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Can the recovery of lower limb fractures be achieved by use of 3D printing mirror model?

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ABSTRACT

Introduction: : The mirror imaging 3D printing model can be used a as a reference for anatomical reduction in unilateral lower limb fractures. However, the premise of using mirror technology is that the bilateral lower limb bones are similar enough. Because one side had a fracture, it was impossible to compare this directly to the other side. Usually, surgeons think that the bilateral bones are symmetrical and use mirror technology without judging their symmetry.

Methods: In patients with a unilateral lower limb bone fracture, we measured the long axis and short axis of the three selected transverse sections of the bilateral long bone for comparison to judge the symmetry of the bilateral long bones on CT images. Then, we printed a life-size normal mirror image of the long bone that is similar to the affected side. The model was used as a reference for the anatomical reduction of fractures and preoperative practice.

Results: Seventy-eight patients with lower limb bone fracture were included in this study. 24 groups of data were generated according to the same level and same axis. There were significant differences between the short axis of the left and right femoral condyle 5 cm from the intercondylar keel ($p = 0.011$), and the short axis of the distal tibia 15 cm from the ankle dome ($p = 0.026$). There was no significant difference between the left and right sides in the other 22 groups. Of all of the patients in our research, 3 patients decided to forego the surgical treatment and the operation was performed on the model instead, and the lengths of 2 patients showed deviation in actual operations, preventing anatomical reduction. The remaining 73 patients used the pre-bended plates and screws from preoperative practice in the actual operations, and postoperative X-ray examinations showed that the length of the deviation was within the permissible range.

Conclusion: The "Comparison of long axis and short axis of three equidistant transverse sections" method makes it easy to judge the symmetry of the bilateral long bones, and prevents the blindness of preoperative planning using the contralateral mirror model directly.

Introduction

It is common for lower limb bone fracture to occur in traumatic orthopaedic patients [1]. For apparently displaced fractures, which often require surgery, proper internal fixation and accuracy reduction can partially avoid complications such as malunion, refracture, and breakage of internal fixation [2,3]. Currently, most doctors visualise the fracture morphology using plain X-ray films and CT scanning images, including CT 3-dimensional (3D) reconstruction images. However, it is difficult to observe the fractures from arbitrary angles with these radiological imaging data. Thus, some doctors have used a 3D printing technique to print a real-size unaffected mirror image of the bone that is similar to the affected side, which is utilised preoperatively for practice, to refine the surgical approach and intraoperatively as a reference for anatomical reduction of the fracture [4–7]. The premise of generating mirror image models requires bilateral long bones that are extremely similar; as one side has a fracture, it is impossible to compare it directly with the other side. Surgeons previously thought that bilateral bones were symmetrical. However, not all patients have ideal mirror image relevance [8]. Environmental factors and heterauxesis may lead to asymmetry of the bilateral lower limbs, such as polio, unilateral limb had a history of fracture, unilateral limb excessive used, etc. The question of how to judge whether the mirror imaging 3D printing model can really help with restoration of the fracture bone has not been addressed.

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Before printing the 3D mirror image model, it is necessary to verify the symmetry of the bilateral long bones. Comparison of the bilateral bones involves a direct comparison between the two entities. It is very difficult to make a point to point comparison between two bones. Although the technology of feature extraction and matching approach for face recognition can reduce the amount of data compared [9], it is still complex and difficult to promote. We will describe a method to verify the symmetry of the bilateral long bones, including the fracture side. First, a CT scan is taken of the bilateral long bones. Then, three equidistant transverse sections of the CT images are selected, measuring the characteristic long axis and short axis, and compared the data. We named the method "Comparison of long axis and short axis of three equidistant transverse sections". The aim of the present study is to provide a simple method for verifying the symmetry of the bilateral long bones of the lower limbs, in order to provide a more accurate and effective reproduction of the injured bone.

Patients and methods

Patients

Between October 2015 and September 2016, 78 patients with unilateral lower limb bone fractures were prospectively included in this study after obtaining informed consent. There were 41 males and 37 females aged between 19 and 90 years (median age of 56 years). The fractures included 1 femoral head fracture, 12 femoral neck fractures, 9 femoral intertrochanteric fractures, 1 femoral shaft fracture, 3 distal femur fractures, 13 tibial plateau fractures, 12 tibiofibula fractures, 4 Pilon fractures, and 23 ankle fractures. All of the patients underwent CT scanning. Patients with lower limb deformity, bilateral fracture at the same site, bilateral limb development asymmetry or congenital malformation were excluded.

Selection criteria: select all kinds of lower limb fracture and above the age of 18, can cooperate with a CT scan.

Exclusion criteria: Incomplete body; Bilateral fracture on the same parts; the asymmetric limb on both sides; Congenital malformation; Inspection and operation can not match.

CT scanning and data acquisition

In patients with a unilateral lower limb bone fracture, a CT (PHILIPS iCT 128 row spiral CT) scan was taken of both sides with a 1 mm slice thickness. On the affected side, if the length of unaffected region was less than 10 cm, the near long bone was also scanned for measurements. The images were stored in Digital Imaging and Communications in Medicine (DICOM) format and 3D reconstructed using Mimics 15.0 (Materialise Interactive Medical Image Control System Software, Materialise, Belgium). With the Mimics workstation, we measured the long axis and short axis of the three selected transverse sections of the bilateral long bone.

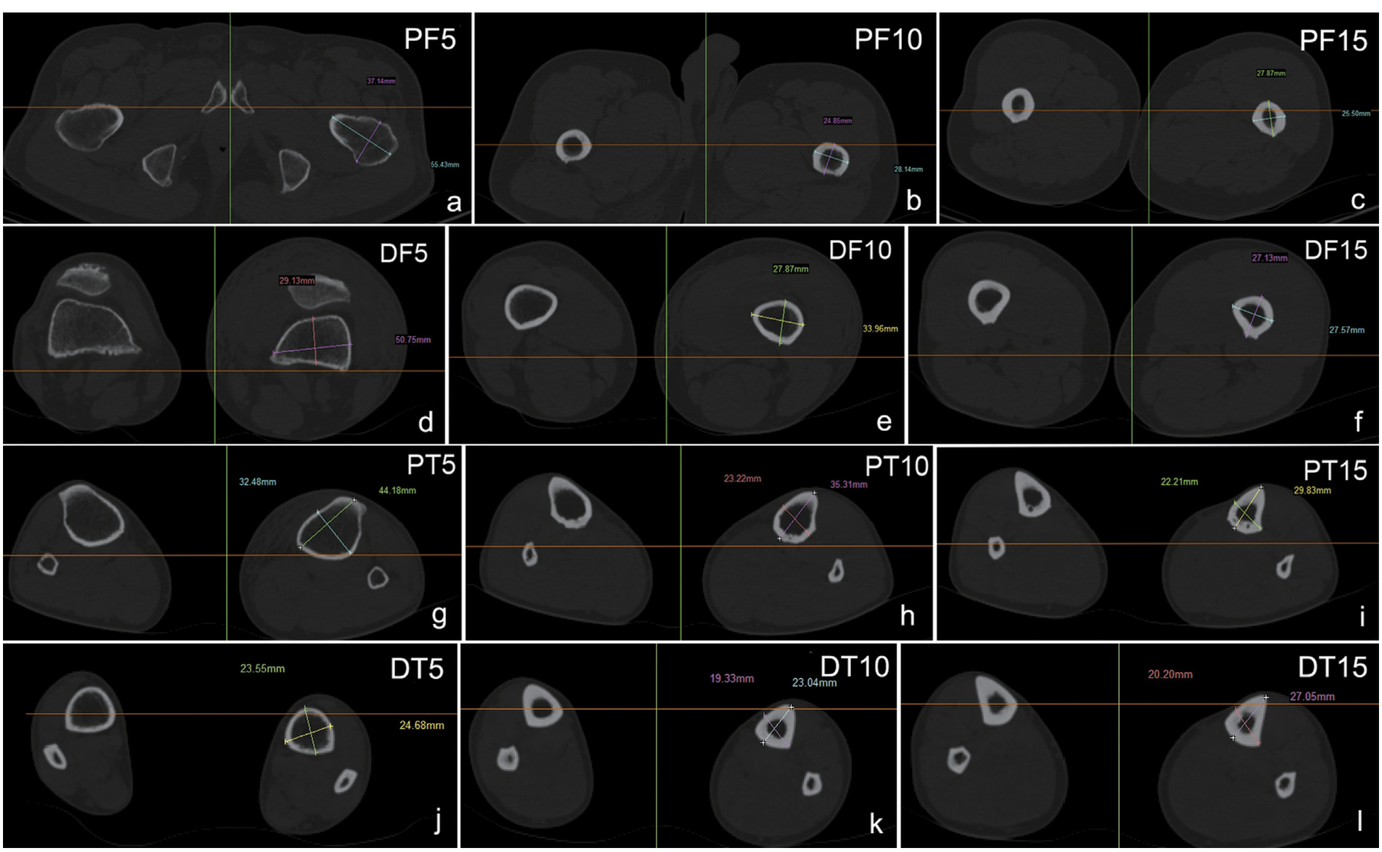

Fig. 1. Example of four sections of long and short axis positioning: (a) a section 5 cm from the vertices of the femoral head of the left femur, where the blue line is the long axis; (b) a section 10 cm from the vertices of the femoral head of the left femur, where the blue line is the long axis; (c) a section 15 cm from the vertices of the femoral head of the left femur, where the blue line is the long axis; (d) a section 5 cm from the second baseline of the left distal femur, where the purple line is the long axis; (e) a section 10 cm from the second baseline of the left distal femur, where the yellow line is the long axis; (f) a section 15 cm from the second baseline of the left distal femur, where the blue line is the long axis; (g) a section 5 cm from the second baseline of the left proximal tibia, where the green line is the long axis; (h) a section 10 cm from the second baseline of the left proximal tibia, where the purple line is the long axis; (i) a section 15 cm from the second baseline of the left proximal tibia, where the yellow line is the long axis; (j) a section 5 cm from the third baseline of the left distal tibia, where the yellow line is the long axis; (k) a section 10 cm from the third baseline of the left distal tibia, where the blue line is the long axis; and (l) a section 15 cm from the third baseline of the left distal tibia, where the purple line is the long axis. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)