VIDEO OF ORTHOPAEDIC TECHNIQUE

Internal Fixation of Complicated Acetabular Fractures Directed by Preoperative Surgery with 3D Printing Models

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The purpose of this article is to evaluate the efficacy and feasibility of preoperative surgery with 3D printing-assisted internal fixation of complicated acetabular fractures. A retrospective case review was performed for the above surgical procedure. A 23-year-old man was confirmed by radiological examination to have fractures of multiple ribs, with hemopneumothorax and communicated fractures of the left acetabulum. According to the Letounel and Judet classification, T-shaped fracture involving posterior wall was diagnosed. A 3D printing pelvic model was established using CT digital imaging and communications in medicine (DICOM) data preoperatively, with which surgical procedures were simulated in preoperative surgery to confirm the sequence of the reduction and fixation as well as the position and length of the implants. Open reduction with internal fixation (ORIF) of the acetabular fracture using modified ilioinguinal and Kocher–Langenbeck approaches was performed 25 days after injury. Plates that had been pre-bent in the preoperative surgery were positioned and screws were tightened in the directions determined in the preoperative planning following satisfactory reduction. The duration of the operation was 170 min and blood loss was 900 mL. Postoperative X-rays showed that anatomical reduction of the acetabulum was achieved and the hip joint was congruous. The position and length of the implants were not different when compared with those in preoperative surgery on 3D printing models. We believe that preoperative surgery using 3D printing models is beneficial for confirming the reduction and fixation sequence, determining the reduction quality, shortening the operative time, minimizing preoperative difficulties, and predicting the prognosis for complicated fractures of acetabulam.

Key words: Acetabulum; Fracture fixation, internal; Three-dimensional printing; Treatment outcome

Introduction

Acetabular fractures usually result from high-energy trauma, the incidence of which has increased gradually in recent years[1]. The treatment of complicated acetabular fractures is challenging for surgeons because of significant intraoperative difficulties and postoperative uncertainties. If the fracture is old or there is malunion, the likelihood of surgical difficulties and complications increases greatly. Reduction quality and fixation strength are the key factors in evaluating the prognosis[2,3]. Without being able to simulate the operation, operative planning may not be helpful in achieving successful intraoperative management. Surgeons often try to reduce and fix the acetabular fractures intraoperatively[4,5]. But 3D printing models could provide a complete observation, which is very beneficial for the accurate classification and treatment of acetabular fractures. The 3D technique could improve the surgeon's efficiency in the operating room, shorten operative times, and reduce the incidence of iatrogenic complications[6]. What is the most remarkable difference between 3D-simulated models and radiology? In our opinion, the biggest advantage is manipulation of preoperative surgery using 1:1 printing model that can confirm the ideal sequence of reduction and fixation, determine the optimal position of implants and evaluate prognosis. Studies have shown that it is important to combine open reduction and internal fixation with 3D printing technology to economically and effectively prepare for the surgical reconstruction in the case of complicated acetabular deformities[7–9].

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Orthopaedic Surgery

In this article, a retrospective review was performed for internal fixation of complicated acetabular fractures directed by preoperative surgery with 3D printing models. The aim of this study is to describe how to design the preoperative planning, evaluate the clinical feasibility and find out the shortcomings using 3D printing-assisted preoperative surgery.

Case Presentation

History and Presentation

A 23-year-old man was sent to the emergency department after he fell from a height of 5 m 3 h earlier.

Physical Examination

He had a shortened and externally rotated left lower limb. On assessment, tests on distraction and compression of pelvis and thoracic tenderness were positive and the neurovascular status of the lower extremities was normal.

Imaging Assessment

X-rays showed a displaced fracture of the acetabulum. A cystogram revealed compression of the bladder by the fracture fragments. 3D CT demonstrated a displaced acetabular fracture with T-shaped involving posterior wall and part of the femoral head running into the pelvic cavity through the quadrilateral area. CT angiography (CTA) showed the superior gluteal artery passing through the fracture fragments.

MRI displayed undamaged pelvic organs.

Preoperative Planning

The patient was hemodynamically unstable after initial trauma so he was transferred to the intensive care unit (ICU) immediately. According to patient's general condition, surgery was permitted 25 days following the trauma. The superior gluteal artery that passed through the old fracture fragments was embolized with a spring coil by a vascular surgeon before surgery.

The 3D model showed that the posterior column and wall were displaced significantly so the Kocher–Langenbeck approach was selected for use. In addition, the fragments of posterior column and medial wall displaced into the pelvic cavity, almost near the middle line of the sacrum, because of the impaction of the femoral head. For this reason, an anterior approach was effective for exposing the fragments. Moreover, because of the existing anterior wall fracture, it was a wise choice for the application of the ilioinguinal approach.

The next step is the preoperative surgery with 3D printing tool. First, we removed the femoral head in the 3D printing model to observe the acetabulum, in which there were no isolated fragments compromising reduction. During the reduction procedure, the first step was to raise the posterior wall fragment and reconstruct the length of posterior column, then the posterior wall was reduced and temporarily fixed with Kirschner pins. Second, two pre-bent construction plates with 5 and 7 holes were inserted and screws were tightened up in the most optimal directions. After anterior residual displacement was reduced, another pre-bent construction plate with 12 holes was placed on the anterior column of the acetabulum. The directions and lengths of screws and the position of plates were recorded. Finally, the implants were removed to sterilize for intraoperative use.

Surgical Treatment

Following administration of general anesthesia, pelvic area cleaning and draping were completed in the lateral position. A modified ilioinguinal approach to the acetabular fracture was performed first in the supine position. After incising the skin and subcutaneous fat, we exposed the deep structures underneath the inguinal ligament. In addition, we opened three windows in a reverse direction to decrease bleeding. When the anterior fracture lines were released, the incision was closed temporarily. Then a posterior Kocher–Langenbeck approach was used to expose the fractures of the posterior column and wall in the lateral position. In accordance with the preoperative surgery, the procedure of reduction and fixation was completed successfully with short operative time and little blood loss. An X-ray image was obtained before closure to confirm satisfactory implant placement. After performing multiple washes, the drainage tubes were placed and two incisions were closed, respectively.

Results and Follow-up

The duration of the operation was 190 min and blood loss was 900 mL. The lower extremities were equal in length. Antibiotics were routinely administered for 48 h postoperatively.

Antero–posterior, obturator oblique, and iliac oblique views showed that the acetabulum was anatomically reduced and the hip joint was congruous. The position and length of the implants were in general accord with preoperative surgery using 3D printing models. The direction and length of the plates or screws implanted were highly consistent with the preoperative planning. No screws went into the hip joint cavity. The functional assessment, which included squat and full weight-bearing on the injured limb, at 6-month follow-up was excellent.

Discussion

Development of 3D Technique

Before the advent of 3D printing models, the surgeons can only cognize fractures through imaging examinations even during operation. Because of the complicated structures in the pelvic cavity, pelvic and acetabular fractures are more difficult to treat than other fractures. There are a number of problems to face if open reduction and internal fixation of acetabular and pelvic features are only directed by imaging data.

With the development and utilization of Materiaise's interactive medical image control system (MIMICS) software, some of the above problems were solved. Fragments could be dissociated and reduced using MIMICS, but the sequence of reduction and fixation cannot be confirmed; moreover, MIMICS is difficult for some surgeons to manipulate.

3D printing is a novel method whereby an actual structure is created by using CT digital imaging and communications in medicine (DICOM) data, which relays the signals to the 3D printer. The appearance of 3D printing technique is an epoch-making contribution to medicine area, especially for orthopedics. 3D printing is being increasingly used in clinical treatment in orthopedics, including in fractures, bone defects, bone diseases, and bone tumors[10–13].

Advantages of 3D Printing in Complex Acetabular Fractures

3D printing models are being rapidly developed in the orthopedic fields because of their specialized advantages. 3D printing plays a vital role in planning and training for surgical procedures. First, pelvic models provide a multi-angle and multi-directional view, making it is easier for surgeons to understand the preoperative situation in cases of complex fractures; they are also helpful in accurately classifying fractures[14]. Second, they are useful in choosing the best approach, confirming the sequence of reduction and fixation, pre-bending the appropriate length plates, determining the optimal position of plates, selecting the most effective angle and length of screws, and deciding on the most deliberate preoperative plan, thereby shortening operative time[9]. Third, 3D printing models can be used for realistic preoperative simulation. Preoperative surgery using 3D printing pelvic models could determine the optimal osteotomy position and plane and rotation angle for malunion fractures, decreasing the operative difficulties and risks[8]. Finally, preoperative surgery help to accurately confirm the prognosis.

Considerations and Complications

The position, range, and displaced degree of fractures could be clearly shown on the 3D printing models of pelvis, nevertheless, which cannot locate important blood vessels and nerves in the pelvic cavity accurately. The printing technique with the construction of pelvic models has been used in clinic to help locate blood vessels and nerves. However, even minimal deviation can impact outcomes intraoperatively because of the difference between blood vessels and the nerve and musculoskeletal system. Therefore, computed tomography angiography (CTA) is still vital for getting the position of important arteries accurately, such as the corona mortis and superior gluteal artery.

In addition, because of the limited amount of material, the fracture fragments printed were connected by polylactic acid filament. Fragments may be lost as a result of the external force. Moreover, the material used in the models has poor elasticity, so the gaps among the fragments can never be totally eliminated. If the key fragment were absent, the reduction quality of the acetabular fracture would be affected. Therefore, the intraoperative reduction and fixation might be different to what is expected based on the preoperatively plan, thus affecting the surgeon's judgment during the surgery. In view of the above-mentioned facts, it is important to contrast the structure of 3D printing models with CT carefully before surgery.

In short, the 3D printing technique assists in the treatment of complicated acetabular fractures, and demonstrates better feasibility and effectivity than conventional methods[15]. 3D printing models could be considered as a new technique to achieve a real preoperative tangible evaluation of fractures. In our study, we suggest that preoperative surgery with 3D printing models would be an innovative method that could simulate surgical procedures, such as establishing the sequence of the reduction and fixation, getting the quality of the reduction and fixation, pre-bending the plates for intraoperative use and confirming the length and direction of screws.

Highlights and Pitfall

1. 3D CT can clearly show the position, range, and degree of displacement of fractures, but 3D printing models can be used to classifying the fractures and to understand the relationship among the fragments.
2. 3D printing for preoperative surgery should use 1:1 simulated models; this way, the position and length of plates and screws can be determined.
3. There was no attachment of muscles or ligaments, so reduction was much easier when the simulated operation was done with models *in vitro*. However, if soft tissue needs to be considered, the length and number of plates and screws may be adjusted.
4. 3D pelvis models offer a good guide for surgery, but the associated costs are high. If the fracture is simple, 3D models may be less need to use.

Video Image

Additional video images may be found in the online version of this article. Visit http://onlinelibrary.wiley.com/doi/10.1111/os.12324/suppinfo

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