EXAMINING AND DEVELOPING A MEDICALLY RELEVANT COMPONENT THROUGH REVERSE ENGINEERING

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Abstract: *This project focuses on the examination and design of a medically relevant component, specifically a dental prosthesis, using the method of reverse engineering. Reverse engineering involves a thorough analysis of an existing piece to understand its functioning and specifications, with the aim of creating an improved or adapted version. In the medical context, this approach is employed to develop a specific component with medical significance. This study explores the steps of this process, emphasizing detailed understanding, design, and implementation of this dental prosthesis, with a particular focus on its utility and importance in the medical field*

Keywords: *Print 3D, geomagic, , cura, medical, Reverse engineering.*

1 INTRODUCTION

The intersection of medicine and technology is a dynamic and evolving space, where continuous innovation is not only desired but imperative. As the demand for sophisticated medical equipment rises, the exploration of innovative methods to design, enhance, and create these essential components becomes a priority. In this context, reverse engineering stands out as a strategic and promising approach.

Reverse engineering, a concept often associated with reverse engineering, goes beyond the traditional analysis of existing objects [1-7]. It encompasses a methodology of thorough investigation, where every detail of a component is meticulously examined to understand its structure, functionalities, and specifications. This approach goes beyond merely understanding the design of a component; it paves the way for improvements, adaptations, and innovative creations.

In this study, we delve into the application of reverse engineering to the creation of a specific component in the medical field. This detailed exploration aims to demonstrate how this approach can meet the specific needs of modern medicine by designing essential components [8-10]. Emphasis is placed on the importance of this component in the medical context and its potential to enhance healthcare and treatments [11].

Therefore, this investigation provides an opportunity to understand not only the process of reverse engineering but also its potential impact on advancing medical solutions. By highlighting this innovative approach, this study aspires to contribute to the constant evolution and continuous improvement of medical equipment and care.

This work distinguishes itself by focusing on reverse engineering in the medical field. It concentrates on the in-depth study and creation of a medically significant component using this method. Reverse engineering involves a thorough analysis of an existing piece to understand its specifics and functionalities, with the aim of creating an improved or adapted version. In this medical context, this approach is applied to the design of a specific component. This study explores the different stages of this process, highlighting detailed understanding, design, and implementation of this component, underscoring its relevance and crucial impact in the medical field.

2 EXPERIMENTAL TECHNIQUES

As part of this project, our approach involved the use of specialized software such as Geomagic and Cura for data digitization and the generation of the necessary G-code for printing [12-15]. Simultaneously, we utilized cutting-edge hardware tools, including an Anycubic 3D printer and a Faro scanner. The combination of these software and hardware components was crucial in achieving our modeling and production objectives in this study. It's worth noting that the dental prosthesis used was obtained from a private dental surgery clinic located in M'sila, Algeria.

2.1 3D printers from Anycubic

Anycubic 3D printers stand out for their precise and diverse features. With an adjustable layer resolution ranging from 0.05 to 0.3 mm, they enable detailed and customizable printing. The heated bed, with a temperature capacity of up to 110°C, promotes better material adhesion during printing. The print volume varies across models, offering dimensions ranging from 210 x 210 x 205 mm to 300 x 300 x 305 mm. Anycubic 3D printers are equipped with a user-friendly 2.8-inch diagonal touchscreen, simplifying interaction with the device. Some versions incorporate an auto-leveling system to facilitate preparation before each print. They are compatible with various materials such as PLA, ABS, PETG, and TPU. The printing speed can be adjusted, ranging between 20 and 100 mm/s to meet quality and speed requirements. The assembly of these printers is simple and quick, typically requiring no more than 30 minutes and no specific tools. These values are typical estimates and may vary depending on the specifications unique to each model (Fig 9).

2.2 FARO-type scanners

3D scanners for dental prosthetics are revolutionizing the way these devices are designed and manufactured. Using advanced technologies, these scanners meticulously capture the structure and dimensions of teeth with precision, enabling the creation of custom prosthetics. This advancement significantly reduces manufacturing times and enhances accuracy, ensuring more comfortable and better-fitted prosthetics tailored to individual patient needs. These 3D scanners pave the way for more personalized and efficient dentistry, providing high-quality prosthetic solutions for improved oral health (Fig.1).

FARO 3D scanners represent a major technological breakthrough, offering exceptional technical features. Their scanning accuracy, reaching up to 0.04 mm, ensures detailed captures of objects. Some models offer an impressive range from 0.6 to 330 meters, allowing the capture of objects at various distances. The scanning speed is remarkable, reaching up to 976,000 points per second for fast and precise analyses. Portability is a major asset, with lightweight and mobile models suitable for on-site scanning. These scanners also offer high spatial resolution, up to 0.043 mm at a distance of 1 meter, capturing tiny details with precision. Some models enable the capture of color and high-definition data for more accurate visual representation. Additionally, they come with powerful software for data processing and modeling. These devices are widely used in various industrial sectors such as engineering, architecture, and other fields where precision and detailed data capture are essential for advanced applications. Specific values may vary depending on the models of FARO 3D scanners available in the market.

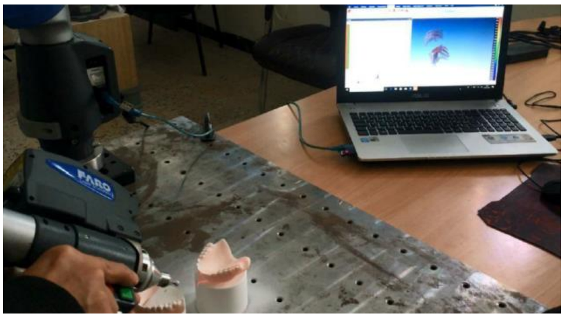

Fig1 : 3D scanners for a dental prosthesis

3 THE 3D CASTING REVOLUTION

Medical advancements are rapidly multiplying, providing improved inventions every day that enhance our well-being and simplify our daily lives. Among these recent breakthroughs, 3D casting represents a significant leap forward (Fig 2). This emerging technology, increasingly relevant, is revolutionizing how three-dimensional structures precisely conform to the muscles and individual needs of patients. Its snug fit combined with the ability to allow the skin to breathe makes it a major asset. Although several startups worldwide are dedicated to developing this technology, its full integration into our healthcare system might take a bit longer than anticipated, even though we remain optimistic about its gradual adoption.

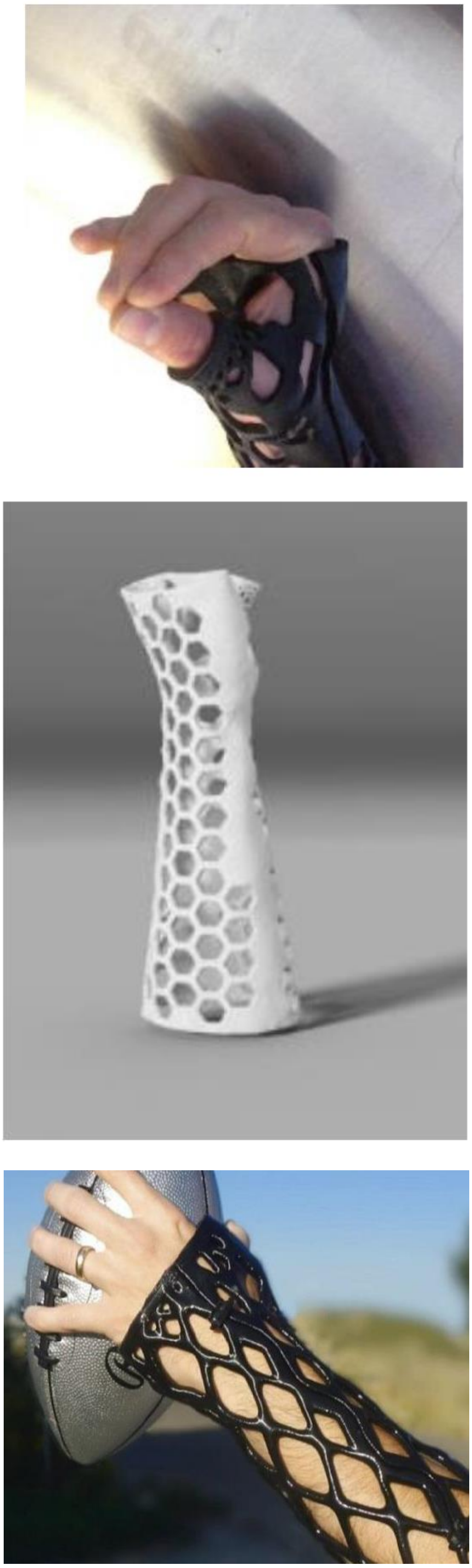

Fig2 : 3D Structure Tailored to the Patient's Muscular Needs [16,17]

4 OBJECT MODELING

The object to be printed is designed in three dimensions using Computer-Aided Design (CAD) software such as CATIA, SolidWorks, or ProEngineer, among others. The resulting 3D file is then processed by specific software, known as a "slicer," which divides it into slices and sends them to the printer. The printer deposits or solidifies the material layer by layer to achieve the final piece, using a variety of materials such as plastics, polymer resins, ceramics, metals, or even cell inks instead of traditional ink.

3D printing encompasses various techniques, each with notable differences in terms of equipment, materials, and achieved results. These processes fall into three main categories: techniques based on fused deposition of material, those based on photopolymerization (transforming a liquid material into a solid using light), and those using powder binding, where a binder is applied to agglomerate particles. Before proceeding with the scanning, two preliminary steps are essential in handling the prosthesis. Firstly, meticulous cleaning of the piece is imperative to avoid any damage to its delicate surface. This initial step requires careful attention to preserve the integrity of the prosthesis. Next, a surface spray with a liquid product like SHERWIN (Fig 3) is applied. This action aims to optimize the reflection of laser rays toward the FARO scanner sensor, thus allowing precise data acquisition. These two preparatory steps are crucial to ensuring an accurate and complete scanning of the prosthesis while preserving its quality and intact structure.

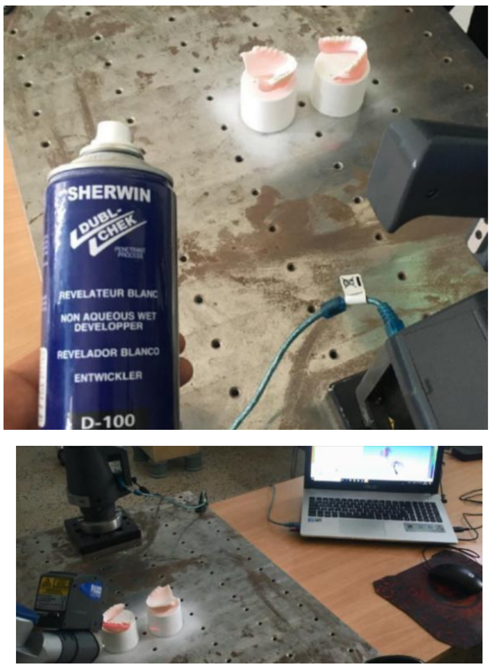

Fig3: Dental Prosthesis Scan (MEI M'sila).

5 RESULTS AND DISCUSSIONS

5.1 Geomagic Design X

Geomagic Design X is a suite of 3D design and data processing software commonly used in the fields of modeling, reverse engineering, 3D scanning, and additive manufacturing. These software tools are renowned for their ability to process digital data from 3D scanners and other capture devices, enabling the creation of precise and detailed 3D models. Geomagic offers a range of tools for 3D model creation, reverse engineering, data quality verification, and file preparation for manufacturing, contributing to various industries such as engineering, healthcare, automotive, and aerospace (Fig 4).

Geomagic is often employed in the dental field for the design and manufacturing of 3D dental prosthetics. 3D scanners accurately capture the structure of teeth and gums, and Geomagic software processes this data to create precise 3D models of the prosthetics. These models are then adjusted to perfectly fit the oral morphology of the patient, providing custom-fit prosthetics. Geomagic plays a crucial role in the design process by enabling dental healthcare professionals to visualize, modify, and produce customized dental prosthetics, enhancing precision and comfort for patients.

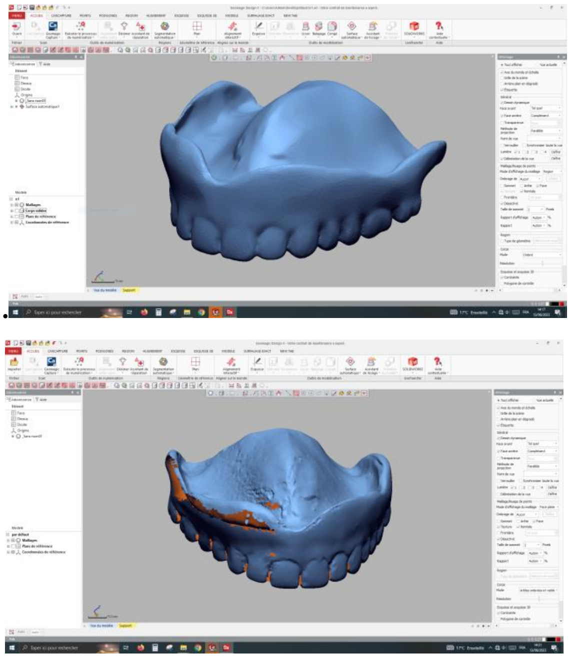

Fig4 : Scanned Prosthesis meshed in STL format before preparation.

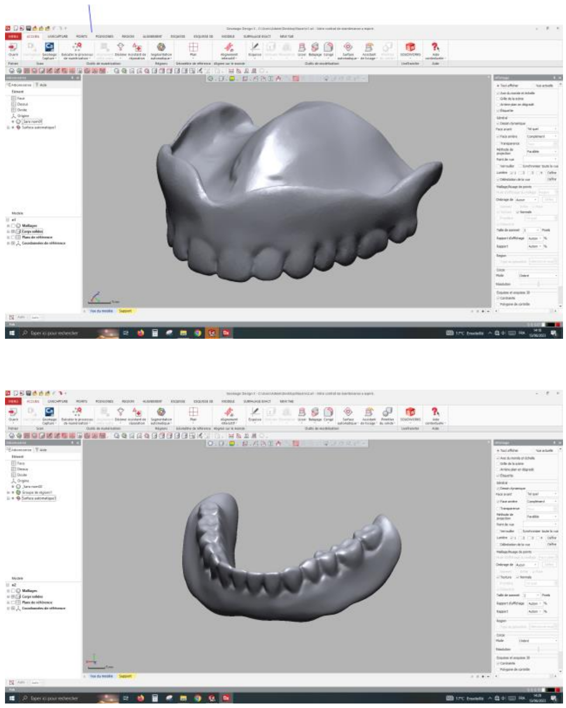

Fig 5 : Final 3D Model

The final 3D model (Fig 5) is the accomplished result of the design and modeling process. It is the finished product that represents the shape, structure, and details of the object or digital creation you have designed. This model can be used for various purposes, whether it be for visualization, animation, manufacturing, or other applications depending on the intended use.

The creation of the final 3D model often involves multiple stages, including conceptual design, detailed modeling, adding textures, applying materials, lighting, and rendering to achieve a realistic appearance. Once completed, this model is ready for use in projects, presentations, or any other requirement.

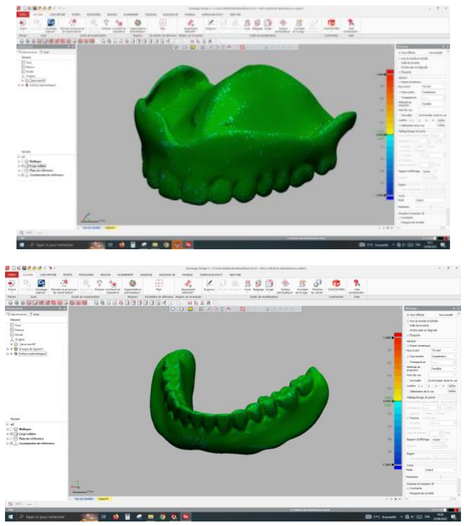

Fig 6 : Comparison between the scanned body and the final 3D model.

The comparison between a final 3D model and a scanned body aims to assess the accuracy of the created model compared to the real object (Fig 6). The process begins with the precise scanning of the object to obtain its geometric data. Simultaneously, the 3D model is designed based on measurements and references to replicate the shape of the scanned object. By overlaying the two models, comparison tools analyze discrepancies, measuring differences in terms of shapes, alignment, and distances. These differences are visually represented, often using color maps to highlight areas where differences are most significant. By adjusting the 3D model based on identified discrepancies, the goal is to minimize these differences until the 3D model accurately represents the scanned object. This comparison is crucial to ensure the accuracy of the final model, particularly in fields where the precision of 3D models is essential, such as engineering, manufacturing, or medicine.

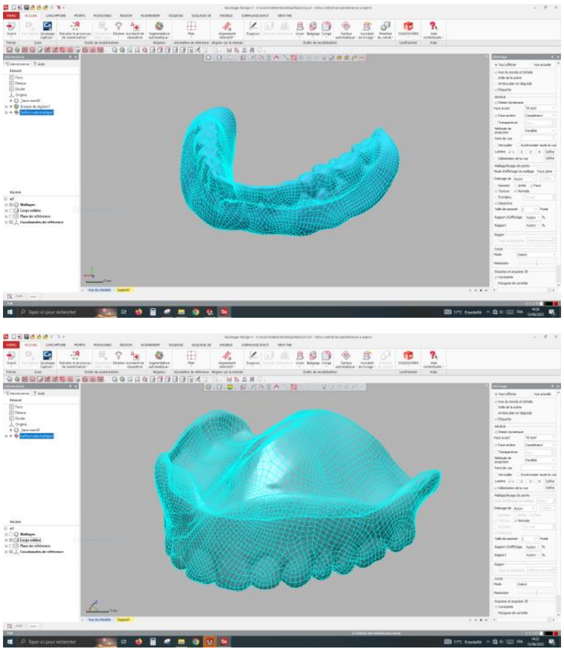

Fig 7. Creating curves to build the surface body.

Creating a surface body involves using curves as a foundation to define the desired shape (Fig 7). These curves serve as guides for modeling, drawn in a plane or in space depending on the desired form. Modeling software provides specific tools to transform these curves into surfaces, whether through lofting, sweeping, coating, or other techniques. By adjusting and manipulating these curves, the shape of the surface body can be refined. It is crucial to check the consistency and accuracy of the model by verifying continuity between surfaces and adjusting control points as needed. Finally, once all the surfaces are created, they are assembled to form the complete surface body using assembly or fusion operations. If specific instructions for a particular software are required, feel free to ask for guidance.

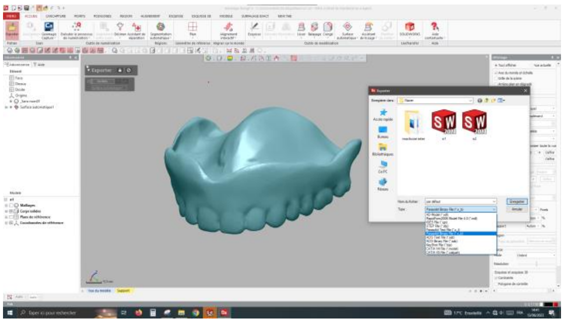

Fig 8. Exporting file for 3D printing.

5.2 Printing 3D model

To prepare a 3D model for 3D printing, start by checking its geometry to avoid any defects. Next, export it in a format suitable for your 3D printer, such as STL or OBJ, using the export options available in your modeling software. You can adjust the export settings for resolution or file size if necessary. Also, make sure to scale, orient, and configure settings specific to the printing process using slicing software if needed. Once these adjustments are made, export the final file and perform a test print to check the quality and compliance of the model. Finally, load the file into your 3D printer control software and start the print following the recommended settings for the selected material. Following these steps will allow you to effectively prepare your 3D model for 3D printing.

Fig 9. 3D printing (LMMS Lab M'sila).

3D printing of dental prosthetics is revolutionizing the manufacturing of these devices. Using advanced printing technologies (Fig 9), dental prosthetics can be produced with precision and customization. 3D scanners capture specific details of the patient's mouth, and design software transforms this data into digital 3D models. These models are then printed layer by layer using specialized 3D printers, often utilizing biocompatible materials. This method provides superior customization and precision, enabling dentists to deliver custom-fitted prosthetics that perfectly match the patient's oral morphology, enhancing comfort and the effectiveness of dental treatments.

6 CONCLUSION

This project focuses on the exploration and creation of a medical-purpose piece through reverse engineering. Analyzing the obtained results, several key conclusions emerge:

1. Reverse engineering stands out as the most suitable technology to meet the specific needs of healthcare professionals for personalized and customized care.
2. Advances in scanning and 3D printing significantly contribute to improving the fit and durability of prosthetics.
3. Reverse engineering provides high-precision solutions for prosthetists, ensuring remarkable quality and finesse in the design of medical parts.
4. The success of a prosthesis relies heavily on rigorous and expert design by the practitioner.
5. Poorly fitted prosthetics can lead to pain, discomfort, and poor aesthetic appearance, potentially discouraging the patient from wearing them.

It is important to note that the realization of scanned parts in this context requires considerable resources currently unavailable at our university. We hope that this study will encourage our institution to invest in these resources, enabling future master's students to successfully carry out similar projects and bring these pieces to fruition.

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