

Use of 3D Printed Models for Pre-Op Planning, Intra-Op Utility, and Improved Understanding of the Nature of Deformity by Both the Patient and the Trainee

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Statement of Purpose

The purpose of this review is to evaluate the utilization of Three-Dimensional printed lower extremity models for trainee education, surgical planning, and patient understanding in the peri-operative setting.

Introduction and Literature Review

Three-Dimensional printing is an emerging technology with increased interest in numerous fields. There have been a high number of recent publications in developing new clinical uses for 3D Printing (3-9). As the technology continues to become more affordable and reliable, many novel noncommercial uses have emerged particularly in clinical and research applications. Reports of preoperative templating, deformity correction planning, and custom prosthesis printing have been described. (1,3,11) Currently two- and three-dimensional computed tomography images are used in conjunction with plain radiographs to identify the main pathology and their spatial relationship to one another, however, because these images are viewed on a screen, they give the surgeon limited insight into the physical configuration of the pathology leading to difficulties choosing the optimal surgical technique to use. (11). These two-dimensional images can be even more difficult for understanding the complex three-dimensional spatial relationships of the foot and ankle surgery on the use of 3D modelling in education and pre-operative planning. These 3D printed anatomical models are fabricated using routine CT scans obtained for preoperative planning, and 3D printed using printers. We present a mini case series consisting of two patients where 3D printed models were used in unique ways for resident education, pre-operative planning, intra-operative decision making, and patient discussion



Figure 1: Pre-operative comparison of 3-D printed model compared to the patient's foot from case #1. a: medial view of patient's foot and 3D model. b: dorsal view comparison of patient's foot and 3D model. c: intra-operative utility with to-scale pin-pointing of hardware.

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Case #1 Report

75-year-old with a past medical history of type II diabetes, hypertension, hyperlipidemia, and peripheral neuropathy presents with chronic non-healing plantar foot wound. Patient previously undergone exostectomy with medial column fusion eleven months prior. Presents with broken hardware, further collapse of midfoot, and worsening plantar wound. Using a 3D printed model based on CT scan, the apex of the deformity was noted to be a significant plantar cuboid prominence which helped confirm the decision for cuboid exostosis. The hardware was able to be color coded and detached from the model. Pre-operatively the model was placed on the table and a rocker bottom deformity was clearly visible.

Subjectively, this deformity was significantly more than the resident's expectations based on imaging studies. The patient felt an improved understanding. Intra-operatively, the model became a guide for pinpointing the hardware with ease, assessing the length of screws, and confirming the adequate resection of the plantar prominence.

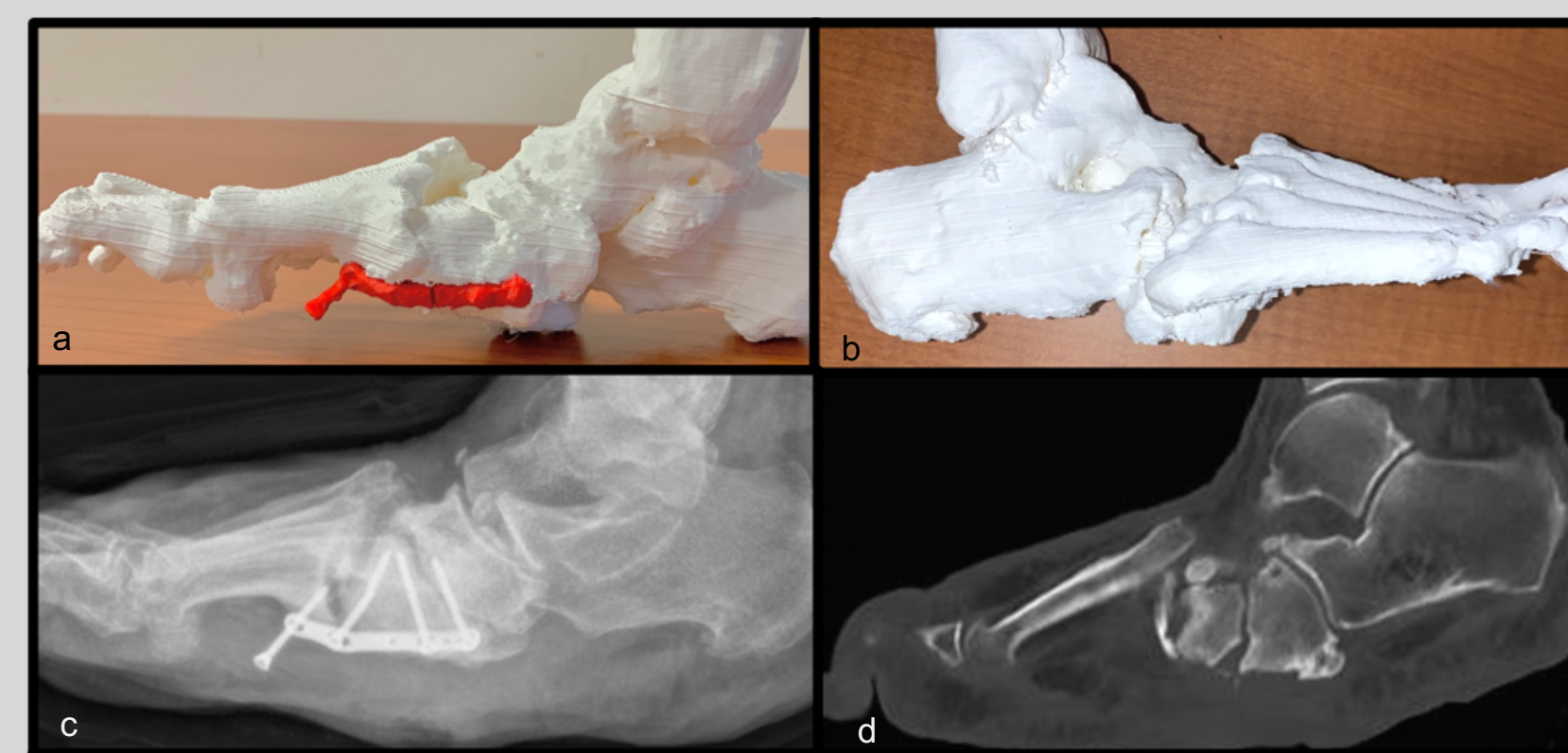


Figure 2: a: Medial view of 3-D printed model on weightbearing surface. b: lateral view of 3D model. c: lateral plain-film radiograph pre-operatively. d: sagittal CT scan showing plantar prominence, note the inability to view entire foot in one view.

Case #2 Report

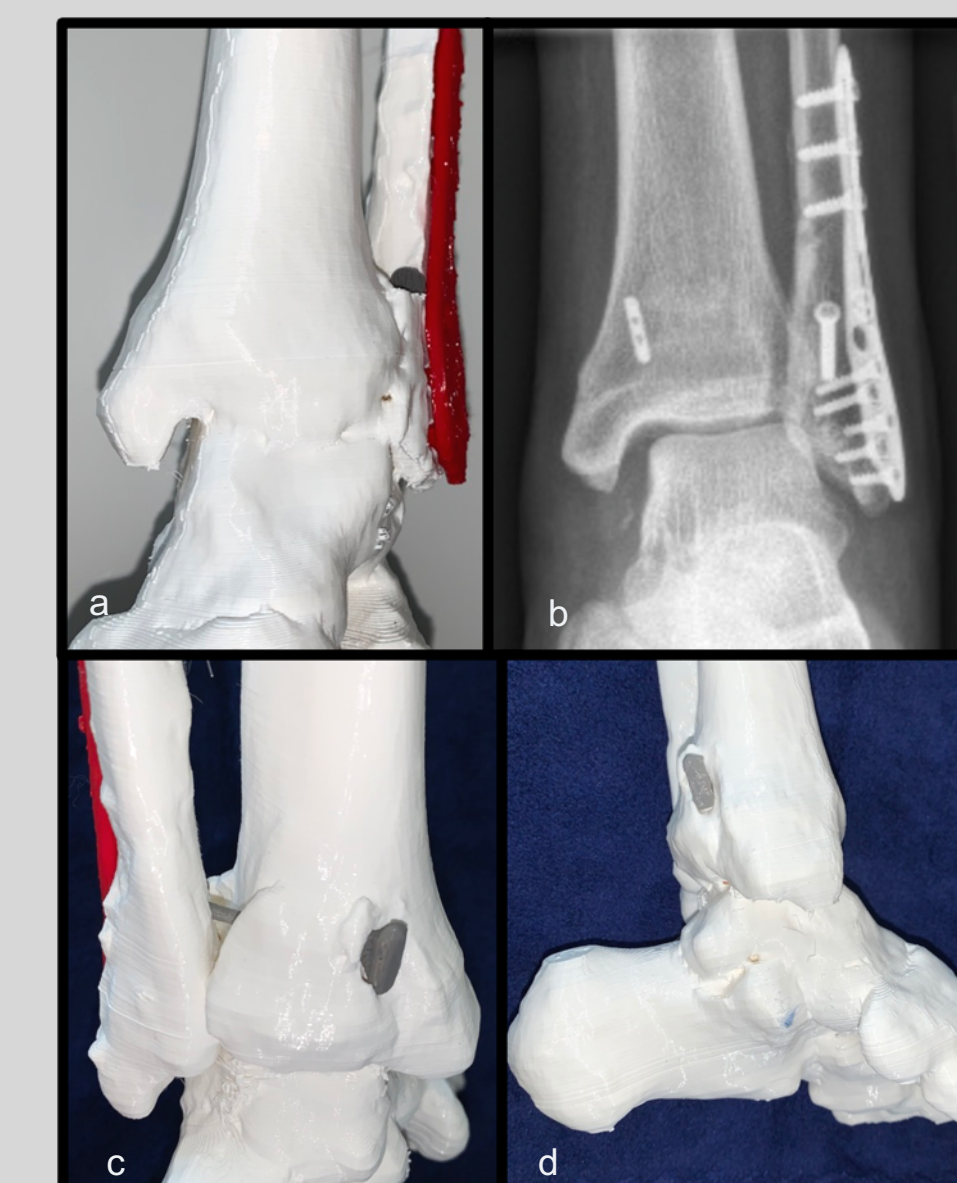


Figure 3: a. Frontal view of the 3D model showing widening of medial clear space. b: AP ankle radiograph with malposition of the syndesmotic fixation. c: posterior view of ankle joint with mal-positioned posterior malleolus. d. Medial view of ankle on 3D model.

46-year-old female with past medical history of diabetes presents as follow up for a tri-malleolar treated with lateral fibular plate and dynamic stabilization of the syndesmosis. Over the course of the previous 6 months, serial radiographs noted the syndesmosis to be widening 0.2mm at 2-week intervals. A CT scan was obtained showing a mal-positioning of the syndesmotic tightrope placed through the posterior malleolar fracture line. The patient stated she was impressed with her ability to see the model. Subjectively, the trainees stated they could now visualize exactly how the mal-positioning of the dynamic stabilization led to a lateral displacement of the posterior malleolus. Intra-operatively the model assisted in pinpointing the interfragmentary screw rapidly and visually changed the decision to leave the lateral fibula plate intact and gave a spatial orientation for which holes to place the syndesmotic screws.

Discussion

The primary purpose of this study was to show multiple uses of three-dimensional printing and its aid in treating patients and improving trainee's education. To fully grasp the complex three-dimensional spatial anatomy in foot and ankle surgery can be challenging for junior residents and patients alike(1). Three-dimensional printing has been shown to facilitate patient education during consultation, increase patient's understanding of the surgical procedures, and leads to improved patient satisfaction (2,12). Three-dimensional printed models of complex fractures have been shown to be a valuable educational tool especially for less experienced junior trainees (1,10). In addition, these models have been shown to reduce operative time and blood loss for complex surgeries by facilitating preoperative planning, shortening intra-operative fluoroscopy, decreasing blood loss, and improving efficiency in operating time especially in cases of hardware removal and revisional surgeries. (1,10) This increased visuospatial appreciation provided to the surgeon allows for aid in optimal approach and fixation technique including size of implants and trajectories of screws leading to a reduction of overall-all surgical time and decreased radiation to the surgeon and the patient (11) Given the relatively low cost, the use of 3D printed foot models provides educational value especially in the teaching

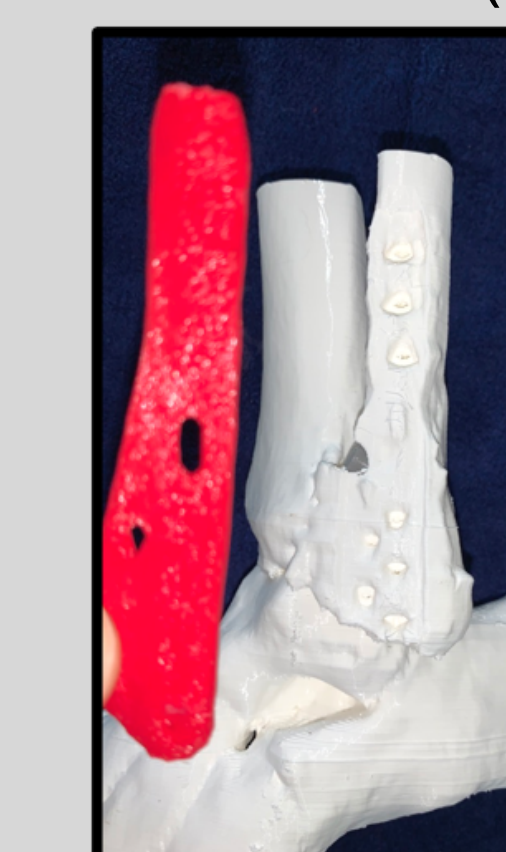


Figure 5: The detachable nature of 3D printed models to isolate hardware or fracture lines

hospitals. Limitations to our study include that it is a case series with a small number of cases reviewed mainly on subjective data. As with many revisional surgeries, it can be challenging to assess improvements in operative time, blood loss, and decreased fluoroscopy usage and these were not included in this study. This study further reinforces the growing body of evidence suggesting improved educational value of Three-dimensional printing especially in trainee and education.



QR Code: Scan for video for case #1 deformity

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