Balloon osteoplasty—a new technique for reduction and stabilisation of impression fractures in the tibial plateau: A cadaver study and first clinical application

Philipp Ahrens · Gunther Sandmann · Jan Bauer · Benjamin König · Frank Martetschläger · Dirk Müller · Sebastian Siebenlist · Chlodwig Kirchhoff · Markus Neumaier · Peter Biberthaler · Ulrich Stöckle · Thomas Freude

Received: 3 April 2012 / Accepted: 29 May 2012 / Published online: 24 June 2012
© Springer-Verlag 2012

Abstract

Purpose Fractures of the tibial plateau are among the most severe injuries of the knee joint and lead to advanced gonarthrosis if the reduction does not restore perfect joint congruency. Many different reduction techniques focusing on open surgical procedures have been described in the past. In this context we would like to introduce a novel technique which was first tested in a cadaver setup and has undergone its successful first clinical application.

Methods Since kyphoplasty demonstrated effective ways of anatomical correction in spine fractures, we adapted the inflatable instruments and used the balloon technique to reduce depressed fragments of the tibial plateau.

Results The technique enabled us to restore a congruent cartilage surface and bone reduction.

Conclusions In this technique we see a useful new method to reduce depressed fractures of the tibial plateau with the advantages of low collateral damage as it is known from minimally invasive procedures.

Introduction

Tibial plateau fractures are often related to osteoporosis or high-impact injuries. In this context surgical procedures must follow the demographic changes and the increased physical activity of elderly people. In past decades, open reduction techniques for tibial plateau fractures have provided adequate results, but are associated with the disadvantage of an arthrotomy and prolonged rehabilitation and severe collateral damage. Tibial depression fractures are amongst the most difficult to reduce and require highly

P. Ahrens and G. Sandmann have contributed equally to this study.

P. Ahrens (✉) · G. Sandmann · F. Martetschläger · D. Müller · S. Siebenlist · M. Neumaier · P. Biberthaler
Department Traumatology, Technical University,
Ismaningerstr. 22,
81675 Munich, Germany
e-mail: ph.ahrens@gmail.com

J. Bauer · C. Kirchhoff
Department of Orthopaedic Surgery, Klinikum rechts der Isar,
Technische Universität München,
Ismaningerstrasse 22,
81675 Munich, Germany

J. Bauer
Department of Radiology, Klinikum rechts der Isar,
Technische Universität München,
Ismaningerstrasse 22,
81675 Munich, Germany

B. König
Department of Traumatology, BG Clinic Tübingen,
Technische Universität München,
Schnarrenbergstrasse 95,
72076 Tübingen, Germany

B. König · U. Stöckle · T. Freude
Department of Traumatology, BG Clinic Tübingen,
Eberhard Karls Universität Tübingen,
Schnarrenbergstrasse 95,
72076 Tübingen, Germany

C. Kirchhoff
Department of Trauma Surgery, Klinikum rechts der Isar,
Technische Universität München,
Ismaningerstrasse 22,
81675 Munich, Germany

Fig. 1 *Left*: fenestrated cannula. *Right*: inflated balloon, notice the directed expansion

trained surgeons to restore acceptable joint congruency with varying results [1–4]. In this context we would like to introduce a novel technique for minimally invasive fracture reduction which was tested in a cadaver setup and used later in some clinical cases. Observing the literature of recent decades, it can be stated that many attempts have been made to restore joint congruency to avoid further degenerative changes and accelerated gonarthrosis [1, 5–7]. The most usual technique involves open procedures with retrograde elevation through tibial windows and screw fixation or metal plates and filling the defects with autologous cancellous graft [2, 3, 5, 6, 8–11]. Regrettably, many of the reduction techniques are imprecise and lead to major difficulties with regard to failed treatment [12]. In this context, the reduction of tibial plateau fractures is always a challenge and less invasive methods have to be developed. As we have learned from balloon kyphoplasty, even split and cracked vertebral fractures can be reduced and stabilised using the so-called egg-shell technique. We adapted the procedure to reduce Schatzker type III depression fractures of the lateral tibial plateau and stabilised the reduced fragments using bone cement which was forced into the resulting cavity.

Methods

In this cadaver study we used three pairs of fresh full lower leg specimens. To break the rigor mortis each limb underwent ten cycles of passive maximum flexion and extension before the specimens were fixed into a bench device. Inclusion criteria were the external and internal integrity of the knee with no fractures, no signs of osteoarthritis and no previous ligamentous instability or knee surgery. A

computed tomography (CT) scan of each knee was performed before and after creating the fracture and after the balloon osteoplasty procedure (BOP). After a standard arthrotomy and mediatisation of the patella, we created a lateral depression fracture zone using a metal punch after osseus perforation of a standardised in the main weight-bearing area. Using this setup we always achieved Schatzker type III fractures with a broad depressed area. With the specimen placed into the bench we placed a K-wire under fluoroscopic control 3 mm below the centre of the depression area and inserted our custom-built Jamshidi needle to pave the way for the inflatable balloon. This setup was performed only in the cadaver study since the modified Jamshidi needle has no FDA or CE approval. We chose the approach through the tibial tuberosity knowing that this is the most stable osseus region which provides good abutment for the guiding cannula. The Jamshidi needle was modified with a fenestration at the distal end of the cannula, where the expanding balloon can emerge and elevate the fragment above. Another advantage of this device is that the cannula allows steering manoeuvres of the balloon and that the cannula could be used as an abutment by placing the distal end into the cancellous bone (Figs. 1, 2 and 3). We then used the KyphX Xpander® balloon catheter and inflated the device to the maximum of 160 psi with amidotrizoic acid (Gastrografin, Schering, Berlin, Germany). Under both fluoroscopic and arthroscopic control the elevation of the depressed area could be observed. We then used a staged approach starting the reduction in the centre of the fracture. After deflation we guided the fenestration of the cannula like a steering wheel to reach the more remote areas of the fracture and repeated the procedure. With this approach the whole depression area was easily reducible regardless of the fracture

Fig. 2 CT scans showing the situation before the plateau fracture, after creating the fracture and after reduction with cement augmentation

Fig. 3 Intraoperative fluoroscopy presenting the creation of an eggshell and cement augmentation for stabilising the depression fracture

shape. We elevated the fracture plateau 1 mm over the anatomical joint surface and reduced the fragment by slow knee motion. This technique provided a self-reduction of the fracture and tended to produce the best results, with a congruent joint line. As a third step we then injected 1 ml of bone cement (KyphX® HV-R™ bone cement) and reinserted the catheter (KyphX Xpander® balloon catheter), inflated the device gently and pushed the cement into the surrounding cancellous bone. After the polymerisation time, cement was injected again to stabilise the created eggshell (Fig. 3). Afterwards, we deflated the balloon and pulled out the cannula. Another CT scan was performed and an arthroscopic view of the joint line confirmed the visible congruence of the joint line. Furthermore, we did not notice any cement leakage into the joint gap.

Clinical case

We admitted a 70-year-old lady after a bicycle accident with direct impact to the right knee and persistent,

severe pain. In the clinical examination marked swelling, effusion and pain around the proximal tibia were found. X-rays in anteroposterior and lateral views were taken and after identification of a tibial plateau fracture, a CT scan completed the diagnostic process. The patient was transferred to the ward and received thrombosis prophylaxis and analgesics. Based on the Schatzker classification, a type II fracture (AO 41-B3.3) was found and preparations were made for surgical intervention after reduction of the soft tissue swelling. After an anterolateral approach the lateral fragment was mobilised and gently reduced to the main part of the tibial plateau. To reduce the depressed fragment, which was 13 mm lower than the main joint block, one Kyphon Exact catheter was used for the reduction of the fragment. After withdrawal of the catheter, two K-wires were placed to temporarily fix the fragment. Thereafter, the lateral fragment was reduced and fixed with an angular stable plate.

Postoperatively, the reduction was checked by X-rays and a CT scan of the knee, which showed congruency of the joint

Fig. 4 A 70-year-old woman after a bicycle accident. Preoperative X-rays and CT scan showing the Schatzker type II fracture. Intraoperative augmentation using the inflatable balloon. After reduction, the fracture is fixed by temporary K-wires. Postoperative X-rays and CT scan showing the anatomical reduction and the osteosynthesis with two screws (7.0 mm) and a lateral locking compression plate (LCP)

line. The patient was mobilised under partial weight-bearing (15 kg) and was discharged seven days after surgery (Fig. 4).

Discussion

Tibial plateau depression fractures usually occur in osteopaenic and older persons [13, 14] so many attempts have been made to reduce the surgical impact on the joint and individual [15, 16]. The reduction of tibial depression fractures is a challenge demanding highly skilled surgeons [17] but may be more easily achieved using inflatable tamps as have been described in numerous other fields [18–21]. With this minimally invasive surgical technique, a reduction with less collateral damage and reduced convalescence is possible. We used the described technique first in a cadaver setup and later in some clinical cases and achieved very promising results. However, since the number of treated patients is low we are looking forward to applying this technique more often. The modifications of the cannula as used it in the cadaver setup allowed highly exact and reproducible placement of the inflatable device and the handling was also easier than using K-wires for the abutment. Additionally, the eggshell technique also seems to be a reliable method to avoid cement leakage into the joint gap and permits stable augmentation of the fragment. It is questionable if the created cancellous cavity needs to be filled with either biological material [22, 23] or bone cement to support the stability of the fracture or if limited weight-bearing after eggshell osteoplasty alone is sufficient. Since we always supported our reduction with a plate and screws we could also imagine a stable situation while using only two screws directly under the cortex [24] of the fractured zone in young and compliant patients. If this method is applied the procedure will become a completely minimally invasive technique. Rather than bone cement we recommend absorbable material to limit complications if knee arthroplasty should become necessary. Further work is needed to assess long-term outcomes and to identify the most suitable fracture types while improved instruments will facilitate the implementation.

Conflict of interest We did not receive material funding from a third party. The authors declare that they have no conflict of interest.

References

- Burri C, Bartzke G, Coldewey J, Muggler E (1979) Fractures of the tibial plateau. *Clin Orthop Relat Res* 138:84–93
- Boisrenoult P, Bricteux S, Beaufils P, Hardy P (2000) Screws versus screw-plate fixation of type 2 Schatzker fractures of the lateral tibial plateau. Cadaver biomechanical study. *Arthroscopy French Society. Rev Chir Orthop Reparatrice Appar Mot* 86 (7):707–711
- Gordán F, Tóth K (1993) Experience with the surgical management of fractures of the tibial head. *Magy Traumatol Ortop Kezseb Plasztikai Seb* 36(4):305–311
- Caspari RB, Hutton PM, Whipple TL, Meyers JF (1985) The role of arthroscopy in the management of tibial plateau fractures. *Arthroscopy* 1(2):76–82
- Bauer J, Vanicky D, Klima M (1975) Conservative and surgical management of new tibial-head fractures. *Hefte Unfallheilkd* 126:245–246
- Krieg H, Chmielewski W, Sarvestani H (1975) Management of impression fractures of the tibial head using plate osteosynthesis. *Hefte Unfallheilkd* 126:256–257
- Tscherne H, Lobenhoffer P (1993) Tibial plateau fractures. Management and expected results. *Clin Orthop Relat Res* 292:87–100
- Cift H, Cetik O, Kalaycioglu B, Dirikoglu MH, Ozkan K, Eksioglu F (2010) Biomechanical comparison of plate-screw and screw fixation in medial tibial plateau fractures (Schatzker 4). A model study. *Orthop Traumatol Surg Res* 96(3):263–267
- Duan XJ, Yang L, Guo L, Chen GX, Dai G (2008) Arthroscopically assisted treatment for Schatzker type I–V tibial plateau fractures. *Chin J Traumatol* 11(5):288–292
- Egol KA, Tejwani NC, Capla EL, Wolinsky PL, Koval KJ (2005) Staged management of high-energy proximal tibia fractures (OTA types 41): the results of a prospective, standardized protocol. *J Orthop Trauma* 19(7):448–455, discussion 456
- Koval KJ, Helfet DL (1995) Tibial plateau fractures: evaluation and treatment. *J Am Acad Orthop Surg* 3(2):86–94
- Berkson EM, Virkus WW (2006) High-energy tibial plateau fractures. *J Am Acad Orthop Surg* 14(1):20–31
- Hsu CJ, Chang WN, Wong CY (2001) Surgical treatment of tibial plateau fracture in elderly patients. *Arch Orthop Trauma Surg* 121(1–2):67–70
- Gerich T, Blauth M, Witte F, Krettek C (2001) Osteosynthesis of fractures of the head of the tibia in advanced age. A matched-pair analysis. *Unfallchirurg* 104(1):50–56
- Ballmer FT, Hertel R, Nötzli HP (2000) Treatment of tibial plateau fractures with small fragment internal fixation: a preliminary report. *J Orthop Trauma* 14(7):467–474
- Holzach P, Matter P, Minter J (1994) Arthroscopically assisted treatment of lateral tibial plateau fractures in skiers: use of a cannulated reduction system. *J Orthop Trauma* 8(4):273–281
- El Barbary H, Abdel Ghani H, Misbah H, Salem K (2005) Complex tibial plateau fractures treated with Ilizarov external fixator with or without minimal internal fixation. *Int Orthop* 29(3):182–185
- Miki T, Wada J, Haraoka J, Inaba I (2004) Endoscopic transmaxillary reduction and balloon technique for blowout fractures of the orbital floor. *Minim Invasive Neurosurg* 47(6):359–364
- König B, Khodadadyan C, Schäffler A, Pflugmacher R, Stöckle U (2007) Percutaneously navigated balloon fracture reduction in a displaced acetabular fracture. *Unfallchirurg* 110(12):1072–1075
- Heim KA, Sullivan C, Parekh SG (2008) Cuboid reduction and fixation using a kyphoplasty balloon: a case report. *Foot Ankle Int* 29(11):1154–1157
- Iida K, Sudo A, Ishiguro S (2010) Clinical and radiological results of calcium phosphate cement-assisted balloon osteoplasty for Colles' fractures in osteoporotic senile female patients. *J Orthop Sci* 15(2):204–209
- Bansal MR, Bhagat SB, Shukla DD (2009) Bovine cancellous xenograft in the treatment of tibial plateau fractures in elderly patients. *Int Orthop* 33(3):779–784
- Yu B, Han K, Ma H, Zhang C, Su J, Zhao J, Li J, Bai Y, Tang H (2009) Treatment of tibial plateau fractures with high strength injectable calcium sulphate. *Int Orthop* 33(4):1127–1133
- Patil S, Mahon A, Green S, McMurtry I, Port A (2006) A biomechanical study comparing a raft of 3.5 mm cortical screws with 6.5 mm cancellous screws in depressed tibial plateau fractures. *Knee* 13(3):231–235