Injury, Int. J. Care Injured xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Reimplantation of an extruded osteoarticular segment of the femur: Case series and in vitro study in a rat model

Tao Li[a,1], Ze Z. Yang[a,1], Ming Z. Peng[a], Xiao J. Zhou[a], Zhi Y. Liu[a], Bi Y. Rui[b], Qi Li[b], Shang C. Guo[b], Ming Xiao[a,*], Jin W. Wang[a,*]

[a] Shanghai Key Laboratory of Orthopaedic Implant, Department of Orthopaedic Surgery, Shanghai Ninth People's Hospital Affiliate to Shanghai Jiao Tong University School of Medicine, Shanghai, China
[b] Shanghai Sixth People's Hospital Affiliate to Shanghai Jiao Tong University School of Medicine, Shanghai, China

ARTICLE INFO

Keywords:
Trauma
Extruded osteoarticular segment
Femur
Re-implantation

ABSTRACT

Background: The treatment of open femur fractures with reimplantation of large extruded segments remains one of the most difficult clinical management scenarios. The situation is even complicated when the extruded segments contains a large osteoarticular segment and no consensus exist about the efficient sterilization. We successfully managed five cases of open femur fracture by reimplantation of a large osteoarticular segment. While the outcomes were favourable, we performed an in vitro investigation in a rat model to determine whether the bone segment preparation strategy was optimal.
Materials and methods: After meticulous debridement and sterilization with povidone-iodine scrub/orthopaedic antibiotic solution, osteoarticular segments of the femur were reimplanted successfully in five patients with Gustilo-Anderson IIIa-IIIb fractures. Furthermore, in vitro study performed to assess the relative efficacy of various methods of sterilization employed osteoarticular segments of rat femurs. After contamination, osteoarticular segments were treated via one of the following protocols: (1) saline rinse; (2) povidone-iodine scrub and saline rinse; (3) povidone-iodine scrub and autoclaving; (4) povidone-iodine scrub and immersion in antibiotic solution; (5) povidone-iodine scrub and immersion in povidone-iodine solution; or (6) povidone-iodine scrub and gamma-irradiation. The osteoarticular segments were then cultured and finally evaluated for infection and morphological changes.
Results: At the mean 40 month follow-up, there were no infection in the patients and the fractures achieved completed union. For the basic research, only approaches involving povidone-iodine scrub with autoclaving or antibiotic solution immersion were 100% effective in eliminating bacterial growth. Furthermore, povidone-iodine scrub with antibiotic solution immersion preserved the articular surface morphology.
Conclusion: Our study suggests that reimplantation of extruded osteoarticular segments of long bone may represent a feasible alternative to amputation. This is the first description of such a technique and its long-term outcomes in the clinical setting, which were corroborated with the outcomes of in vitro investigation in a rat model, concluding that contaminated extruded osteoarticular segments can be adequately sterilized for reimplantation by cleaning with povidone-iodine scrub followed by brief soaking in antibiotic solution. However, it remains unclear whether the antibacterial efficacy of different sterilizations noted in vitro is reflected in vivo, warranting further research.

Introduction

In patients with open fracture of the femur, extruded bone tissue from the diaphyseo-metaphyseal junction manifests as a rare complication of high-energy trauma, representing a considerable challenge for reconstructive surgery [1]. If the extruded segment of bone is available, reimplantation may achieve several important benefits including maintaining the length of the skeletal and soft tissues surrounding the fracture site, averting the morbidity

* Corresponding authors at: Room 701, No.3 Building, 639 Zhizaoju Road, Shanghai 200011, China.
E-mail addresses: xiaoming_xm531@163.com (M. Xiao), jinwuwang123@sina.com (J.W. Wang).
[1] These authors contributed equally to this work.

https://doi.org/10.1016/j.injury.2017.09.024
0020-1383/

associated with autograft harvest, and obviating the need for allograft bone or prolonged bone transport procedures [2,3]. However, adverse events may occur, such as infection (with high risk) or fracture union failure, requiring secondary procedures for treatment. Since the earliest report in 1965 by Kirkup, there are just a handful of papers describing cases that involved replacement of an extruded femoral segment [4–7]. Previous reports have described various sterilisation methods before reimplantation of the extruded bone, including thermal, chemical, or gamma irradiation methods [2]. However, because of the relative rarity of this clinical scenario, there is no established protocol or consensus regarding key aspects such as the timing of reimplantation, stabilization of extruded bone segments, or bone disinfection and sterilization techniques [4]. Moreover, although there are case reports describing the successful reimplantation of extruded femur segments, the articular surface was not affected in any of these previously reported cases. Finally, only one report described the reimplantation of a large extruded osteoarticular segment, namely a segment of the distal tibia in a 14-year-old girl [8]. When attempting reimplantation of an extruded femur fragment containing a large osteoarticular segment, the orthopaedic surgeon should take into consideration not only the high risk of infection and non-union, but also that preserving the chondrocytes at the articular surface is essential for prognosis [8]. Therefore, it is of key importance to determine the best method for cleaning the contaminated bone fragments containing large osteoarticular segments and to ensure the preservation of cell vitality in the cartilage.

Here we reported 5 patients presenting with an open fracture of the femur and an extruded osteoarticular segment ranging from 8-cm to 15-cm that had been completely extruded from the thigh. Although good outcomes were achieved after cleaning and reimplantation of the extruded bone segment, in retrospect, it was questioned whether or not the best method of cleaning had been chosen. Therefore, the present study was undertaken to evaluate the efficacy of several methods for sterilizing the contaminated bone segments and preserving the biological activities of the cartilage.

Materials and methods

Case series

The clinical data of 3 male and 2 femal who were brought to the emergency department from May 2005 to September 2013 were retrospectively reviewed. The injury details of the patients are listed in Table 1. Upon presentation, long segment of extruded femurs ranging from 8 cm–15 cm wrapped in saline-soaked gauze was provided by the rescuers, who had recovered the bone tissues from the scene of the accidents. The patients were conscious, alert, and well oriented, with stable vitals. The major injuries were isolated to the legs. Radiographs revealed an 8 cm–15 cm defect of the femur diaphysis and the concomitant fractures (Fig. 1). Upon examination, the patients were found to have a 6 cm–12 cm long laceration on anterior or lateral aspects of knee, just directly superior to the patella. The limbs had noticeable thigh shortening with exposure of the broken aspect of the femur and tendon. The injured legs were found to be without neurovascular compromise, as the patients had intact dorsalis pedis and posterior tibial pulses, as well as intact sensation to light touch in all aspects of the lower legs.

Initial treatment consisted of intravenous antibiotic therapy with cefuroxime, gentamicin, and metronidazole, per the hospital's protocol. Then, the wound was thoroughly debrided and irrigated with copious amounts of saline and 10% povidone-iodine solution to remove visible debris (Fig. 2A). Simultaneously, the retrieved bone segment, including the osteochondral surface, was washed with copious amount of normal saline to remove visible contaminants, followed by multiple rinses with rifampicin solution (Fig. 2B). Then an "S" or longitude surgical wound extensions (12 cm–14 cm) was surgically applied to the wound at the primary site of laceration. The extruded bone fragment was inserted into the defect of the distal femur, aligned anatomically, and locked in place by fixation of the remaining segment of the metaphysis to the femoral diaphysis using lag screws (Fig. 2C). In the same sitting, internal fixation of the comminuted distal femoral fracture was achieved using distal femoral locking plate (PERI-LOC; Smith & Nephew, Andover, MA, USA). Next, the extruded patella was anatomically aligned with the remaining part and fixed with horizontal screws or using cerclage. The joint capsule was repaired and stitched to the tibia and femoral quadriceps tendon using suture anchors (G4; Depuy Mitek, Inc, Raynham, MA, USA). Then, the open wound over the thigh was sutured primarily (Fig. 2D). All patients received intravenous antibiotics treatment after primary surgery, and took oral antibiotics after they were discharged for two weeks. The patients were followed up at monthly intervals. Weight bearing was allowed after 12 weeks.

Basic research

Specific pathogen-free grade, 8-week-old male Sprague Dawley rats (weight, 320 ± 22.52 g) were randomly assigned to six groups defined in terms of the sterilization procedure applied to the extruded bone fragment. The experimental protocols were approved by the Animal Ethics Committee of Shanghai Ninth People's Hospital, and all procedures were performed in accordance with the appropriate guidelines. Anaesthesia was induced by intraperitoneal injection of 1% pentobarbital sodium (100 mg/kg of body weight). The inner sides of the hind legs were shaved and wiped with 10% povidone-iodine solution, followed by cleaning with 70% ethanol prior to the procedure. A skin incision was made along the lateral side of the thigh, and the femoral condyles were extracted through blunt dissection. After the procedure, the rats were sacrificed by means of an intracardiac barbiturate injection. The bones obtained were cleaned of soft tissue, the femoral condyles were cut using a low-speed separating disc under saline irrigation, and each was divided into four equal pieces. A total of 72 bone specimens were obtained from 18 rat

Table 1
Injury details of the patients.

Case	No.1	No.2	No.3	No.4	No.5
Injury side	Right	Right	Right	Right	Left
Gender	Female	Male	Male	Male	Female
Age (year)	36	49	53	51	48
Etiology	Fall from height	Traffic accident	Traffic accident	Collapse of wall	Traffic accident
Length of extruded fragment (cm)	14	12	15	11	8
Other injuries	0	Patellar fracture	Patellar fracture	0	Patellar fracture
Fracture classification (Gustilo-Anderson)	IIIa	IIIa	IIIb	IIIa	IIIb

Please cite this article in press as: T. Li, et al., Reimplantation of an extruded osteoarticular segment of the femur: Case series and in vitro study in a rat model, Injury (2017), https://doi.org/10.1016/j.injury.2017.09.024