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One visualization simulation operation system for distal femoral fracture

Dan Wang, PhD, Ning Li, MD*, Ming Luo, M.Med, Yao-kun Chen, M.Med

Abstract

A computer-aided 3-dimensional (3D) visualization operation simulation system based on computer-aided design (CAD) Unigraphics NX and Mimics software was established to provide orthopedic surgeons with an actual and reliable system in treating of distal femoral fracture.

According to the preoperative CT data, 3D reconstruction of the distal femoral fracture could be achieved by the Mimics software. Then, the CAD Unigraphics NX software was used to measure the model function of all the related surgical instruments, including less invasive stabilization system (LISS) and retrograde intramedullary nail fixation.

The function of CAD Unigraphics NX and Mimics software was successful in assisting in the treatment of distal femoral fracture with LISS and retrograde intramedullary nail fixation. The operation procedure was actual, visualized, and lifelike. Moreover, the operation effect could be estimated before surgery.

The virtual surgery system may improve the reliability and safety of the operative care of distal femoral fracture.

Abbreviations: 3D = three-dimensional, CAD = computer-aided design, LISS = less invasive stabilization system.

Keywords: 3-dimensional, distal femoral fracture, unigraphics NX, virtual

1. Introduction

The distal femur is an important component of the knee joint. It consists of a thin cortical shell filled with honeycomb-like cancellous bone. High-energy distal femoral fracture often results in fragmentation and severe articular damage making them extremely difficult to manage. At present, the main treatment method is operative using either a locked plate such as the less invasive stable system (LISS) or retrograde intramedullary nail fixation.[1–3] However, each method requires a precise articular reduction and proper application of the implant. This necessitates an excellent preoperative plan to determine how best to do the surgery and what is the proper implant.

Recently, with the development of a virtual operative design system,[4,5] the creation of a precise preoperative plan may be easily performed. The virtual operative design system can preview the whole operative process allowing the orthopedic surgeon to determine potential problems before surgery. Moreover, it is more realistic for trauma surgeon to discuss the operative plan and results with lifelike 3-dimensional (3D) images.

Using Mimics and computer-aided design (CAD) Unigraphics NX software, we established a virtual operative design system in order to provide a preoperative plan that would allow the surgeon to virtually perform the surgery, assure proper implant choice, and better chose operative approach.

2. Methods

This study was approved by the Institutional Review Board in Zhengzhou University. Computed tomographic (CT) scans were performed according to a standardized trauma protocol at our radiology unit. Axial-oriented images were reconstructed from the CT datasets using a slice thickness of 0.625 mm. In addition, the LISS plate and retrograde intramedullary nail fixation were scanned by the same CT equipment.

First, the CT data of distal femoral fracture with DICOM format were imported into Mimics software 10.01 (Materialise, Belgium). The user can interact with these objects through the haptic device, dragging and rotating them into anatomically correct positions. This process is supported by visual as well as haptic feedback in order to achieve precise bone fragment positioning. The overlaps of colliding bone fragments are visually encoded by different color. After the 3D reconstruction finished, the fracture model reconstruction was imported into the CAD Unigraphics NX software. Both the LISS plate and retrograde

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Department of Orthopedics, The First Affiliated Hospital of Zhengzhou University, Zhengzhou, China.

** Correspondence: Ning Li, Department of Orthopedics, The First Affiliated Hospital of Zhengzhou University, 1 Jianshe Road, Zhengzhou 450052, China (e-mail: lining117826@126.com).*

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intramedullary nail system (Depuy Synthes, Shanghai, China), including a sleeve, lock screw, bolt, screw, nail, guide, locator, pole, guide bar, etc, had 3D reconstruction made. At last, according to the general situation of the patient, economic condition, bone fragment positioning, the trauma surgeons, and patients can have a more detailed and informative preoperative discussion of the management and expected results of the surgery leading to less patient misunderstanding.

3. Results

We presented a tool for the preoperative planning of a distal femoral fracture. The system used patient-specific models built from CT data, where bone fragment segmentation and mesh generation were performed with available software. Figure 1 shows a femoral fracture model in Mimics software. Figure 2 shows a virtual fracture reduction model in 3D Unigraphics NX software. Figures 3 and 4 show the LISS and retrograde intramedullary nail system, respectively.

The current system has 2 main parts: the virtual reduction of the bone fragments, and the virtual adaptation of the osteosynthesis implants to the distal femoral. Both parts were supported by visual and haptic feedback and could be performed in real-time on common workstations. The reduction of the fracture was facilitated by the freedom of bone fragment motion by the virtual fixtures. The system improved user interaction and was helpful for users not familiar with the haptic interface. The placement of the osteosynthesis implants was performed by drawing a sketch the desired path of the plate on the bone. The system automatically determined the position, orientation, and deformation of the plate. Finally, the system afforded the possibility to measure angles, length of the plate, and the fragments in 3D space. This information was exported as screenshots to the Unigraphics NX system, thus

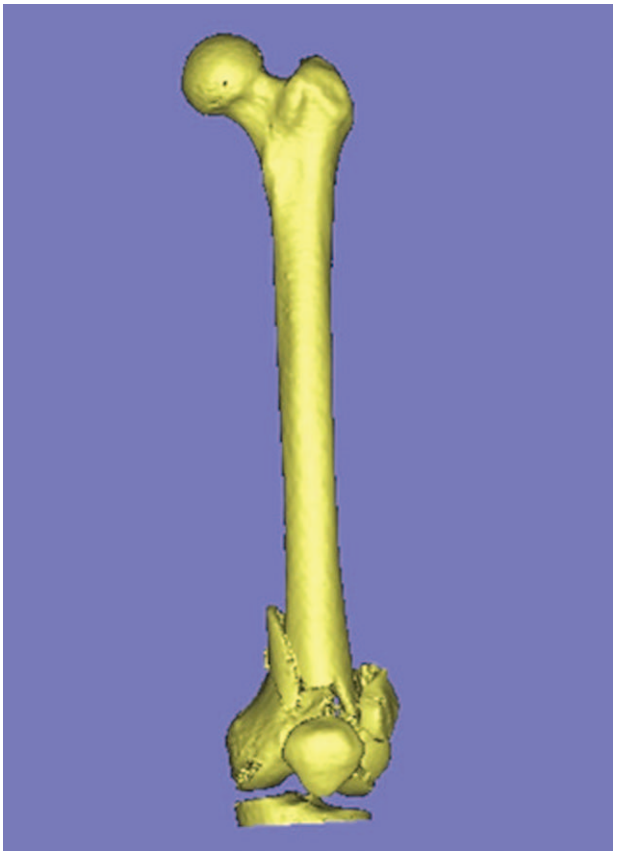

Figure 1. Example of high-quality mesh of a severely injured distal femoral.

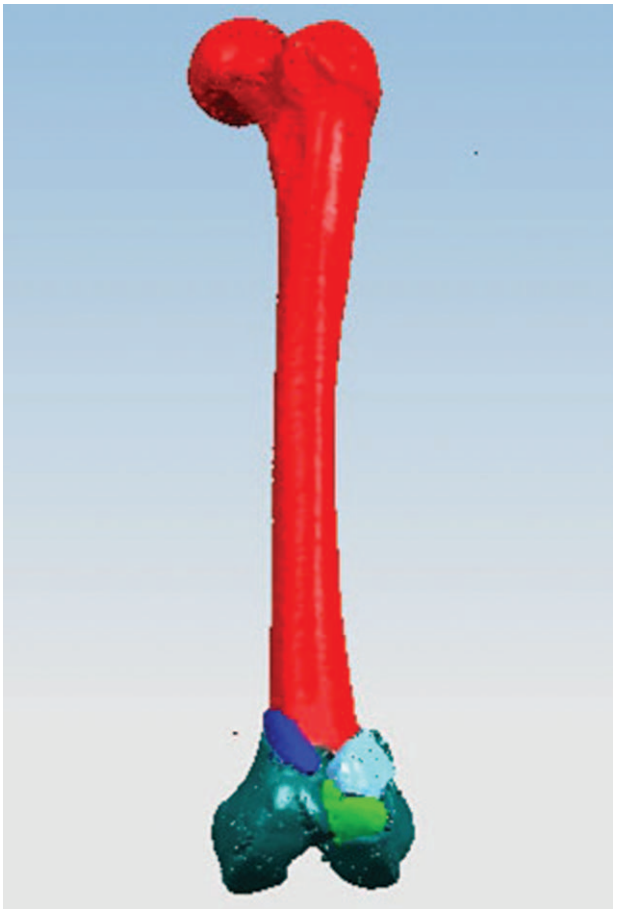

Figure 2. Example distal femoral case after fracture reduction with the proposed system.

Figure 3. Less invasive stabilization system.

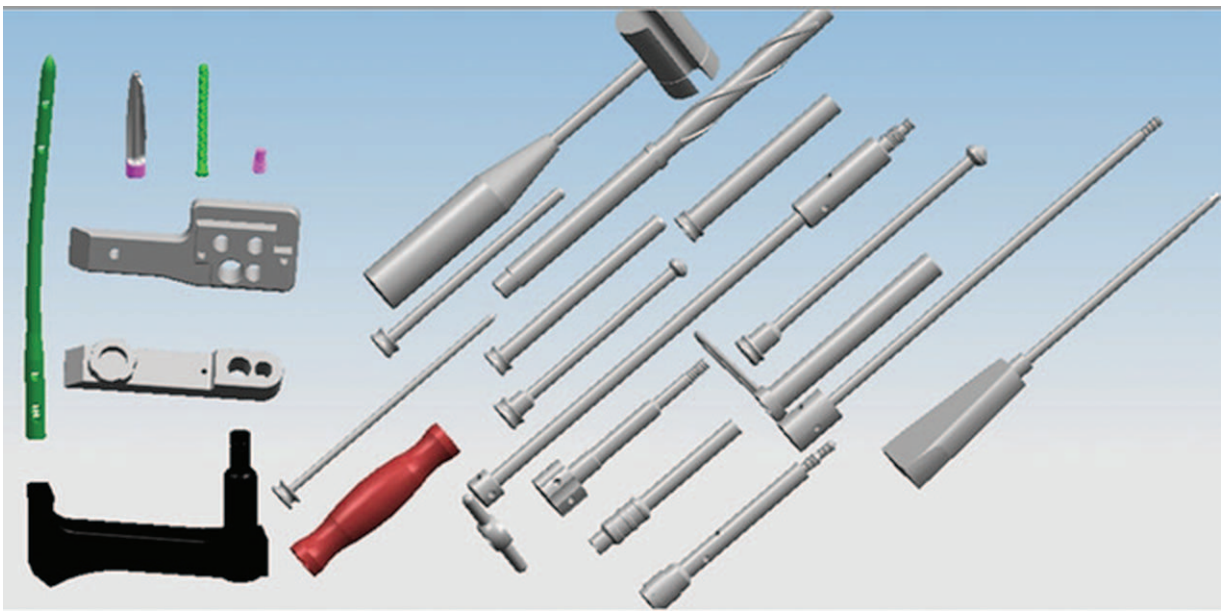

Figure 4. Retrograde intramedullary nail system.

making the images available to the trauma surgeons in the operating room (Figs. 5 and 6).

4. Discussion

With the development and penetration of medical 3D imaging and computer technology, virtual surgical training has become a very promising research direction. In recent years, researchers have developed a series of virtual surgery planning system in order to meet the needs of orthopedic clinical, such as computer-aided 3D virtual bone cutting system,[6] virtual arthroscopic surgery simulation system,[7] and virtual knee joint replacement surgery system.[8] These systems can presently be applied to orthopedic clinical problems with acceptable results.

A high energy distal femoral fracture is difficult to manage. Virtual reality technology provides a feasible way to better understand this problem. The current study adopts CAD Unigraphics NX4 (Eden Prairie, America) and Mimics10.0 software to allow reduction of the fracture and then application of surgical instruments and implants. Consequently, the surgeon is able to practice the whole operation preoperatively. This system is also useful for basic skills training in the management of this injury.

The current virtual surgery system has 4 strengths. First, the 3D images are lifelike and in stereo. Second, it is extremely convenient for trauma surgeons to make an operative plan for different types of fracture. Third, the virtual operation design system can preview the whole process and compare the operative choice to perhaps provide the best one for the patient. Besides, the trauma surgeons

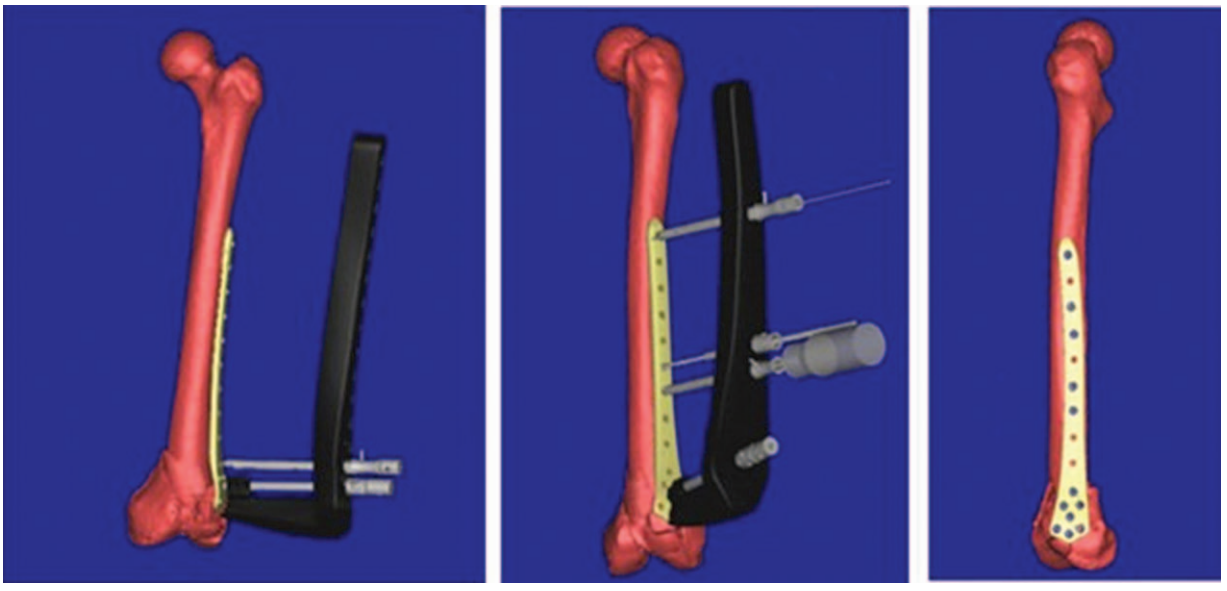

Figure 5. Osteosynthesis implants automatically adapted to example distal femoral (LISS).

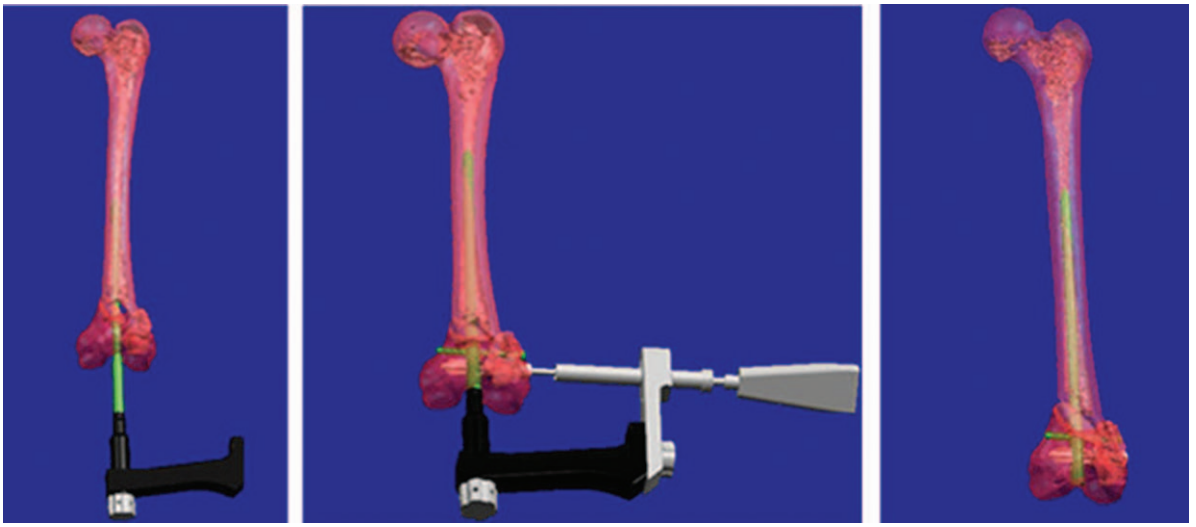

Figure 6. Osteosynthesis implants automatically adapted to example distal femoral (retrograde intramedullary nail system).

and patients can have a more detailed and informative preoperative discussion of the management and expected results of the surgery leading to less patient misunderstanding.

In conclusion, the current virtual surgery system is very helpful in improving the reliability and safety in treating of distal femoral fractures. Future endeavors will simplify the whole system making easier to use in the clinical setting.

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