REZMER, Jakub, WASILEWSKA, Inga, HOMA, Wojciech and WANAT, Joanna. The 3D printed ring-based finger splint - a cheap and lightweight alternative. Journal of Education, Health and Sport. 2025;80:59425 eISSN 2391-8306.
https://doi.org/10.12775/JEHS.2025.80.59425
https://apcz.umk.pl/JEHS/article/view/59425

The journal has had 40 points in Minister of Science and Higher Education of Poland parametric evaluation. Annex to the announcement of the Minister of Education and Science of 05.01.2024 No. 32318. Has a Journal's Unique Identifier: 201159. Scientific disciplines assigned: Physical culture sciences (Field of medical and health sciences); Health Sciences (Field of medical and health sciences).
Punkty Ministerialne 40 punktów. Załącznik do komunikatu Ministra Nauki i Szkolnictwa Wyższego z dnia 05.01.2024 Lp. 32318. Posiada Unikatowy Identyfikator Czasopisma: 201159. Przypisane dyscypliny naukowe: Nauki o kulturze fizycznej (Dziedzina nauk medycznych i nauk o zdrowiu); Nauki o zdrowiu (Dziedzina nauk medycznych i nauk o zdrowiu).
The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 13.03.2025. Revised: 04.04.2025. Accepted: 20.04.2025. Published: 23.04.2025.

The 3D printed ring-based finger splint - a cheap and lightweight alternative

1. **MD Jakub Rezmer**
   Samodzielny Publiczny Specjalistyczny Zakład Opieki Zdrowotnej
   ul. Węgrzynowicza 13, 84-300 Lębork, Poland
   https://orcid.org/0000-0002-0717-9061
   jakubrezmer1@gmail.com - corresponding author

2. **MSD Inga Wasilewska**
   Indywidualna Praktyka Lekarska lek. stom Marlena Wilczyńska-Rezmer
   ul. Bohaterów Monte Cassino 15D, Lębork, Poland
   https://orcid.org/0000-0002-0864-9993
   wasilewskainga@gmail.com

3. **MD Wojciech Homa**
   Wojewódzki Szpital Specjalistyczny
   al. Kraśnicka 100, 20-718 Lublin, Poland
   https://orcid.org/0000-0003-2177-8818
   wojciech.homa2@gmail.com

4. **Joanna Wanat**
Medical University of Lublin
Aleje Racławickie 1, 20-059 Lublin, Poland
https://orcid.org/0009-0009-3349-3618,
asiawanat2000@gmail.com

Abstract:

Introduction and purpose

The orthosis is used to assist the function of the injured limb or to stop or limit the movement during the healing process. The actual process of making the orthosis is quite time-consuming [1]. An addictive manufacturing process, known commonly as 3D printing can be advantageous in creating cheap and highly customizable prosthetics. Using Fusion Deposition Modeling (FDM), where each layer of material is deposited right on the previous one is now fully available both in professional and consumer-grade printers.
The main aim of this study was to create an easily customizable and cheap 3D printable finger splint with the use of Fusion Deposition Modeling technology.

Material and methods

BambuLab P1P 3D printer with CoreXY kinematics was used.

The filament used was the 1.75mm PLA (polylactic acid).

OnShape was used as CAD software.

Results

Basing our project on the three rings, which dimensions can be easily measured with a set of calipers or basic measuring tape we were able to develop a fully customizable finger splint that weighed less than 10 grams and could be fully prepared within 1 hour, including taking measurements, modifying the 3D model and printing it. Due to the fact, that PLA starts to deform around 60-65 degrees Celsius, with the use of hot water we could thermoform the splint after the printing, providing an even more precise fit with the "injured" finger. Modifying every measurement and aspect of the splint is simple due to the use of parametric design rules.

Conclusions

We were able to create a cheap splint, easy to print, and highly customizable to fit as many different patients as possible. In our opinion, 3D printing is a promising technology. With the lowering cost of equipment and filament, one day it might be a viable option in the process of creating individualized orthosis on a mass scale.

Keywords: 3D printing; Finger splint; Orthosis; Customizable medical devices; Fusion Deposition Modeling

Introduction

The orthosis is a device used to assist the function of the injured limb or to stop or limit its movement during the healing process. The process of making the customized orthosis is quite time-consuming and challenging due to its complex design [1]. Over the past 15 years, the use of 3D printing technology has experienced a significant increase in popularity due to patent expirations, expansion of the range of low-cost 3D printers and 3D printing materials, and thus a reduction in overall printing cost. As a result, 3D printing is no longer confined solely to industrial applications but has become increasingly accessible for various fields.[2] One of its key advantages is its effectiveness in rapid prototyping, as it enables the efficient and cost-effective production of individual components within a relatively short time.

Fusion Deposition Modeling (FDM) technology, in which successive layers of material are deposited directly onto the previous layer, is now widely utilized in both professional and consumer-grade 3D printers. In this process, the filament is drawn from a spool and fed into the extruder, where it is guided and directed by drive gears into a heated nozzle. The printhead moves along the X, Y, and Z axes according to a previously programmed pattern, precisely depositing material in a layer-by-layer fashion to construct the final three-dimensional structure. With the use of complementary software, such as Computer-Aided Design (CAD), there is a possibility for rapid fabrication of customized orthotic devices, with individual orthoses capable of being produced in under an hour.

Purpose

The primary objective of this study was to develop a cost-effective and easily customizable 3D-printable finger splint utilizing Fusion Deposition Modeling (FDM) technology.

Material and methods

A BambuLab P1P 3D printer, utilizing CoreXY kinematics, was used for the fabrication process. The printing material used was a 1.75 mm PLA (polylactic acid) filament. The 3D model of the individualized finger splint was created using OnShape Computer-Aided Design (CAD) software.

Results

Measurements methods

To develop an efficient and rapid method for acquiring finger dimensions, a ring-based approach was implemented. Specifically, three rings were utilized as reference points, allowing for precise adjustment of axis positions, angles, and overall splint placement on the finger. Determining the optimal size for each ring is a straightforward process, as it can be accomplished using internationally standardized ring sizing sets, which are both cost-effective and widely available - they are commonly used by jewelers.

As an alternative measurement method, simple digital calipers can be used to directly obtain finger dimensions. While photogrammetry and 3D scanning were also considered, these techniques were ultimately excluded due to their higher technical complexity, which limits accessibility for non-experts.

The design of the splint was based on parametric modeling principles, ensuring that modifications to a single dimension automatically adjust the entire model structure. This approach significantly enhances efficiency, as it enables rapid customization possibilities without requiring specialized knowledge beyond fundamental proficiency in Computer-Aided Design (CAD) software.

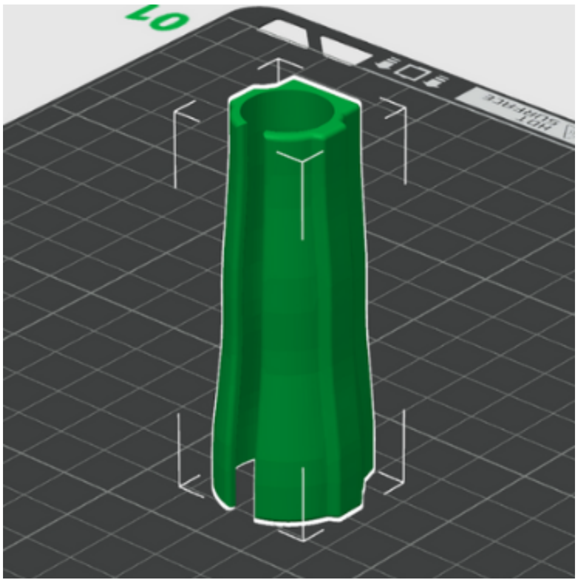
CAD

3D-printed version

Ring based approach

Initial design: Solid splint

The first iteration of the splint design featured a solid structure and was optimized for fast printing as it did not require additional support structures. The design incorporated a closed framework reinforced with three structural ribs, with the primary rib being wider than the other two. While this approach enhanced rigidity, it resulted in excessive stiffness and increased weight compared to subsequent models. The printed splint had a total mass of approximately 11 grams. Additionally, a cut was intentionally incorporated into the circular section to allow for thermoplastic adjustments, enabling minor modifications to fit the user's finger more precisely.



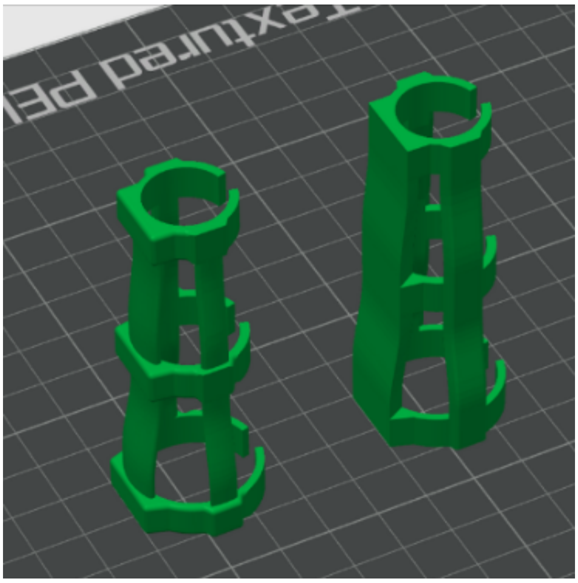
CAD

3D-printed version

First design - solid splint

Second Design: Slimmer and Improved Structure

Building on the insights gained from the first design, the second iteration featured a slimmer structure with the removal of the closed framework. This modification not only reduced the weight of the model by approximately 50% but more importantly, it allowed proper ventilation of the skin, significantly improving comfort during wear. Two variations were developed: one with sturdier reinforcement ribs and another with thinner ribs. The thinner rib version was selected for its optimal balance of flexibility and rigidity, offering sufficient structural support while enhancing comfort and usability.



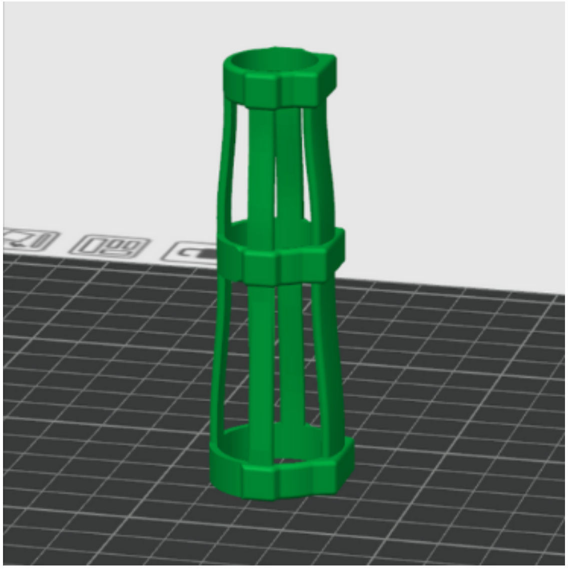
CAD

3D-printed version (with visible supports)

Second design

Final Design

In the final iteration, the design was further refined by closing the ring, ensuring that even the slightest movement in the finger joints was prevented. To enhance the structure's rigidity, a fourth reinforcement rib was incorporated at this critical junction. This modification increased the rigidity compared to the second design, while only adding **1 gram** to the overall weight. The print time for this final model was notably efficient, taking just under **40 minutes** to complete.



CAD

Final design

3D-printed version (front, side, back view)

Thermoforming Process

Given that polylactic acid (PLA) begins to deform at temperatures around 60-65°C, this characteristic was leveraged in the thermoforming process. The thermoforming station consisted of a water bath and a TP101 temperature probe for precise temperature monitoring.

For optimal results, 1 minute at 64°C was sufficient to soften the side reinforcement ribs, while 2 minutes at the same temperature was required to soften the rings. This process was straightforward to execute and allowed for precise, on-the-fly adjustments to the fit of the reinforcement ribs directly on the user's finger.

The model on the left represents the splint before thermoforming, while the model on the right demonstrates the maximal bend achieved in the ribs after thermoforming. However, it was observed that extended exposure to this temperature caused the rings to deform into elliptical shapes, which limited the precision of the fit when the splint was held at temperature for too long.

Thermoforming process

Thermoforming station

Splint before (left) and after thermoforming (right)

Discussion

This study demonstrates the potential of 3D printing, specifically through Fusion Deposition Modeling (FDM) technology, to create highly customizable, cost-effective, and lightweight finger splints. The use of parametric design in combination with easy-to-access measuring techniques, such as standardized ring sizing sets and digital calipers, allowed for a streamlined process of obtaining precise measurements and adjusting the splint's design to meet the specific needs of individual patients. This approach significantly reduces the complexity and time typically associated with traditional orthosis manufacturing.

The rapid fabrication process, taking less than an hour from measurement to final print, highlights the efficiency of FDM in the production of individualized medical devices. Given that the technology can be operated with minimal technical expertise, it holds considerable promise for widespread adoption, particularly in resource-limited settings or small clinics. Furthermore, with the growing accessibility of 3D printers, this method provides a scalable solution for mass customization.

The incorporation of a thermoforming process allowed us to further enhance the fit of the splint. PLA, when exposed to temperatures of 60-65°C, softens enough to allow the material to mold to the user's finger, ensuring a more comfortable and precise fit. This is a significant advantage over rigid, prefabricated splints that may require multiple fittings or adjustments. The ability to make modifications directly on the finger without the need for additional equipment is a key benefit, as it reduces patient discomfort and streamlines the fitting process.

However, certain limitations were encountered during the thermoforming process. Extended exposure to heat caused the splint's circular rings to deform into elliptical shapes, which compromised the accuracy of the fit. This issue highlights the importance of balancing the duration of thermoforming with maintaining the structural integrity of the splint. As such, further refinements in the thermoforming procedure, including precise temperature and time controls, will be necessary to avoid such deformations and ensure consistent results. These limitations could also be avoided with multi-material 3D printing - the rings and ribs could be printed with different materials with different softening temperatures.

Another key consideration is the choice of material. While PLA is a cost-effective and widely used filament for 3D printing, its mechanical properties may not always be ideal for every type of orthosis. In this study, the flexibility and rigidity balance achieved with PLA were sufficient for creating a functional finger splint; however, for more demanding applications or long-term use, materials with higher durability, such as ASA or nylon, could be further explored. Furthermore, future studies could investigate the potential of combining PLA with other materials to enhance comfort, flexibility, and wearability.

In terms of patient-centered design, the use of a ring-based measurement system enabled quick and easy adjustments for a variety of finger sizes, making the splint highly adaptable. This flexibility addresses a key challenge in orthosis design, where finding an appropriate fit for individual anatomical variations is often difficult. The simplicity of the system, which requires no specialized tools beyond basic measuring devices and CAD software, makes it an accessible option for clinicians and patients alike.

The scalability of this approach is another area for further exploration. As 3D printing technology becomes more affordable, its use in creating individualized orthoses could become standard practice in many healthcare settings. This would reduce wait times for patients and potentially lower the overall cost of orthotic devices, making them more accessible to a wider population. However, regulatory and clinical validation processes must be considered before this technology can be adopted widely for medical use.

Conclusions

The results of this study support the feasibility of using 3D printing to create cost-effective, customizable, and comfortable finger splints. By leveraging FDM technology and thermoforming, we were able to create a device that meets the needs of individual patients in a fraction of the time and at a significantly lower cost compared to traditional methods. Future developments should focus on material optimization and refinement of thermoforming techniques. With continued advances in 3D printing technology, personalized 3D printed orthoses will likely become an increasingly viable option for a wide range of medical applications.

Disclosure

Author's contribution

Conceptualization, Jakub Rezmer and Inga Wasilewska and Wojciech Homa; methodology Jakub Rezmer and Inga Wasilewska; check, formal analysis Jakub Rezmer and Inga Wasilewska, investigation Jakub Rezmer, resources: Jakub Rezmer; data curation, Jakub Rezmer, Joanna Wanat; writing - rough preparation - Jakub Rezmer, Inga Wasilewska, writing - review and editing - Jakub Rezmer, Inga Wasilewska, Wojciech Homa, Joanna Wanat. All authors have read and agreed with the published version of the manuscript.

Funding

The research received no external funding

Institutional Revier Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Acknowledgments

We would like to express our sincere gratitude to Professor Łukasz Świątek from the Department of Virology with Viral Diagnostics Laboratory, Medical University of Lublin, Doktora ul. Witolda Chodźki 1, 20-400 Lublin, Poland for his support and for providing access to the water bath used in the thermoforming process. His assistance was invaluable in the successful completion of this research.

Conflicts of Interest

The authors declare no conflict of interest.

References:

[1] Choo YJ, Boudier-Revéret M, Chang MC. 3D printing technology applied to orthosis manufacturing: narrative review. Ann Palliat Med. 2020 Nov;9(6):4262-4270. doi: 10.21037/apm-20-1185. Epub 2020 Sep 24. PMID: 33040564.
[2] Rezmer, J. et al. 2022. The use of 3d printing technology in the development of a prosthetic thumb. Journal of Education, Health and Sport. 12, 7 (Jul. 2022), 405–409. DOI:https://doi.org/10.12775/JEHS.2022.12.07.039.