The use of 3D printing pelvis and hip in a complex THA: clinical experience and reports of literature

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Research

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Abstract

Background: Total hip arthroplasty(THA) is a good solution of developmental dysplasia of the hip(DDH). However, patients diagnosed with Crowe type IV are difficult to deal with. With traditional operation skills, the operation time is quite long and the patients will lose a lot of blood.

Case presentation: We present the case of a 58-year-old male patient who underwent left THA due to Crowe type IV DDH with the help of 3D printing models. Before the operation, we put the CT image into a computer software named mimics. After getting the stl. document, we use 3D printer to print the models out. By using the models, we planned the operation in advance. And after sterilizing the models, we put them in the operation area, which saves a lot of operation time and reduces much blood loss by giving surgeons a better anatomy view.

Conclusion: THA with the help of 3D printing pelvis and femur can result in a relatively short recovery time and provide good clinical efficacy of type IV DDH patients.

Background

Developmental dysplasia of the hip (DDH) is a condition characterized by morphological abnormalities of the acetabulum and femur. And surgeons classified it according to dislocation severity, from I to IV, most commonly based on the Crowe rubric. And the type IV is the most severe of the four types[1]. Primary total hip arthroplasty (THA) is complicated and difficult in patients with Crowe type IV (type IV from here forward for simplicity) DDH because the pathological anatomical changes that accompany this condition. Compared to traditional THA, the operation time is longer and intraoperative bleeding is much more.

In the 1970s, John Charnley introduced the trochanteric osteotomy for complicated primary hip replacement, including in patients with type IV DDH[2]. Along with the good performance of the patients after the operations, is the longer operation time and more intraoperative bleeding

Some Crowe type IV DDH patients undergoing THA require a femoral shortening osteotomy to equalize the length of the lower extremities and decrease the difficulty of intraoperative reduction and the incidence of complications [3–5]. The femoral subtrochanteric transverse osteotomy is one of the most common forms of osteotomy [6, 7].

Although several such surgical protocols have been reported to yield excellent results, each has drawbacks. Thus it is necessary to invent a method to save operation time and reduce intraoperative bleeding.

With the development of the 3D printing technique, 3D printing pelvis and femur can be of great use in the surgeries of THA. Our study reports the case of a patient with type IV DDH who underwent THA with the help of 3D printing pelvis and femur. The time and blood control of the surgery and recovery time after THA are discussed based on literature reports.

Case Presentation

The patient we operated on is a 58-year-old male, who came to our hospital because of the limited activity of the left hip. He suffers from the intermittent pain of the hip for more than 40 years and the pain aggravated for 6 months. We X-rayed his pelvis and found that his left hip was dislocated(Fig. 1). Then he was diagnosed with Crowe type IV with a Harris score of 23 and visual analogue scale (VAS) score of 8. After the physical examination, we found that the patient's left leg is shorted by 4.2cm and he suffers from the pain of hip rotation. The degrees of right hip joint motion were as follows: adduction, 10°; internal rotation 10°; and external rotation, 10°; flexion, 80°; and outreach, 15°. There is no other diseases reported by the patient.

First, we collected the patients' image data by using MRI(Siemens, Berlin, Germany) and CT (Philips, Eindhoven, Netherlands) plain scans. Then we import the MRI and CT data (DICOM format) for the surgical area into the computer and reconstructed it via Mimics 21.0 software (Materialize, Leuven, Belgium). We used different colors to distinguish different parts of the structure and finally we got a 3D digital model. (Fig. 2). After getting the 3D digital model, we analyze the condition of the patients and developed a surgical plan, which helped us get to know the patients better. And then we use 3D printer to print the model out and sterilize the 3D model. (Fig. 3).

We performed the surgery through the posterior-lateral approach. The patient was placed in the right lateral position after sciatic nerve block and lumbar plexus anesthesia. We made a roughly 12-cm posterolateral incision on the left hip of the patient right after disinfection and draping. And the epidermis and subcutaneous tissue of the surgical area were dissected to expose the selected bony landmark according to the surgical plan. First, we compared the sterilized 3D model with the patient's structure. Second, in the preoperative design of the acetabulum cup position, we use the acetabular reamer with a diameter of 36 mm to grind to a diameter of 46 mm (Fig. 4A), and then we inserted a 48 mm diameter cementless acetabular cup and reinforced it with two acetabular screws (Fig. 4B). Time to time, we used the 3D printing model to avoid extra procedures. And then we opened the femoral medullary cavity enlarged it to the size of 10.5 with the medullary cavity file(Fig. 4C). We installed the femoral prosthesis with a 36mm diameter short neck head. At last, we reset the hip joint and checked its motion. (Fig. 4D). Before suturing layer by layer, we placed a drainage tube deep into the surgical area. The operation lasted for 2h, which is much quicker than traditional DDH surgery. Also with the help the 3D printing models, the intraoperative bleeding is less than usual.

To prevent infection, the patient received antibiotics right after the operation. And he toke the X-ray on the second day of the surgery, which shows good position of the implants.

Discussion

The other name of three-dimensional printing (3DP) is rapid prototyping, which constracts 3D models layer by layer. It is an additive manufacturing process that promote the production of the complex geometrical. The development of imaging modalities and the 3D printing technology enables a big advancement in the use of 3D printing models of some operation practices. (10,11).

Nowadays, the use of 3D printing technology in clinical practice focuses on 3D printing models(12-15). Previous researchers made a lot of researches(16-18) in virtual and haptic patient specific anatomical models, often termed biomodels (19). It can help surgeons to plan the operations in advance and save their operation time. So we operated this special operation:3D printing models assisted complex THA.

According to the previous researches, surgeons all around the world hold the opinion that the 3D printing models are quite beneficial when they are operating difficult operations. [20] Previously, before and during the operations, most of the surgeons relied on two-dimensional (2D) images, for example, X-ray, CT and/ or MRI. And the 1:1 scale 3D printing models could provide the surgeons with the better understanding of the anatomy compared to the 2D visualization.

Also, before the operations, we can sterilize these models. In that way, surgeons could use these models to get a template to review intra-operatively[21,22]. However, the work people have done on the models is limited. Previous researches have found that, compared to traditional operations, the application of 3D printing models can offer more accurate evaluation of relevant surgical structures in complex cases, for example, acetabular fractures and spinal deformities.[22]

Besides the subjective benefits, we can also find some other objective advantages of the 3D printed models. Researchers found that compared to traditional operations, the surgery time, intraoperative blood loss and fluoroscopy time are much less[23-30], which improves the quality of planned placement of implants and selection of instrumentation. And thus the need to contour and the implants number of adjustments intraoperatively are reduced.

Nowadays, surgeon often use subtrochanteric shortening osteotomy to deal with the type IV DDH. And in our study, with the usage of the 3D printing models, the surgery time, intraoperative blood loss and fluoroscopy time are much less, which is of great benefit.

Disadvantages are also obvious. First is the cost. For better evaluation, we have to compare the potential savings of the improved operations and production cost of the 3D printing models. Second is that the 3D printing model don’t include the soft tissue structures, as well as the nerves and blood vessels. To better serve the clinical practice, further studies and a streamlined protocol for the 3D printing models are needed in the future.

Conclusion

THA with the help of 3D printing pelvis and femur can result in a relatively short recovery time and provide good clinical efficacy of type IV DDH patients.

Abbreviations

3D: Three-dimensional; DDH: Developmental dysplasia of the hip; CT: Computed tomography; THA: Total hip arthroplasty

Declarations

Acknowledgements

Not applicable.

Authors' contributions

CYH and QQY contributed to the study design and the drafting of the article. WL, CT and BW collected CT data and CAD. JYL, HKZ and CYH cleaned, prepared and sterilized the model. JTL and LMW contributed to all surgical procedures. The authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figures

Figure 1

Patient X-ray image before the operation

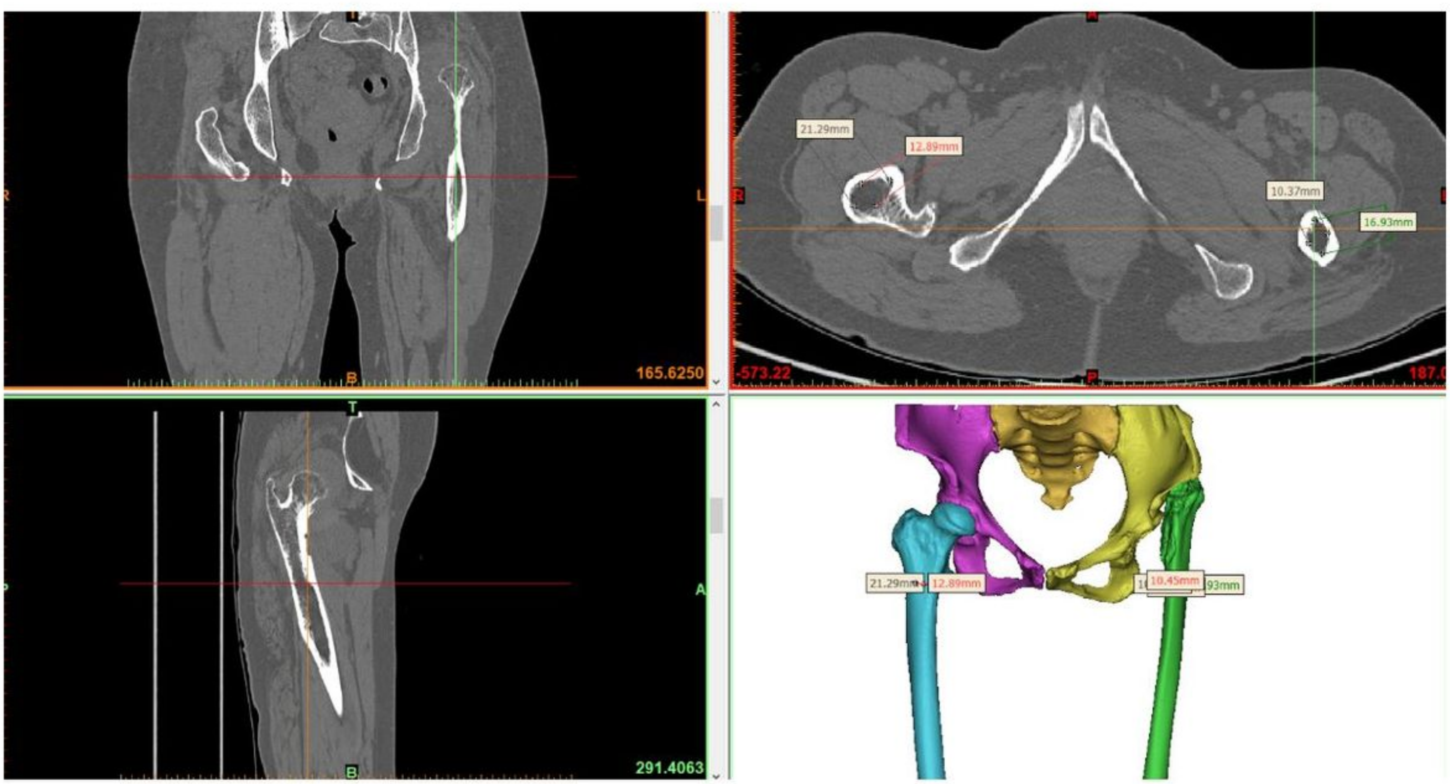

Figure 2

3D digital model of the patient

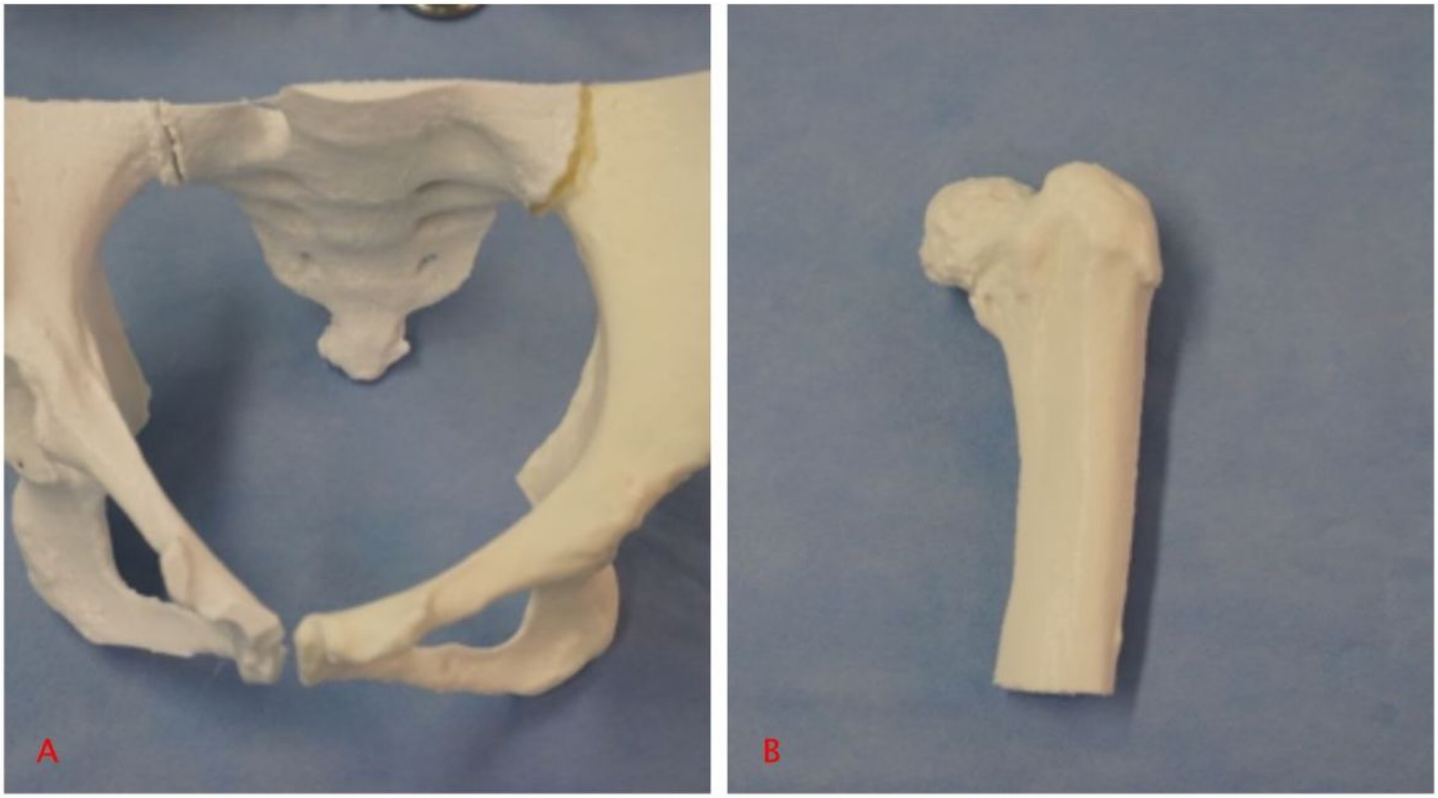

Figure 3

3D printed models

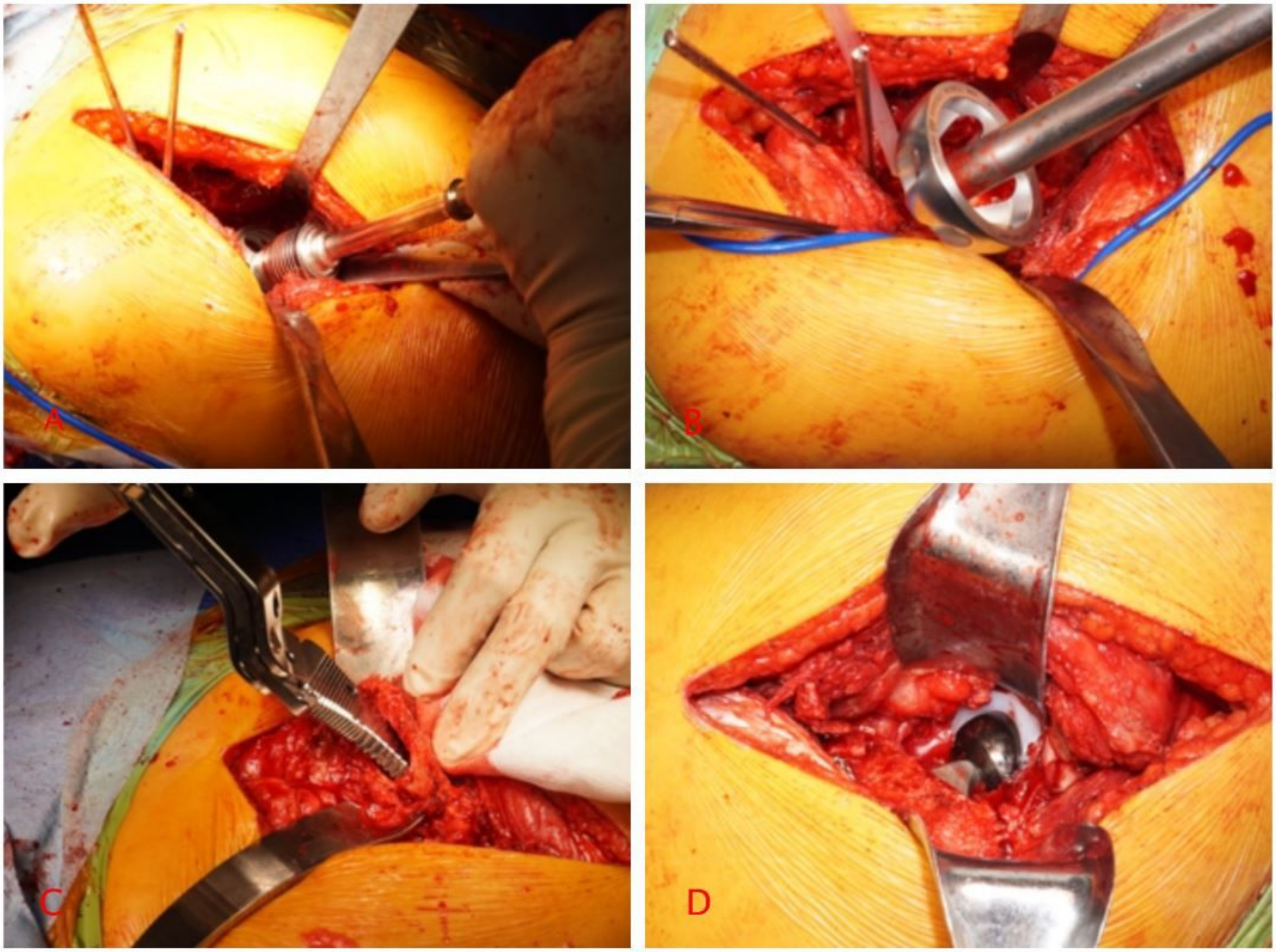

Figure 4

Procedure of the surgery