Case Study

CAD/CAM APPLICATION WITHIN INDUSTRY 4.0 IN HEALTHCARE

Keywords: *CAD, Healthcare, Volumetric CAD, surgical guide, Industry 4.0*

Background to Case Study

CAD/CAM (Computer-Aided Design / Computer-Aided Manufacturing) is the use of computer software to design and manufacture prototypes, products and production runs. CAD/CAM is an essential technology of Industry 4.0 implementation in the SMEs specialised in product development and manufacturing. It represents a pivotal part of the data stream that starts with the input from clients and ends with the final product or service.
There is an increasing need of rapid-product-development services in the field of healthcare, in order to provide doctors and patients with surgical guides and custom implants. SMEs can deliver these in a fast and cost-effective manner by taking advantage of the developments in CAD, rapid manufacturing and biocompatible materials.
Volumetric CAD is based on voxels which stick together to create a solid mass and can be sculpted just like clay or wax. Consequently, this type of CAD software gives designers speed and design freedom with complex, organically shaped objects.

This case study presents a SME that leverages volumetric CAD in order to provide advanced product design services in healthcare.

Introduction to the Case Study and it's growth within Industry 4.0.

TPC Design (https://tpcdesign.net/) is a SME located Hummelstown, USA, that offers expert product design and development consulting services in industries such as medical, aerospace and automotive.

This case study shows how TPC is using volumetric CAD to improve and speed up the design and manufacture of a surgical guide for craniosynostosis repair (a surgery to correct a problem that causes the bones of a baby's skull to join together too early).

The healthcare sector is currently transformed by Industry 4.0 and its underlying technologies. Among these, advanced (volumetric) CAD technology can be employed to model very complex objects, previously impossible to be handled digitally, such are human skulls. In the same time, rapid prototyping technologies, such as CNC and Additive Manufacturing, can accurately and quick produce these objects. In addition to CAD and rapid prototyping, digital medical imaging equipment, like Radiography (X-rays), Magnetic resonance imaging (MRI) and Computed tomography (CT) can be also included in the data flow, as well as various digital simulation tools (i.e., Finite Element Analysis (FEA)).

This case study is showing how the digital integration of medical image data, CAD, simulation software and rapid prototyping are making the design and manufacturing of medical devices faster, more convenient and more accurate.

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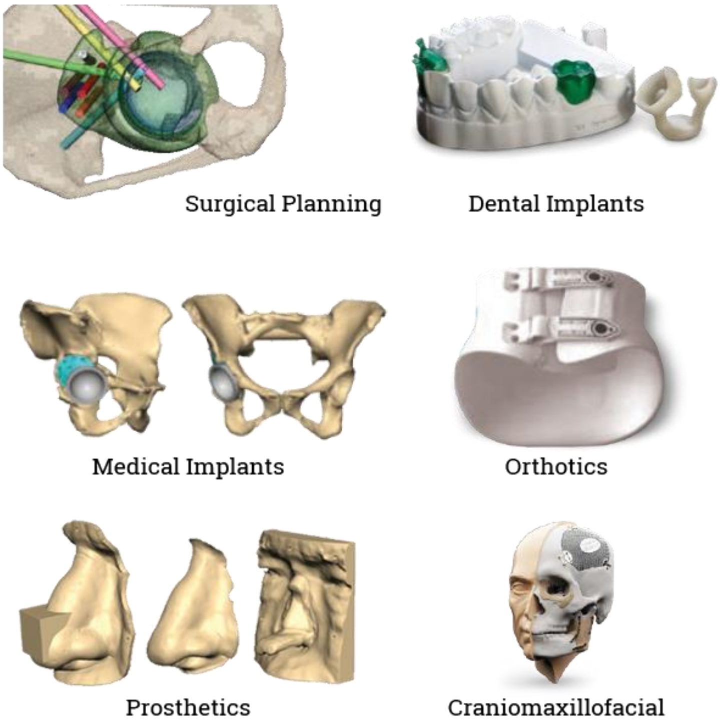
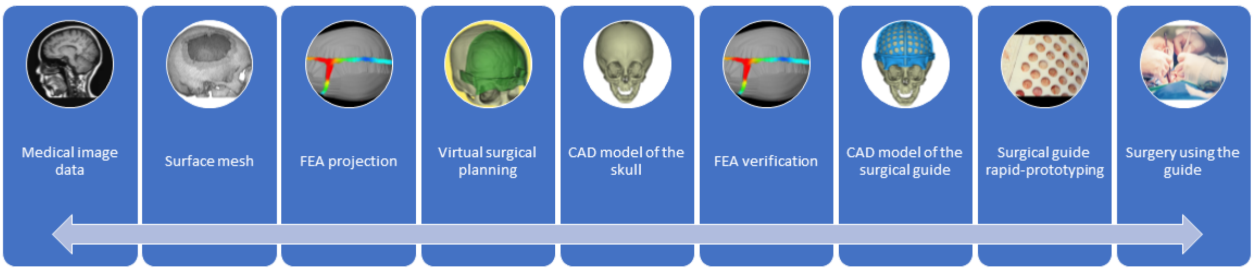
The Case Study and Industry 4.0 Elements: A Pictorial Overview



Uses of volumetric CAD. Image source: https://gomeasure3d.com

TPC Design designed and manufactured a surgical guide for a surgeon working on a craniosynostosis case.

The application of volumetric CAD supports the growth of the SME under study by allowing it to model very complex shapes and to integrate the digital model in a workflow that uses medical image data, finite element simulations and rapid prototyping in order to design and manufacture medical devices fast, cost-effective and accurate. Consequently, TPC is now able to offer new high-quality services in the fast-growing market of medical industry.



The digital workflow of TPC. Image source: Ludor Engineering

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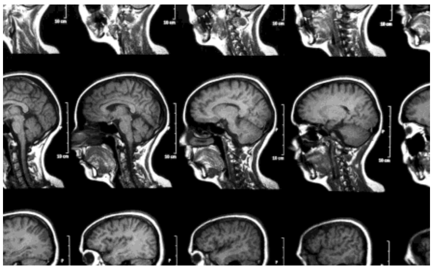
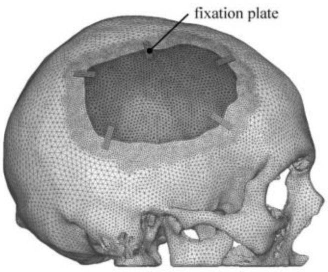
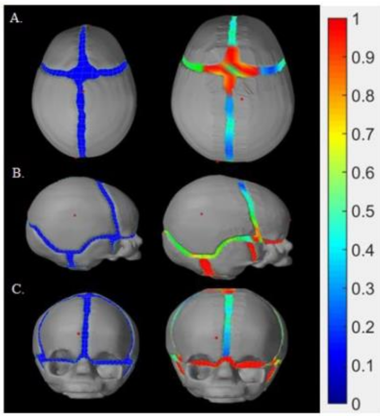
CAD/CAM APPLICATION WITHIN INDUSTRY 4.0 IN HEALTHCARE

The Element Explored within Industry 4.0 Application.

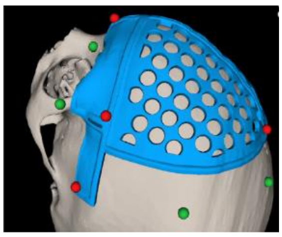

CT scans. Image source: medicai.io



Mesh of a skull. Image source: [1]



Simulation of skull growth. Image source: [2]


Surgical guide. Image source: [3]

The digital workflow implemented by TPC in order to design and manufacture surgical guides for craniosynostosis repair consists of several steps, detailed below.

1. *Medical image data of the patient's skull are obtained by Computer Tomography (CT).*
2. *CT data are processed by the TPC engineers in order to clearly identify the cranial fissure lines.*
3. *A surface mesh is created using Geomagic® Freeform® volumetric CAD software, in order to ensure that the varying thicknesses of the skull is accurately captured in the design.*
4. *The mesh is used as a source for a Finite Element Analysis (FEA) projection of the baby's head shape if it was allowed to grow several months without surgery.*
5. *Surgeons use the highly accurate, digital model delivered by FEA to plan the specific surgical bone cuts needed.*
6. *In the CAD software, the surgical bone cuts are performed and the bone is placed back into the anticipated post-surgical position. For this, the surgeon and TPC engineers work together over a computer.*
7. *The design file is adjusted and the FEA is repeated in order to confirm that the new shape would have uniform stress predictions throughout the skull, thus maintaining the desired shape as the baby's brain grows.*
8. *Based on the final skull shape, TPC design a surgical template for the surgeon to guide the bone cuts for the ideal skull shape.*
9. *After surgeon review and approval of the surgical guide, TPC confirm the final placement of the patient-specific template on the skull model and simulates the future shape.*
10. *TPC use rapid-prototyping machine to build the disposable template out of a suitable biocompatible resin for the actual surgery.*
11. *For the surgery, the surgeon lays the template on top of the bone to guide the cuts.*

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Application Target Audience	*The results of the case-study are intended for use by SMEs and entrepreneur subjects.*
Resources Used:	https://ecss.sg/using-geomagic-haptic-device-and-geomagic-freeform-software-to-reshape-heads-in-biomedical/ https://tpcdesign.net/ https://www.3dsystems.com/software/geomagic-freeform
Further Reading:	*References* 1. *Tsouknidas, A. et al. (2011). FEM assisted evaluation of PMMA and Ti6Al4V as materials for cranioplasty resulting mechanical behaviour and the neurocranial protection. Bio-medical materials and engineering. 21. 139-47. 10.3233/BME-2011-0663.* 2. *Jin J, Eagleson R, de Ribaupierre S (2018) Skull Development Simulation Model for Craniosynostosis Surgery Planning. Biol Eng Med 2: DOI: 10.15761/BEM.1000138* 3. *García-Mato, D., Ochandiano, S., García-Sevilla, M. et al. Craniosynostosis surgery: workflow based on virtual surgical planning, intraoperative navigation and 3D printed patient-specific guides and templates. Sci Rep 9, 17691 (2019). https://doi.org/10.1038/s41598-019-54148-4*

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