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Case Report

3D printing mirror model to assist MIPPO technology in the treatment of displaced midshaft clavicle fracture: a case report

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Abstract: Purpose: We introduce a novel method to treat the displaced midshaft clavicle fracture using a 3D printing model to assist MIPPO technology. Methods: A mirror model of the displaced midshaft clavicle fracture was constructed and printed by the contralateral clavicle. The operation simulated and the anatomical locking plate pre-bent and pre-shaped were performed by the model at preoperative. The displaced midshaft clavicle fracture was reconstructed and fixed with the pre-bent and pre-shaped plate by MIPPO technology combined with anatomical locking plate. Results: The operation was completed successfully with the plate matching the clavicle bone surface perfectly. Conclusions: The 3D printing mirror model had the advantages of optimizing preoperative plan and design, providing personalized and accurate treatment. 3D printing mirror model to assist MIPPO technology may have good feasibility in the treatment of displaced midshaft clavicle fracture.

Keywords: Clavicle fracture, 3D printing mirror model

Introduction

Displaced midshaft clavicle fracture was a common fracture and usually treated with open surgical reconstruction combined with anatomical locking plate at present [1]. But the surgery had the disadvantages of large trauma and widely stripping periosteum, which may decrease the blood supply of the fracture end and delay the fracture union, even nonunion. MIPPO (Minimally Invasive Percutaneous Plate Osteosynthesis) technology could get rid of those disadvantages.

3D printing technology is gradually applied in the field of department of orthopedics, which may optimize preoperative plan and design and provide personalized and accurate treatment [2]. Based on the 3D printing technology, the 3D printing mirror model assisted MIPPO technology combined with anatomical locking plate method to treat the displaced midshaft clavicle fracture may have good safety and feasibility.

Case report

A 58-year-old male encountered an injury to his left shoulder when he was falling down from about 1 m high platform. He was sent to the department of orthopedics and referred to fracture syndrome. The soft tissue of the left clavicle was swelling and tenderness obviously. The clavicle fracture was abnormal and the bone rubbing sensation and abnormal motion could be reached.

He underwent an X-ray examination and a computerized tomography (CT) scan preoperative (**Figure 1A**, **1B**). The original image data of the CT scan was saved in the Dicom (Digital Imaging and Communications in Medicine) format, and then transplanted it into the 3D reconstruction software Mimics 17.0 (Materialise company, Belgium) to construct contralateral clavicle model. Then the mirror model was constructed by the contralateral clavicle model and saved in the STL (Standard Triangulation Language) format. The STL file was imported into the 3D light curing printing machine to print out the mirror model with photosensitive resin. There is an extremely similarity between the mirror model and the injured side clavicle before fractured (**Figure 2**). Not only was the operation simulated and performed on the model before operation, but also the plate was pre-bent and pre-

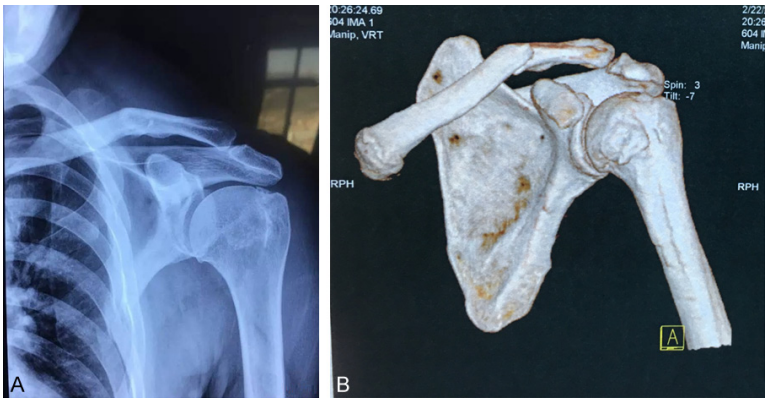

Figure 1. The X-ray and CT scan pictures of the light clavicle (A). The X-ray showed the lift clavicle was fractured (B). The CT scan showed the lift clavicle was fractured.

Figure 2. The 3D printing mirror mold was quite similarity with the fractured clavicle. The upper one was the real fracture clavicle mold and the lower one was the mirror mold.

Figure 3. The anatomical locking plate was pre-bent and pre-shaped by the mirror mold.

shaped so that the plate could fit perfectly to the clavicle bone surface (**Figure 3**). Meanwhile the length and number of screws to be inserted could be measured as well.

After the cervical plexus block anesthesia was done, he was supine and the scapula area elevated by a pillow to make an extremely expanding chest position. First, the fracture was reduced by hand. Then two 2.5 cm skin incision was selected at the upper ends of the clavicle. A channel between subcutaneous fascia and periosteum, which retained the periosteum of the fracture, was established by a narrow side periosteal elevator. The fracture reduction was confirmed by C-arm fluoroscopy. The pre-bent and pre-shaped anatomical locking plate was inserted through the channel and in touched with clavicle tightly. And the fixation device was fixed with 8 screws, which were pre-measured by the mold, and closed the incision (**Figure 4**). The operation was completed successfully and the fracture healed in 12 weeks after the operation (**Figure 5**).

Discussion

At present, most of the displaced midshaft clavicle fractures were treated with open surgical reconstruction combined with plate and screw fixation. The produce of fracture reduction needed an extensive stripped revealed, which may cause serious damage to the blood circulation of the fracture section and the soft tissue around. What's more, it may increase the risk of delayed union and nonunion, even nonunion [4]. At the same time, the clavicle had a special "S" shape and the individual shape varied in various degrees, so even the anatomic locking plate could not match the clavicle shape of each patient perfectly [5]. This required the operator to bend and shape the existing plate during the operation. On the one hand, it may cause the deformation of the locking hole, which may ease the screw loose and emerge, contrary to the idea of locking; on the other hand, the plate strength may reduce if there was too much bending and shaping. Additionally, nonunion was easy to happen due to the plate breakage. At the same time, because of the lim-

Figure 4. Two 2.5 cm skin incision was selected at the upper ends of the clavicle.

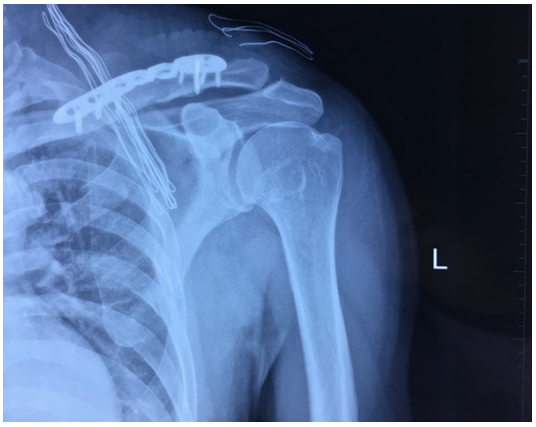

Figure 5. The X-ray showed the clavicle fracture was reduced and the anatomical locking plate was attached to the clavicle perfectly.

ited exposure, it was a certain degree of difficulty to bend and shape the plate, and the final plate may not match perfectly with the surface of the clavicle.

MIPPO technology had the advantages to maximize the protection of blood supply, promote fracture healing and reduce the risk of infection and re-fracture, maintain the stability of fracture so as to reduce the demand of bone graft. The method of manual reduction combined with MIPPO technique for the treatment of displaced midshaft clavicle fracture was mainly aimed at that it was easy to make reduction while difficult to do fixation of clavicle fracture. By means of manual reduction, the iatrogenic injury caused by open surgical reduction may be avoided maximally. By ways of the MIPPO technique and anatomical locking plate, the fracture could be firmly fixed. This method may not only make the fracture obtain good reduction and firm fixation, but also does not destroy the original physiological environment of the fracture place.

3D printing technology has been applied in the department of orthopedics, and it could optimize the preoperative planning, provide individual and accurate treatment [2]. By means of computer aided design and 3D printing software, the characteristics of human clavicle with good symmetry, the mirror image of the uninjured clavicle was designed and printed. The mirror image model was highly similar to the primitive morphology of the fracture clavicle [6]. The preoperative planning and surgical simulation were performed on the mirror image model of the clavicle. Before the operation, the plate could be pre-bent and pre-shaped to ensure the plate strength and perfectly fit to the clavicle bone surface. And the screw length and intraoperative difficulties, which may arise, could also be predicted. Therefore the plate processing steps may be abandon, operation time be shorten, intraoperative bleeding be reduced, the incidence of postoperative complications be decreased. Zhao [7] reported that the using of 3D printing technology to print the clavicle model, which could pre-bend the plate by the model and initially evaluate the direction and the scale of screw placement, so that to reduce the operation time and the risk of surgery in a great extent. Jeong et al [8] also reported that the 3D printing technology might allow for easy reduction of fractures with accurate pre-bent plates via the 3D printing models. The fracture was complicated and the surgical incision was limited. So it should be the most appropriate treatment plan in theory with preoperative planning and preoperative simulation via the mirror clavicle model which was printed by the patient's own situation.

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Disclosure of conflict of interest

None.

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