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Case study on viability of rapid prototyping application in Health industry

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Abstract *- The technology of Rapid prototyping is relatively new to the field of the health industry. This paper presents the procedure for 3D printing using the Rapid prototyping method for manufacturing teaching aid/ prototypes used in Medical application is presented in detail using the completed case study. The case study presented is for Human Jaw replacement surgery, and the 3D printing procedure is elaborated and discussed using design stages and photos.*

***Keywords* —** *3D printing, Medical applications, Procedure, Rapid prototyping; Teaching aid.*

I. INTRODUCTION

3D printing is emerging as the first preference in designing and manufacturing of industrial, commercial, defence and medical parts in the past decade [1]. The use of sophisticated designing software coupled with 3D printers is paving the way for innovative solutions for the already optimized processes. The applications of 3D printing in medical sciences are consistently increasing. Especially in orthopaedics, the applications are but not limited to production of surgical implants for bones, joints, spine, customized jigs for trauma, complex fractures, and arthroplasty [2]. The surgeons are already applying the 3D printed implants for various orthopaedic trauma surgeries [3]. The process begins with taking the MRI or CT images of the patients, which provides details about the damage, thus enabling the surgeon to understand the precise patho-anatomy. In the next step, doctors plans for the implant by considering the traumatized bones, soft tissues and normal areas. Once the problem is analyzed, the next step is the creation of 3D designs which can be printed via 3D printers [4].

The traditional 3D printing techniques employ various etching methods to create the final object. There is another kind of 3D printing known as additive manufacturing/printing [5]. In this kind of printing, the successive layers are laid upon one another until the final object is created. The design is first completed in the designing software such as CAD, and the resultant file is then exported in Standard Triangle Language (STL) format. This is an industry-standard file type for 3D printing. The researchers have classified the 3D printing into three major classes, i.e. facilitative, selective and generative 3D printing services [6].

II. 3D Printing Contribution to Health Industry around the World

Additive manufacturing (3D printing) is leading a design and industrial revolution, in different areas such as aerospace, energy, automotive, medical, tooling and consumer goods. One of the major sectors -that is dramatically expanding-is medical industry. As we can see in Figure 1 below the medical application shares was 16 % in 2013.

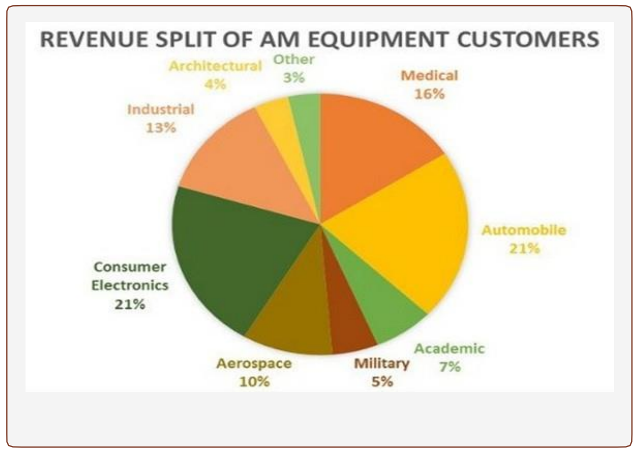

Fig 1: Industrial split of AM equipment customers [7].

Figure 2 below displays the country based contribution during 2015-2018 on 3DP application in clinical trials.

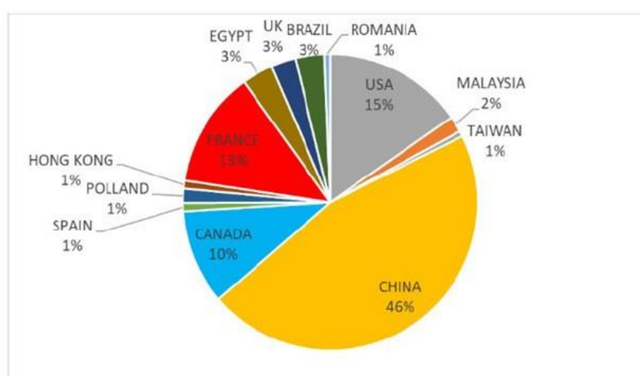

Fig 2: Completed clinical trials using 3DP around the world during 2015-2018 [ClinicalTrials.gov].

In the following section, the major divisions in the application of 3D printing in the health industry are elaborated. Two of the application areas are further analyzed with detailed design procedure and case study examples of the design procedure, and recent advances.

III. Application Areas of 3D Printing to Health Industry

The primary applications of additive manufacturing in the medical industry can be broadly classified into:

a) Prototype and teaching aids,

b) Jigs and fixtures,

c) Tooling and

d) Implants/ end-use parts.

These are further explained below:

- Prototypes & Teaching Aids: Is the most common application of 3D printing in the health industry, and this technology is widely termed as 'rapid prototyping'. Teaching aids/ prototypes allow doctors and physicians to practice on true, life-size models before actual surgery/procedure. Physician and patient feedback reviews prove better physician confidence, improved post-treatment experience and reduced surgical times.
- Jigs & fixtures: To maintain quality and process efficiency for delivering accurate, high-quality outcomes.
- Tooling: The use of additive manufacturing in tooling production reduces the lead times and costs. Also, it improves functionality and enhances the ability to customize.
- Implants/ End-use parts: A final product that will be used by the customer such as medical devices, implants, orthopaedic, hearing aids and dental applications.

IV. Prototypes & teaching aids – Case study

Figure 3 displays a flowchart denoting the process/ methodology of creating a 3D printed prototype using the Rapid prototyping technology [7-11].

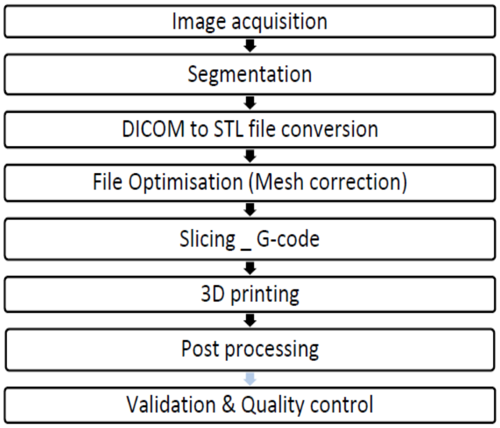

Fig 3: Flowchart for 3D printing of Prototype for pre-surgical planning.[8].

A. Case Study - Methodology

The below case study is completed at the 3Dvinci laboratory for pre-surgical planning.

- Case Diagnosis: The patient has a part broken from the Jaw during a car accident.
- Status: The patient has a part broken from the Jaw during a car accident.
- Procedure: The required CT scanning was handled. Then, the segmentation -in which a specific region of clinical interest is selected on each axial images based on pixel information to construct a 3-D model- was done. Figure 4 shows the model with the X-Ray view, and Fig 5 displays the STL file model. Recently, Medical images are stored as DICOM (Digital Imaging and Communications in Medicine). However, 3D printing machines can only recognize certain formats such as STL, obj and wrl. So the 3D model was converted to STL, and then the file was optimized for 3D printing. Before starting the 3D printing process, the file needs to be sliced and saved as G-code (Figures 5 & 6).

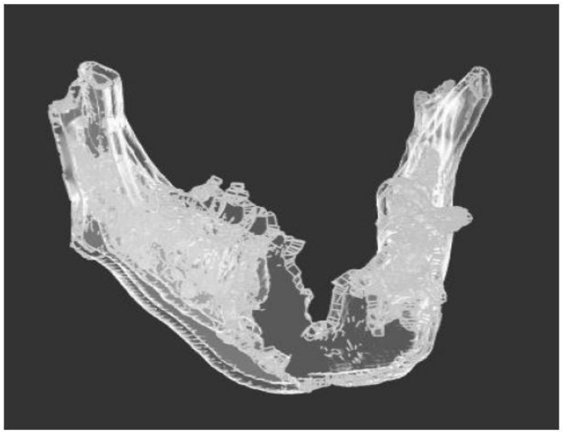

Fig 4: X-Ray view of the Jaw.[9]

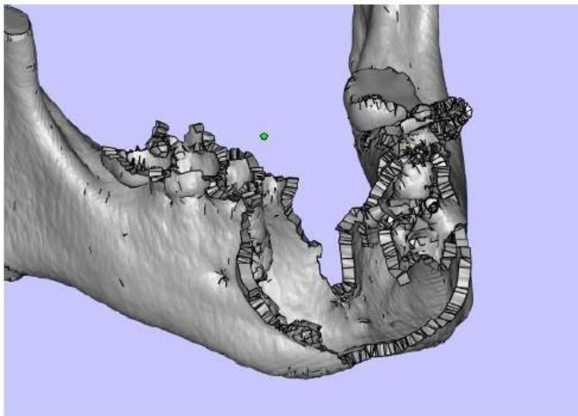

Fig 5: The Jaw front-broken part in STL Format.[9]

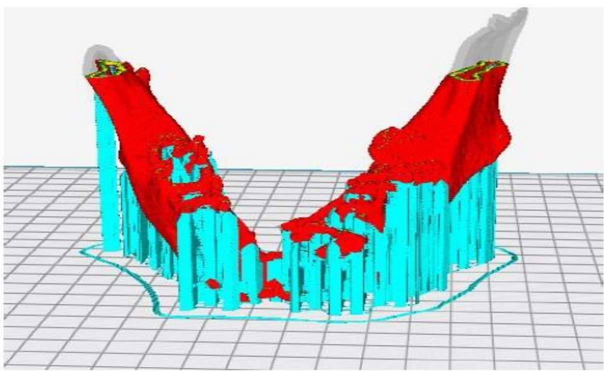

Fig 6: File preparation (Slicing).[9]

Once the STL file is created, and Slicing is done, the part was printed using FDM technology. The printing material was PLA. Figure 7 shows the process of 3D printing. The same steps are done to produce a negative mold. It will be used to produce the broken part of the jaw Figure 8. The cross-section of the negative model in STL format and slicing process is displayed in Figures 9&10. Figure 11 shows the 3D-printed parts after post-processing. These two parts are used for pre-surgical planning.

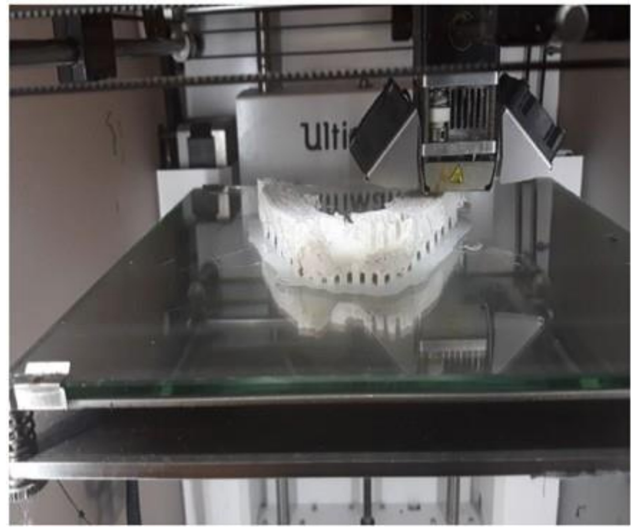

Fig 7: 3D printing process using FDM Technology. [9]

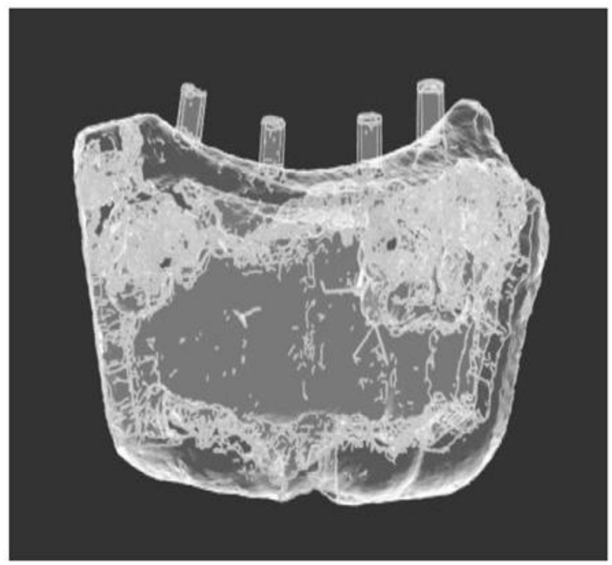

Fig 8: X-ray view of the negative mold. [9]

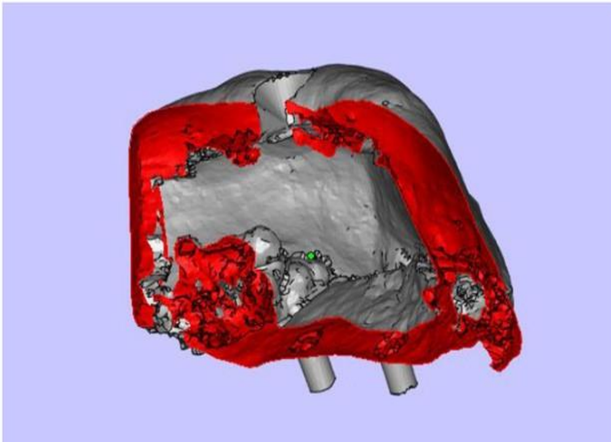

Fig 9: The guiding mold for 3D printing.[9]

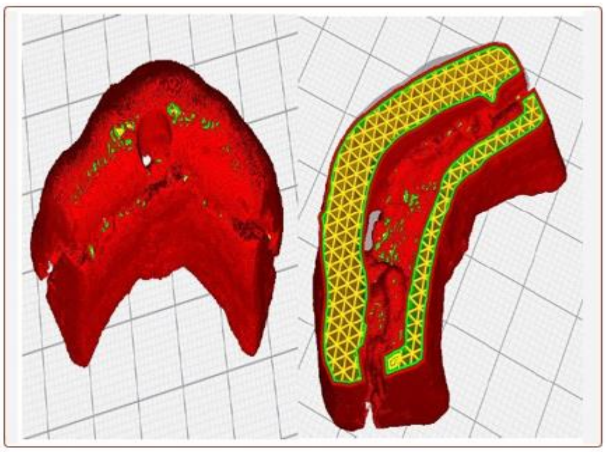

Fig 10: The slicing process using Cura-Software.[9]

Fig 11: 3D-Printed parts after post-processing.[9]

The 3D printed part was used for training purposes before the actual surgical procedure was conducted. This resulted in a reduction of the Surgery training time, improvement of surgical results, and better confidence levels among patients and surgeon.

B. Case Study – Results

- Modifications were applied many times to get the right mold. This reduced the risk of having tight or wide tolerance. Figure 6 shows the 3D model of the final verified mold trial during the production preparation. In the end, the patient got a customized part gained from the perfect mold.
- The time of surgery reduced by 30% as the doctor practiced on real-life models.
- The patient feedback was fantastic about the comfortability of the part.

V. Acknowledgement

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VI. Conflict of Interest

No conflict of interest.

REFERENCES

[1] SC Ligon, R Liska, J Stampfl, M Gurr, R Mülhaupt (2017) Polymers for 3D printing and customized additive manufacturing. Chem Rev 117(15): 10212-10290.

[2] S Gao et al. (2019) 3D Printing in Orthopedics: Upper Extremity Trauma and Deformity. in 3D Printing in Orthopaedic Surgery, Elsevier, pp. 85- 94.

[3] DM Cheriachan, M Di Paola, JP Iannotti, ET Ricchetti (2019) 3D Printing in Orthopedics—Upper Extremity Arthroplasty. in 3D Printing in Orthopaedic Surgery, Elsevier, 151–169.

[4] M Dipaola, FM Wodajo 3D printing in orthopaedic surgery. Elsevier Health Sciences (2019).

[5] TD Ngo, A Kashani, G Imbalzano, KTQ Nguyen, D Hui, Additive manufacturing (3D printing): A review of materials, methods, applications and challenges. Compos Part B Eng 143 (2018) 172–196.

[6] H Rogers, N Baricz, KS Pawar, 3D printing services: classification, supply chain implications and research agenda. Int J Phys Distrib Logist Manag 46(10) (2016) 886–907.

[7] Wohlers Report, 3D printing in biomedical applications: Overview and Opportunities., 3D Printing Metal Market Size, Share & trends analysis report by form (filament, powder), by product (steel, titanium, nickel), by application (medical, aerospace & defence), and segment forecasts (2013).

[8] "A Roadmap from Idea to Implementation – 3D Printing for Pre-Surgical Applications. 1st Edition Hui Jenny Chen MD Michelle Gariel, MS, M.B.A. 18.

[9] 3DVinciCreations-Dubai- Practical case study by Eng. Hussam Salah.