Research and Studies

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IMP&ACTE3D project: Introduction of 3D printing technology for manufacturing of orthoses in West Africa - Technical aspects

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About the project

The IMP&ACTE 3D Project (3D Printing & Access to Telerehabilitation) was implementted between November 2017 and April 2019 in 3 countries, namely Togo, Mali and Niger. The objective of the study was to see how innovation and, in our specific case, the use of 3D printing technology in orthotics in West Africa can improve access to physical rehabilitation services for the most vulnerable and isolated people in low-income countries and in fragile humanitarian contexts.

About this brief

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About this study

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A. Context of the study

A majority of people with disabilities live in developing countries, meanwhile almost all major prosthetic / orthotic manufacturers are located in western countries and most of their products are aimed at the western market. As a result, the majority of people with disabilities do not benefit from technological developments in the production of orthopedic appliances.

According to the World Health Organization (WHO), more than 30 million people in low-income countries need an artificial limb or an orthopedic device but only 5% to 15% of them can access to this service. The production is too low, often of poor quality, while the manufacturing time remains too long and therefore too expensive for patients, especially for those who have to travel long distances for their treatment. In addition, there is a shortage of trained personnel to manage the manufacturing of such equipment, particularly at the provincial and district levels.

During recent years we see an increasing interest from the orthopedic sector worldwide to use additive manufacturing (3D printing) for production of orthopedic devices. 3D printing is extremely suitable for producing complex anatomically shaped objects such as orthoses and prostheses. The use of this digital method of production brings a number of advantages such as a reduced waste production, improved accuracy and repeatability of produced orthoses, simple digital storage of 3D shape of the patient's limb and the orthopedic device....

Moreover, a digital workflow that uses 3D scanning and 3D printing also offers the advantage that you can easily perform a 3D scan measurement at a remote location, and then send the 3D scan to a central Fablab where the orthopedic device is designed and 3D printed. Finally, the orthopedic device is sent back to the remote location where it is further finished before it is delivered to the patient. In this way, the need for a fully equipped workplace at remote locations can be eliminated, making it easier and cheaper to help people with disabilities in remote areas.

B. General and specific objectives

Within the Imp&Acte3D project we wanted to investigate the technical feasibility of the use of such a digital workflow in a West African context. Furthermore we wanted to compare the clinical effects of orthosis produced with 3D printing with traditionally manufactured orthosis.

The general technical objective of the IMP&Acte3D was the implementation of a complete digital workflow for the production of all orthopedic devices within the project. To achieve this general objective several specific objectives had to be reached.

Specific Objectives:

- Identify suitable 3D printing technique and 3D printers for use in this context.
- Test and identify 3D printing materials for the production of orthopedic devices.
- Determine a good set of print settings and print strategies to be used for the production of orthosis.
- Identify suitable 3D scanner and 3D scanning software + computer hardware.
- Train personnel from OADCPH to prepare 3D models for printing and operate and maintain the 3D printers.
- Set up a Fablab facility with all necessary computer hardware, a controlled environment. (temperature, humidity) and a stable power supply (back-up generator, solar panels, ups…) to ensure the proper operation of the 3D printers.
- Train clinical staff in the different orthopedic centers to use the 3D scanner and 3D scan software instead of plaster casting for measurement of the patient.
- Implement a digital rectification process using CAD software for O&P.

C. Methods

In order to determine the most suitable 3D printing technique and 3D printer to be used within the project, different printing techniques and printers were evaluated on different criteria such as price, accuracy, complexity of the print process, printer specifications, printer reparability, sensitivity to environmental factors, available printing materials and availability and price of these materials. In a next step several 3D printer producers and resellers where asked to print sample orthosis to get a better idea of the accuracy print speeds and capabilities of the different 3D printers. The FDM technique was chosen over other techniques such as Laser sintering, multi jet fusion or SLA. The main reasons for this choice are the lower complexity of the FDM print process compared to the other processes, the repairability, the price of the available printers, sensitivity of the print process to environmental factors. In the end two Stacker FDM printers (Stacker S2 and Stacker S4) where bought. Numerous other FDM printer brands were compared, such as German reprap, WASP and aon3D. The printer specifications of the WASP 3D printers where similar to the specs of the Stacker printers, but these printers were not chosen due to the poor accessibility of the distributor.

The same exercise was done for the 3D printing materials, here different materials where evaluated taking into account printability (low warping), price/kg, impact resistance, strength, hygroscopic nature, adaptability after printing (grinding, drilling holes, attachment of straps)…

Once it was decided which 3D printers would be used within the project, a series of lab test was conducted to determine the influence of print strategies and print settings on the 3D printed orthosis. The printability of different materials was assessed and a number of dogbone samples was printed. Tensile tests were conducted on these samples in order to get a better insight into the influence of print settings on the material properties of the end product. Furthermore this allowed us to compare the mechanical properties of different 3D printing materials in a more quantified way. Based on these tests the XT filament (PETG) was initially chosen for the production of the orthosis. At that time this filament promised to be a good combination of price, material properties, printability.

Another important choice we had to make at the beginning of the project was the type of 3D scanner we would use. Keeping in mind that the digital workflow should be as economically viable as possible, a good tradeoff between price and accuracy of the scanner was an important factor. The sense scanner (3D systems) was chosen, partly because this scanner was already used during the previous 3D printing project in Syria.

The personnel of OADCPH that will run the Fablab were trained, during the visits of the engineer Thomas More, on several topics such as: preparation of 3D models for printing, the use of slicer software, the use of different free software packages to fix defects in 3D models, 3Dprinter operation and maintenance. Furthermore we used teleconferencing and remote desktop software to resolve printer related problems together.

D. Findings

During the course of the project problems occurred with orthoses printed with this filament. Multiple orthosis that were printed in this material showed fractures over time. These failures occurred more often in the dynamic orthosis compared to the postural orthosis.

It turned out that this material was very susceptible to high impact forces which caused brittle fractures of the orthosis. Because of these strength issues, additional tests were carried out to improve the printability of pp and nylon filaments. These materials are more ductile and should therefore be able to withstand the forces typically acting on such orthosis in a better way. Even though the initial material tests at the beginning of the project showed that these materials are very difficult to print, we were able to come up with a method to significantly improve the printability of these filaments. In the end, PP was identified as the most suitable material, since is not susceptible to humidity unlike nylon. By using an additional PP print plate, we were able to resolve a lot of the printability issues we noticed during our initial tests.

Even though all clinicians were trained to use the 3D scanners at the start of the project, we noticed that it remained difficult for some of them to produce 3D scans with a consistent quality. This fact underlines the importance of the user friendliness of both 3D scanner and 3D scanner software. In future projects this problem could be partly resolved by choosing a 3D scanner with a build in screen. Experience shows that such a scanner is perceived as more user friendly because the operator does not need to look at the screen of an additional laptop and can focus on the object that's being scanned. Apart from that, the clinicians should receive a more in depth training so they have a better understanding of the influence of the 3D scan software parameters on the resolution and accuracy of the final 3D scan. Furthermore they should be aware of the fact that the quality of the 3D printed orthosis largely depends on the accuracy and quality of the 3D scan used as a starting point of the digital workflow.

Another factor which is at the root of many of the 3D printer and material related problems we encountered during the project is the environment in which the printer needed to work. More specifically the high humidity should be taken into account both when choosing a 3D printer and printing materials.

A lot of thermoplastic materials (such as nylon but to a lesser extent also PETG) have the tendency to absorb moisture. This will have a negative influence on the printability of the material and the mechanical properties of the printed orthosis. In order to avoid this problem non-hygroscopic materials (such as PP) are preferred.

In addition, the humidity can also have a direct influence on the lifespan of the 3D printer. Near the end of the project, we started to notice that some mechanical and electronical components of our 3D printers already started to rust. This phenomenon may be exacerbated by the proximity of the sea and the salty sea air.

Finally, we encountered a lot of 3D printer electronic component failures. To date, the exact cause of the failure of these electronical components remains unclear. Possible causes include the high ambient temperature that prevents the electronics from efficiently dissipating its heat, power surges, quality of electrical power delivered by the electrical grid.

E. Conclusion

After completion of this project we can conclude that it is indeed possible to implement a digital workflow for the production of orthopedic devices in a West African context. We were able to successfully 3D print a large number of orthosis throughout the duration of the project in spite of the many failures of the printers. The experience and insights gained within this project can be a good starting point for future projects to build on. Given the rapid pace of evolution of the current 3D printing landscape, future projects should keep exploring new 3D print technologies, 3D printers and materials that could potentially offer better material properties, higher print speeds... The same goes for the 3D scanning technology.

The complete study is available. To access it, please click here.

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- 3D & clinical aspects in West Africa
- 3D & étude d'impact social en Afrique de l'Ouest (Only in French)
- Les TIC dans la santé : Togo, Mali, Niger (Only in French)