibial plateau fracture, three transtibial amputees with a femoral shaft fracture, and four transfemoral amputees with a femoral neck fracture. Considering that the affected side was retained as much as possible as a principle of amputation [4], transtibial amputees are more common in our practice. No complications have been encountered related to the application of the rapid reductor.

Fractures in the lower extremities are common but not frequently seen in a residual limb. Therefore, these cases are reported sporadically in the literature [5–7], with few pieces of information regarding the management of fractures in patients with ipsilateral above or below knee amputations.

Researchers have shown that amputees exhibit large decreases in bone mineral density (BMD) [8, 9], both at the hip and at the end of the residual limb compared with the contralateral side, which put amputees at increased risk for fragility fractures in the stump. In addition, individuals with lower extremity amputations have difficulty standing with one leg, turning around, and performing sit to stand with assistance [10]. In conclusion, with a lack of coordination when standing or performing simple activities, increased metabolic cost of ambulation and affected limb predispose to osteoporosis associated with a lower extremity amputation [11], lower extremity amputees are usually prone to suffer an ipsilateral fracture of the residual limb.

Some doctors suggest that conservative treatment should be provided for most amputees with fractures [5], as the use of these methods avoids malunion and intra-articular complications. The limitations of conservative treatment are ineffective limb alignment control, inadequate reduction of the fracture, and prolonged hospitalization and rehabilitation, which cause muscle atrophy and restricted range of movement. Operative treatment restores articular congruity, axial alignment, and joint stability and enables early mobilization while decreasing the risk of post-traumatic arthritis [12]. In our study, the patients were of an average age of 36 years (range, 29–52 years). We ruled out conservative treatment to prevent functional deterioration in relatively young patients, who were usually suitable for reduction and fixation of the fractures.

Special challenges are presented in the operative management of amputee patients who require internal fixation of their fractures. Limbs that have undergone a transfemoral or transtibial amputation can have stumps that can be very challenging to position or apply any manipulation. The positioning of the patient on the operating table is critical to the successful reduction and operative fixation of the fracture [7]. Traditional traction table can securely fasten the foot of the affected side in a traction boot or a similar device with the lower limb-fractured patient positioned supine. Skin traction is given to reduce the fractured limb. This standard setup is quick and is achievable with relative convenience in patients with intact lower limbs.

For amputees with an ipsilateral fracture, securing the amputated limb on a traction table poses a challenge, and in most situations, a traction table is not possible, and a special instrument should be considered in the meantime.

In some cases, adhesive fabric tape and a crepe bandage were used circumferentially around the distal stump to secure the limb to the foot piece of the traction table or the distal end of the fracture table [13], and then skin traction was applied in a similar manner of the non-amputees. Stumps in these trials could not be fixed as firmly as skeleton traction, most of whom provided the traction force of a certain direction with a lack of rotational control when reducing the fractured limb. If significant traction and rotation control were needed for the reduction and fixation of these fractures, the use of skeletal pin traction may be necessary [7]. Other authors tried to use skeleton traction with different types of devices. Berg et al. [3] built an improvised extension with all the available clamps connected to traction bow to provide traction. McCabe et al. [14] set up a traction apparatus for transfemoral amputees in a familiar way with the assistance of fracture table. All the methods applied by the above authors utilized temporary devices, which demanded prolonged operating time to dispose accordingly, providing traction in only one direction without a proximal traction site and potentially compromising the visibility or scope of operation.

The rapid reductor connected the ASIS to the distal stump with Schantz pins via connecting rod, traction bow, and scaffold, forming a mechanical closed-loop system and providing two-way traction. Enormous force can be generated by skeleton traction through the rapid reductor to reduce displaced fragments of the lower limb more efficiently. In the traditional traction table, a perineum post is employed to counteract the stress of the traction, and multiple traction table-related complications occur. The rapid reductor can resist the pulling force through the connecting rod and avoid the above disadvantages. Chen et al. [1] compared the traction table-based reduction with the rapid reductor when treating femoral shaft fractures using the IM nailing technique. As a result, the rapid reductor makes it easier to perform and more effective to reduce the fracture and maintain its realignment, with a shorter operative time, fluoroscopy time, and less blood loss. Furthermore, each rapid reductor set costs approximately $600, which can be equipped by primary hospitals as well.

Meena et al [6]. preferred closed reduction but ended up with reducing the fracture under direct vision because of the lack of adequate traction with the absence of the distal limb. Overlapping, anterior-posterior, and lateral displacement can all be reduced by the rapid reductor, especially for femoral shaft fractures, via traction and the Schantz pin inserted with a joystick technique. Moreover, rotating the traction bow inward or outward can reduce rotational deformities. In all our cases, closed reduction and minimally invasive internal fixation can be achieved with the use of the rapid reductor, and no case turned into open reduction. Afterwards, excellent alignment was exhibited on the affected side, and no inadequate reduction or angular deformity was shown on the fluoroscopic images. No clinical or reductor-induced complications occurred. In the follow-up stage, no patients suffered malunion or non-union, with no further treatment or operation requested.

There are several limitations of the study. Ipsilateral fractures in lower limb amputees are uncommon; as a result, the amount of the sample size is relatively small. Meanwhile, considering the unstable fixation of the traction table and the large invasion of open reduction, the fractures were not treated by traction table-based reduction or open reduction as a control group.

Conclusion

Lower limb fractures in amputees can be treated by rapid reductor-assisted closed reduction and minimally invasive internal fixation. The rapid reductor can both efficiently reduce and maintain ipsilateral fractures in lower extremity amputees. This latest technique is convenient to perform with satisfactory functional recovery and decreased complications.

Funding information This study was financially supported by the Youth Science and Technology Project of Hebei Provincial Health and Family Planning Commission (Grant no. 20180429).

Compliance with ethical standards

The Institutional Review Board of the local hospital approved this study after a thorough examination. The study was performed in accordance with the ethical standards of the Declaration of Helsinki from 1964.

Conflict of interest The authors declare that they have no conflict of interest.

Statement of informed consent Signed informed consent was obtained from all patients.

References

1. Chen W, Zhang T, Wang J et al (2016) Minimally invasive treatment of displaced femoral shaft fractures with a rapid reductor and intramedullary nail fixation. Int Orthop 40(1):167–172. https://doi.org/10.1007/s00264-015-2829-0
2. Alharthy A, Abed R, Campbell AC (1997) Manipulation of hip fracture in the below-knee amputee. Injury 28(8):570
3. Berg AJ, Bhatia C (2014) Neck of femur fracture fixation in a bilateral amputee: an uncommon condition requiring an improvised fracture table positioning technique. BMJ Case Rep 2014. https://doi.org/10.1136/bcr-2013-203504
4. Russek AS (1961) Management of lower extremity amputees. Arch Phys Med Rehabil 42:687–703
5. Boussakri H, Alassaf I, Hamoudi S et al (2015) Hip arthroplasty in a patient with transfemoral amputation: a new tip. Case Rep Orthop 2015:1–5. https://doi.org/10.1155/2015/593747
6. Meena U, Meena R, Balaji S et al (2015) Management of neglected femoral neck fracture in above knee amputated limb: a case report. Chin J Traumatol 18(6):370–372
7. Davarinos N, Ellanti P, McCoy G (2013) A simple technique for the positioning of a patient with an above knee amputation for an ipsilateral extracapsular hip fracture fixation. Case Rep Orthop 2013:1–3. https://doi.org/10.1155/2013/875656
8. Kandel L, Hernandez M, Safran O et al (2009) Bipolar hip hemiarthroplasty in a patient with an above knee amputation: a case report. J Orthop Surg Res 4(1):30. https://doi.org/10.1186/1749-799X-4-30
9. Sherk VD, Bemben MG, Bemben DA (2008) BMD and bone geometry in transtibial and transfemoral amputees. J Bone Miner Res 23(9):1449–1457. https://doi.org/10.1359/jbmr.080402
10. Wong CK, Chen CC, Welsh J (2013) Preliminary assessment of balance with the Berg balance scale in adults who have a leg amputation and dwell in the community: Rasch rating scale analysis. Phys Ther 93(11):1520–1529. https://doi.org/10.2522/ptj.20130009
11. Amanatullah DF, Trousdale RT, Sierra RJ (2015) Total hip arthroplasty after lower extremity amputation. Orthopedics 38(5):e394–e400. https://doi.org/10.3928/01477447-20150504-56
12. Sament R, Mayanger JC, Tripathy SK et al (2012) Closed reduction and percutaneous screw fixation for tibial plateau fractures. J Orthop Surg (Hong Kong) 20(1):37–41. https://doi.org/10.1177/230949901202000108
13. Edwards DS, Langdown AJ, Gandhe AJ (2013) Simple, cheap and non-invasive intraoperative traction of the femur in amputees. Ann R Coll Surg Engl 95(3):225. https://doi.org/10.1308/rcsann.2013.95.3.225
14. McCabe MP, Davila J (2015) Hip arthroscopy in patients with lower-extremity amputations: patient positioning and traction technique. Arthrosc Tech 4(6):e775–e779. https://doi.org/10.1016/j.eats.2015.07.026