KnE Engineering

DesTech Conference Proceedings
The International Conference on Design and Technology (2017),
Volume 2017

Conference Paper

Custom Design & Fabrication of 3D Printed Cast for Ankle Immobilisation

Guruprasad Kuppu Rao[1]*, Tanmay Shah[1], Dr.Vijay Dayanand Shetty[2], and Prof. B Ravi[3]

[1]Imaginarium India Pvt Ltd, Mumbai, India
[2]LH Heeranandani Hospital, Mumbai, India
[3]Indian Institute Of Technology Bombay, Mumbai, India

Abstract

Management of bone and joint injuries is commonly done by immobilisation using plaster/fibreglass casts. This study describes design and fabrication of patient specific cast using 3D printing. The 3D printed cast while being patient friendly is superior to earlier casts in healing efficacy and hence redefines the joint immobilisation practice. We present here a case of "walk on brace" design and fabrication using 3D printing. The custom design of ankle immobilisation cast was done for an 18-year-old boy having tibia bone fracture during gymnastic activity. The workflow comprises of anatomical data acquisition, CAD, 3D printing, post processing and clinical approval for use. Additional features such as straps, anti-slip inner surface and tread for floor grip were incorporated in the design.

Keywords: Fracture, walking cast, Custom Design, 3D scanning and 3D printing

Corresponding Author: Guruprasad Kuppu Rao

Academic Editor: Paul K. Collins

Received: 28 November 2016
Accepted: 4 December 2016
Published: 9 February 2017

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the DesTech Conference Committee.

OPEN ACCESS

1 Introduction

Ankle fractures result from torsional forces and manifest as tenderness, swelling, deformity and inability to weight bearing [1]. Joint immobilisation for bone and joint injuries is routinely done using plaster cast [2]. While plaster cast effectively immobilises the joint, it has major drawbacks of being heavy, no ventilation and difficulty to clean, etc. This further may lead to itching, sores, bacterial/fungal infection. In recent past years, sleeker fibreglass casting is becoming popular [2]. These are much lighter in comparison to plaster cast but continue to suffer from other limitations such as poor ventilation, infections, sores and in extreme cases leading to amputations.

The most desired attributes of cast are shape conformation, perfect fit, rigidity to prevent the unwanted movement at joint with structural support [3]. 3D printed custom fit leg casts/braces fabrication is attempted by combination of technologies such as 3D scanning, computer aided design (CAD) and computer aided manufacturing (CAM).

3D printed brace [4] for forearm immobilization is described. Our paper shares a step-by-step workflow about fabrication of a 3D printed walk-on brace.

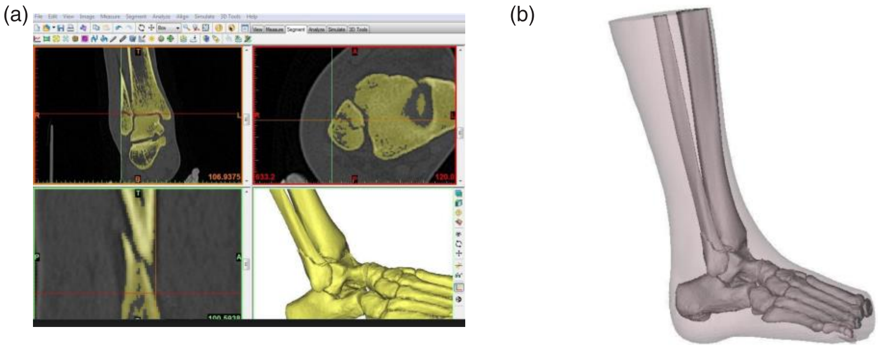

Figure 1: (A), CT slice showing the fracture. (B), 3D reconstruction.

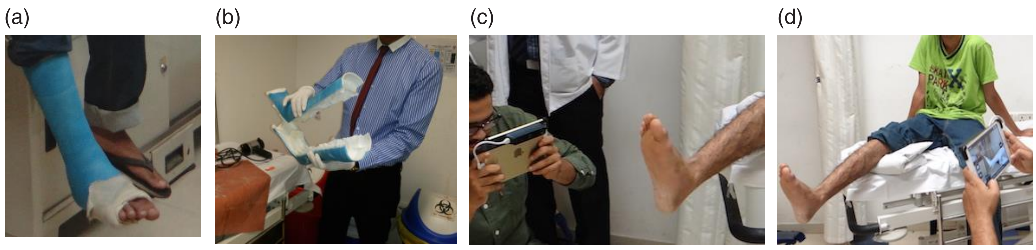

Figure 2: (A), FRP cast done initially. (B), Cast cut and removed as 2 "L" halves. (C), Scanning of Foot by iSense attached to an iPad. (D), iSense being used with iPad to acquire data.

1.1 The case study

An 18-year-old boy had a lateral malleolus fracture due to a fall during gymnastic activity. Diagnostic X-ray and Computerised Tomographic study (CT) was done for clinical evaluation of the injury. CT images [Fig. 1A] and 3D view [Fig. 1B] show the defect clearly.

The condition was initially stabilised with a fiberglass cast. The cast started from the metatarsal heads and was ending close to the fibular head (Fig. 2A). Additional padding was placed over bony prominences, including the fibular head and both malleoli. This cast was not fit for walking, as it would not bear the body weight.

2 Methodology

2.1 Digital data acquisition

The steps involved are obtaining limb surface data by either CT scan or 3D optical scanner, processing of DICOM or point cloud data respectively, building 3D Digital model in STL format, 3D printing, finishing and assembly.

The patient's fiberglass cast (Fig. 2A) was taken off (Fig. 2B) and affected leg was kept at an elevated level (Fig. 2C). The affected foot was kept on plane surface with angle between ankle and foot are at 90 degrees. This is very important step from

DOI 10.18502/keg.v2i2.601

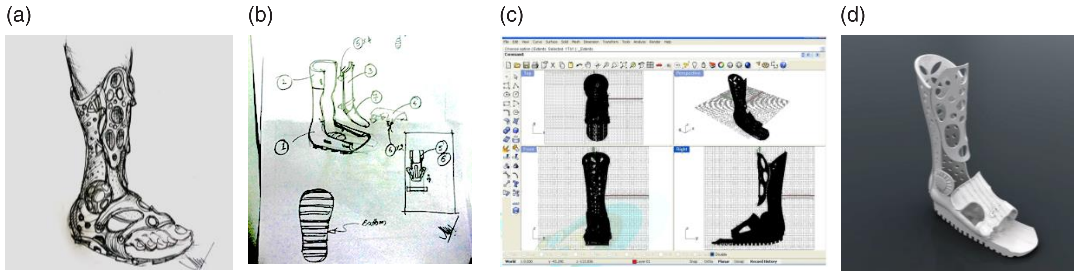

Figure 3: (A), Concept sketch of cast. (B), detailing of the cast concept. (C), CAD modelling using Rhinoceros. (D), Digital Rendering of the cast.

clinical viewpoint [5]. iSense hand held scanner from 3D systems was used with a iPAD to acquire the data (Fig. 2D). The scan was repeated in horizontal position till the complete data is properly acquired. After scan, the data is processed to get a surface of the leg, which is accurate for further processing.

2.2 Digital Cast Design

The surface point cloud data was converted to CAD model by using the two softwares, namely, Blender & Rhinoceros (Fig. 3C). The surface is then provided thickness of 6mm to get a boot structure. This forms an accurate cast of the limb model that is further improved and adopted using CAD software. A side parting line is drawn in L shape either side and is digitally cut into two parts. Care is taken to avoid sharp edges by using fillets wherever possible.

The 2 “L” parts form the basic scaffold. The posterior “L” is provided with a number of ribs to reduce weight without compromising on strength. The anterior “L” is suitably modified so as to strap Velcro bands. The posterior cast is provided with a number of voids along the length, between the ribs for ventilation. This feature not only provides for openings for air passage but also reduces weight.

The sole was added to the cast for walking. Further the sole is rounded in the front and back to allow the teeing and lean back while walking. The walking needs the sole grip and is enhanced by incorporating ribs. The ribs also add stiffness and strength. The thick section is added to sole (Boolean union) and it is hollowed out with a thickness of 2mm. The hollow region is then filled with a lattice structure making it lighter. The floor of the foot is curved as the foot and is quite smooth, which can cause slipping. It is addressed by providing a texture made of a grid of embossed convex rounds.

The anterior L part is also ribbed and adequately perforated for ventilation. It is assembled virtually on computer to ensure fit. The loops and buckles are designed and assembled to check the strap function. As the part is highly curved, it is decided to fix the loops and buckles after the fitting of patient’s foot and was hence made as an item to be fixed later. The whole parts are checked for strength and bottom sole with a FOS of 2 times the stationery load. Boy weight = 50 kg. Load on one foot = 25 kg.

DOI 10.18502/keg.v2i2.601

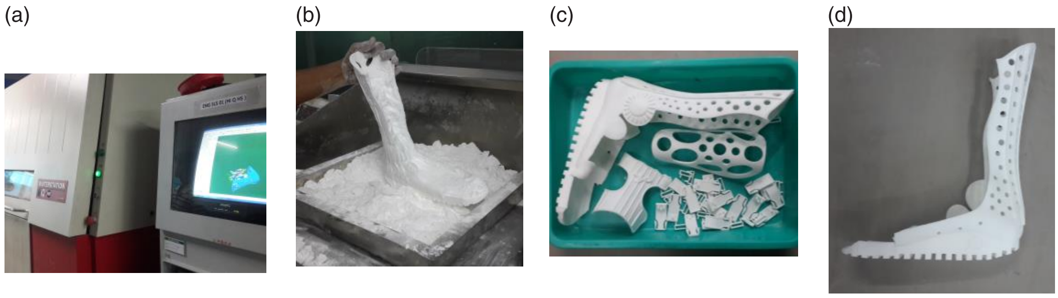

Figure 4: (A), SLS machine used to build the part. (B), Part being removed from the powder cake. (C), Nylon Parts made in SLS. (D), The bottom part of the cast.

Footwear is designed for 25 × 2 = 50 kg. Each part to be 3D printed is exported as STL. This completes the digital design of the cast.

The load bearing and ankle movement forces were considered for the region connecting vertical part of cast with the horizontal footboard. It is fashioned as a round shield with a motif as required by the patient. The completed CAD design was exported in STL file format.

2.3 3D printing

3D printing is a set of Technologies that help produce parts directly from CAD data layer by layer [5][6]. 3D printing due to its capability to fabricate intricate organic shapes is becoming popular in healthcare/medical applications [7] [8]. We choose the selective laser sintering which uses Nylon powder as raw material for this project. It is selected due to its biocompatibility and the build process that does not require any support structure.

The cast was printed using 3D Systems SLS 3D printer (Fig. 4A). This printer uses CO_2 laser for sintering Nylon PA12 material to build the model layer by layer. Post build, The cast was allowed to cool to room temperature. The part is removed from the powder cake (Fig. 4B) followed by cleaning of extra powder by sand blasting, Flexible parts were heat treated for stability. The cast was digitally inspected for accuracy (Fig. 4C & 4D).

2.4 Assembly of parts

The posterior cast is tried out on foot and anterior part was aligned. The loops, straps and buckles are marked for optimum fit. The loops and buckles are fixed in the marked areas (Fig. 5A). Additionally The Velcro straps are used to secure foot and bring about the much-needed immobility of the ankle joint (Fig. 5D)

Figure 5: (A), Cast being tested on patient. (B), Cast tested with foot loading. (C), Cast tested for floor grip. (D), Walking Gait Testing with velcro band holding the foot.

2.5 Cast Try out

The cast thus developed was put on the patient (Fig 5A & 5B) in presence and guidance of clinician. The joint was checked for 90 degree with horizontal and vertical (Fig. 5C) and was strapped with Velcro. The patient experience and clinician observation of walk were recorded (Fig. 5D).

3 Results and Conclusion

The design and fabrication of custom digital walk on cast/brace was completed and tried on patient successfully. The device experience by patient was satisfactory and functional.

This 3-D printed cast was nicknamed Moon walker*, was well conforming to shape of the lower leg. The void spaces in the wall of cast could provide enough ventilation for the skin, besides making it lighter in weight. The patient could maintain cleanliness by temporarily removing the cast. The ankle immobilisation was confirmed by clinical testing. The process shows a lot of potential in immobilisation and is expected to grow in its application and adoption. For the severe leg injuries, the casts can be built with the features such as window for clinical examination of dorsalis paedis and posterior tibial arteries. Similarly, the cast can include oxygen saturation sensors for tissue viability monitoring.

References

[1] R. Singh, T. Kamal, N. Roulohamin, G. Maoharan, B. Ahmed, and P. Theobald, Ankle Fractures: A Literature Review of Current Treatment Methods, *Open Journal of Orthopaedics*, **4**, 292–303, (2014), 10.4236/ojo.2014.411046.

[2] S. V. Casting, Principles of casting and splinting, (2009).

[3] R. Y. Hsu, and J.A.S.O.N. Bariteau, Management of ankle fractures, *RI Med J*, **96**, no. 5, 23–7, (2013).

[4] A. M. Scott, Diagnosis and treatment of ankle fractures, *Radiologic technology*, **81**, no. 5, 457–475, (2010).

[5] C. R. Labella, Common acute sports-related lower extremity injuries in children and adolescents, *Clinical Pediatric Emergency Medicine*, **8**, no. 1, 31–42, (2007), 10.1016/j.cpem.2007.02.010.

[6] N. Hopkinson, R. Hague, and P. Dickens, *Rapid Manufacturing: An Industrial Revolution for the Digital Age*, John Wiley & Sons, New York, NY, USA, (2006).

[7] I. Gibson, D. W. Rosen, and B. Stucker, *Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing*, Springer, Berlin, Germany, (2010).

[8] B. Sanghera, S. Naique, Y. Papaharilaou, and A. Amis, Preliminary study of rapid prototype medical models, *Rapid Prototyping Journal*, **7**, no. 5, 275–284, (2001), 10.1108/13552540110410486.

[9] F. Rengier, A. Mehndiratta, H. von Tengg-Kobligk, *et al.,* 3D printing based on imaging data: review of medical applications, *International Journal of Computer Assisted Radiology and Surgery*, **5**, no. 4, 335–341, (2010), 10.1007/s11548-010-0476-x.