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2ND INTERNATIONAL WORKSHOP

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BOOK OF PROCEEDINGS

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WELCOME

In recent years, the manufacturing processes have undergone a profound transformation, driven by the rapid evolution of additive manufacturing (AM) technologies. What began as a tool primarily for prototyping through stereolithography has now expanded into a versatile and innovative field capable of producing functional, end-use components across a wide range of industries. From fused deposition modeling (FDM) to selective laser melting (SLM) and beyond, AM has unlocked new possibilities in design, material utilization, and production efficiency. Today, additive manufacturing encompasses an extensive array of materials, including metals, polymers, paper, and even biological tissues, enabling applications that span from the mechanical industry to the biomedical sector.

One of the most compelling aspects of additive manufacturing is its potential to drive sustainability in modern production processes. Unlike traditional subtractive methods, which often generate significant material waste, AM builds components layer by layer, minimizing excess material and promoting resource efficiency. Furthermore, the ability to use eco-friendly and recyclable materials aligns with global efforts to reduce environmental impact. AM also supports the production of complex, customized parts on demand, reducing the need for large inventories and long-distance transportation, thereby lowering carbon emissions. By optimizing resource use and enabling more efficient production cycles, additive manufacturing is emerging as a cornerstone of sustainable manufacturing practices.

This proceeding book arrests the latest advancements, challenges, and opportunities in the field of additive manufacturing, with a particular focus on its transformative potential and contributions to sustainability. The works presented here reflect the interdisciplinary nature of AM, showcasing innovative techniques, materials, and applications that are shaping the future of manufacturing. From cutting-edge research to real-world case studies, this collection aims to inspire further exploration and collaboration, driving the adoption of additive manufacturing as a key enabler of sustainable industrial progress. We invite readers to probe into these pages and discover how AM is not only redefining manufacturing but also paving the way for a more sustainable and efficient future.

The IWAM 2024 Organizing Committee,

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Study, design, and manufacturing of 3D-printed orthoses

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ABSTRACT

This study demonstrated that, in relation to Additive Manufacturing, Three-Dimensional (3D) Printing is a technology that is increasingly present in everyday life in the manufacturing of parts. In this case, the piece manufactured using 3D printing was a hand orthosis, intended to alleviate the pain of a woman suffering from a medical condition.

This study highlights the growing presence of three-dimensional (3D) printing in everyday life, particularly in the manufacture of customized medical devices. In the field of additive manufacturing (AM), Material Extrusion (MEX), ISO/ASTM 52900:2023, (fused deposition modeling (FDM)) has become a widely used technique due to its affordability, accessibility, and ability to create personalized solutions.

In this case, a 3D-printed hand orthosis was designed to assist a woman suffering from tendinitis in her thumb. The orthosis was designed to reduce pain and provide support to improve her daily functionality. Material Extrusion (MEX), FDM technology was used to build the device layer by layer, resulting in a lightweight yet durable structure tailored to the patient's needs.

One of the key benefits of 3D printing in orthotic design is the ability to create customized, patient-specific solutions at a lower cost than traditional manufacturing. In addition, rapid prototyping allows for quick modifications based on patient feedback, improving comfort and effectiveness. Traditional orthotic manufacturing methods require expensive molds and labor-intensive processes, whereas 3D printing streamlines production, allowing for efficient, scalable, and precise results.

Another advantage of this technique is the wide range of materials available for use in 3D printing. From biodegradable polymers to highly durable composites, the choice of material can be tailored to the specific needs of each patient, ensuring not only comfort but also long-term durability. For example, in this case, PLA was used, a material known for its low cost, ease of printing, and environmental sustainability.

This study reinforces the potential of 3D printing in medical applications and demonstrates how FDM-printed orthotics can help alleviate pain and improve quality of life for people with musculoskeletal conditions. As the technology continues to evolve, personalized healthcare solutions will become more accessible and efficient. The implications of this advancement extend beyond orthotic production, opening possibilities for broader applications in medical fields, including prosthetics, implants, and even tissue engineering.

Keywords: 3D Printing in Orthotics, Material Extrusion (MEX), Fused Deposition Modeling (FDM), Customized Hand Orthosis, Additive Manufacturing in Healthcare

METHODS

An employee at the School of Technology and Management (ESTiG) of the Polytechnic Institute of Bragança (IPB) began experiencing pain when making movements with her hand. After undergoing medical examinations, she was diagnosed with De Quervain's Tenosynovitis, a musculoskeletal condition also known as Tendinitis. This condition primarily affects the tendons of the thumb, particularly the long abductor tendon and the short extensor tendon. Each muscle in the hand consists of tendons, and each tendon is encased in a synovial sheath. In this pathology, the sheath becomes inflamed and thickened, causing pain when moving the thumb.

To alleviate the pain and improve mobility, a 3D-printed splint was created to immobilize the thumb. An orthosis is a medical device designed to reduce pain and enhance mobility—in this case, of the hand. Unlike traditional orthotic solutions that may require multiple fittings and adjustments, 3D printing offers rapid prototyping and precise customization. This technology enables the creation of three-dimensional objects from digital models by applying material layer by layer until the object is complete. The ability to manufacture customized orthoses using 3D printing greatly enhances patient comfort, as the design can be tailored to the user's exact anatomical specifications. Additionally, digital scanning ensures an accurate fit, reducing the discomfort often associated with standard orthotic devices.

The 3D scanning process begins with the "Sense Pro Handheld" scanner, which the user holds and moves around the hand to be scanned. Using a combination of infrared sensors and cameras, the scanner captures detailed 3D data from all angles, creating a high-resolution digital model of the hand. The user adjusts the angle and moves the scanner to ensure complete coverage. Once scanning is finished, the 3D model is processed and exported in a format compatible with 3D printing.

For the 3D printing process, the exported model is imported into slicing software connected to the Ultimaker and to the Anycubic 3D Printer. The software divides the model into layers and generates the necessary instructions for the printer. The printer then heats the PLA filament, which is fed through an extruder and deposited layer by layer to create the physical object. PLA, a biodegradable thermoplastic, is commonly used for its ease of use, low cost, and versatility. The "Anycubic 3D Printer" ensures precise layer deposition, producing a fully realized 3D object based on the scanned model. Once the printing is complete, the object is removed from the print bed and is ready for use.

This orthosis was produced using an FDM (Fused Deposition Modeling) printer, a widely known Additive Manufacturing technique, also referred to as Material Extrusion. In this process, material is selected and dispensed through an opening. For this print, PLA (polylactic acid) was chosen due to its eco-friendly properties, low cost, and ease of use. As a biocompatible material, PLA is a suitable option for medical applications, minimizing the risk of adverse reactions during prolonged contact with the skin.

RESULTS

To manufacture this orthosis, a handheld scanner, model Sense, from the brand 3D Systems, was first used. This scanner created a precise digital model of the employee's hand, capturing detailed anatomical data to ensure a perfect fit. The ability to obtain a highly accurate 3D representation of the patient's hand is a critical factor in ensuring the effectiveness of the orthosis.

Next, the obtained figure was displayed on the computer screen and refined using two software programs, MeshMixer and MeshInspector. These programs were used to optimize the digital model by creating a mesh around the prototype, allowing for a well-structured and stable orthosis. After refining the model, the final design was prepared for 3D printing by adding necessary supports in the Ultimaker Cura software. Support structures are crucial in 3D printing, as they prevent deformation and ensure the structural integrity of the final product.

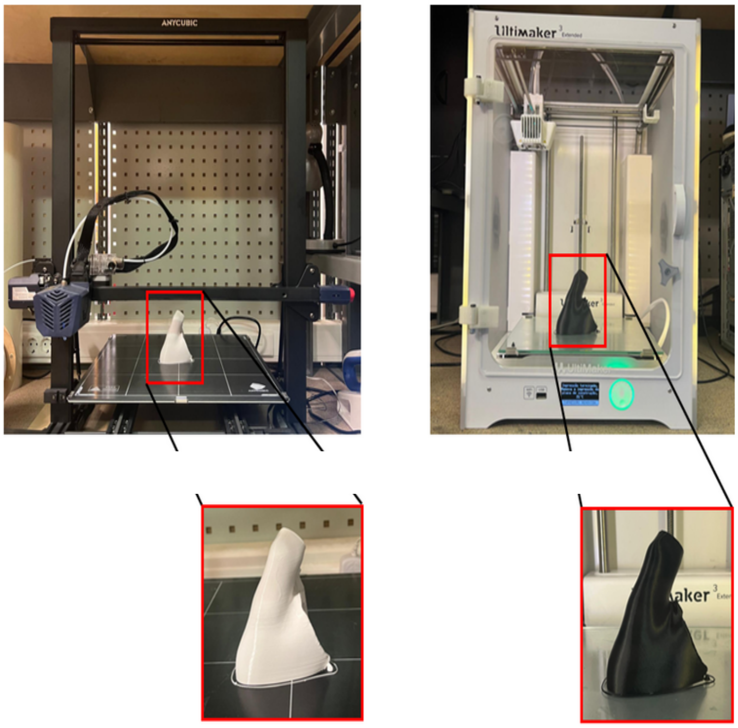

Figure *1*- 3D printing of the orthosis on FDM printers.

Finally, the orthosis was printed using an FDM 3D printer, figure 1. The printer built the orthosis layer by layer, with each layer adhering precisely to the previous one, forming a lightweight yet durable device. The entire printing process was completed within a few hours, demonstrating the efficiency of 3D printing in producing customized medical devices.

CONCLUSIONS

After two months of use, the employee reported that the orthosis significantly alleviated her pain and improved her ability to perform daily activities. This positive outcome confirms the effectiveness of 3D-printed orthoses in treating musculoskeletal conditions such as De Quervain's Tenosynovitis. The ability to create custom-fit devices quickly and affordably is one of the most significant advantages of 3D printing in the medical field.

With this result, it can be stated that 3D printing technology increasingly has a positive impact on the manufacturing of objects, particularly in the healthcare sector. The study highlights how additive manufacturing enables the creation of patient-specific solutions that improve comfort and effectiveness, reducing the need for traditional, labor-intensive manufacturing methods. Moreover, the success of this project suggests that similar applications could be explored for other musculoskeletal conditions, expanding the potential of 3D printing in orthotics and prosthetics.

As 3D printing technology continues to advance, the range of materials available for medical applications will expand, further enhancing the quality and durability of printed medical devices. Future research could explore alternative materials, such as flexible polymers, that could provide additional comfort and adaptability for patients.

Additionally, integrating artificial intelligence (AI) and machine learning into the design and manufacturing process could further improve the customization and efficiency of 3D-printed medical devices. AI algorithms could analyze patient data and automatically generate optimized designs, reducing the need for manual adjustments and enhancing the precision of the final product.

In conclusion, the study demonstrates that 3D printing offers a viable, cost-effective, and highly customizable solution for medical applications. With continuous technological advancements, additive manufacturing is poised to play an even greater role in revolutionizing healthcare, making personalized treatments more accessible to patients worldwide.

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