VISIÓN ELECTRÓNICA VOL. 17 NO. 1 (2023) • JANUARY-JUNE • P.P. 121-128 • ISSN 1909-9746 • ISSN-E 2248-4728 • BOGOTÁ (COLOMBIA)

UNIVERSIDAD DISTRITAL
FRANCISCO JOSÉ DE CALDAS

Visión Electrónica

https://revistas.udistrital.edu.co/index.php/visele

VISIÓN ELECTRÓNICA

A CASE-STUDY VISION

3D Printing for flexible effectors

Impresión 3D para efectores flexibles

Catalina Castillo Rodríguez [1], *Robinson Jiménez-Moreno* [2], *Javier Martínez Baquero* [3]

INFORMACIÓN DEL ARTÍCULO

Historia del artículo:
Enviado: 01/11/2022
Recibido: 20/11/2022
Aceptado: 11/01/2023

Keywords:
Flexible effector
3D printing
Assistive robotics
CAD design

cc BY NC

Palabras clave:
Efector flexible
Impresión 3D
Robótica asistencial
Diseño CAD

ABSTRACT

Local 3D printing in industry and academia has driven development of tailored devices that facilitate mechatronic design systems of varying order of complexity. One of the favored fields is robotics, where design of flexible effectors drives assistive systems to adjust to the needs of the user and the grip of a wide variety of objects. Thus, design and printing of two-finger robotic effector in polylactic acid that can be manipulated by servo-controlled actuators using microcontrolled systems is presented, managing to generate semicircular and circular object grips with a deformation close to 2.5 mm.

RESUMEN

La impresión 3D de forma local en industria y academia ha impulsado el desarrollo de dispositivos a la medida que facilitan el diseño mecatrónico de sistemas de variado orden de complejidad. Uno de los campos favorecidos es la robótica, donde el diseño de efectores flexibles impulsa sistemas asistenciales para ajustarse a las necesidades del usuario y el agarre de gran variedad de objetos. Se presenta así el diseño e impresión de un efector robótico de dos dedos en ácido poliláctico manipulable mediante actuadores servocontrolados mediante sistemas microcontrolados, logrando generar agarres de objeto semicirculares y circulares con una deformación cercana a los 2.5 mm.

---

1 Mechatronics Engineering. Universidad Militar Nueva Granada. Colombia. E-mail: est.catalina.casti@unimilitar.edu.co

2 PhD in Engineering. Universidad Distrital Francisco José de Caldas. Colombia. Professor at Universidad Militar Nueva Granada. Colombia. E-mail: robinson.jimenez@unimilitar.edu.co

3 Specialist in Instrumentation and Industrial Control. Universitdad de Los Llanos. Colombia. Professor, Universidad de los Llanos. Colombia E-mail: jmartinez@unillanos.edu.co

Citar este artículo como: C. Castillo-Rodríguez, R. Jiménez-Moreno, J. Martínez Baquero, "3D Printing for flexible effectors", Visión electrónica, vol. 17, no. 1, pp. 121-128, january-june 2023, https://doi.org/10.14483/22484728.18958

1. Introduction

With the rise of robotics in the framework of Industry 4.0, the use of robots has diversified in various fields. Within its applications, of special interest is the way robots interact with the environment, which is typically given by an end effector. The design of robotic effectors as tools [1], presents a high research interest [2]. This interest ranges from grasping and relocation of objects [3], medical applications in surgery [4], to the use of deep learning techniques for robotic grasping [5].

3D printing systems have revolutionized the design of these effectors [6], both in terms of the material with which they are made [7] and the incorporation of sensorics in their manufacture [8][9]. These designs have focused in turn on the concept of soft robotics, which refers to flexible effectors [10], also with a wide range of applications [11][12].

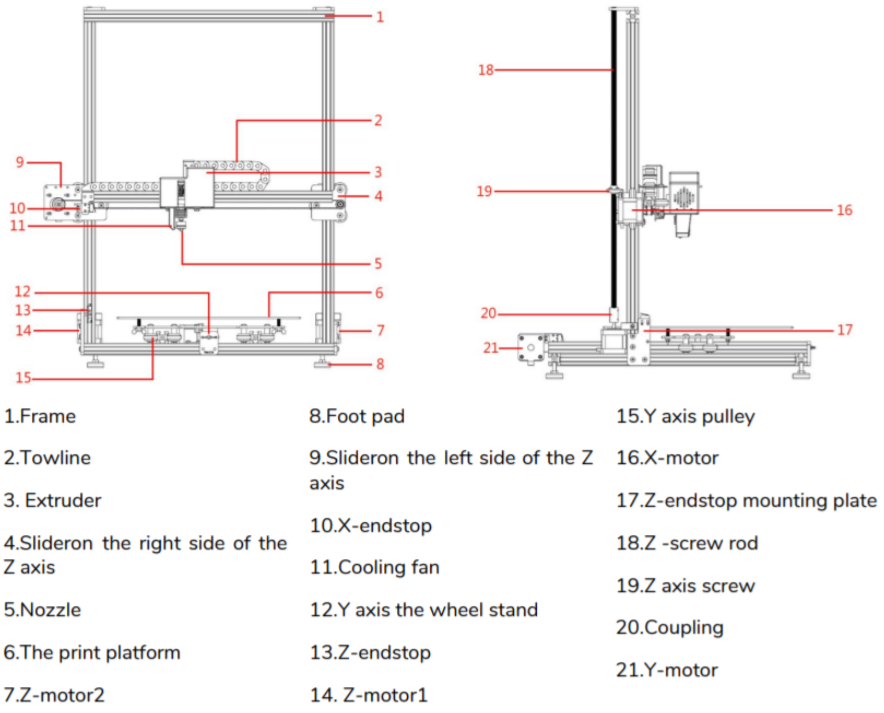
Many of the articles consulted focus on the application or the novel structure, leaving aside the preliminary design, which is why this topic is addressed to complement the state of the art and the tools for the design of robotic effectors.

This article is divided into four sections: the present introduction, section 2, which presents the methods and materials used, section 3, which presents the analysis of the results, and finally section 4, which presents the conclusions reached.

2. Materials and methods

The 3D printing of the developed effector is performed on a system based on the ADIMLab Gantry 3D Printer. Figure 1 illustrates its general composition, where it highlights a mechanical structure of two sections, the first one corresponds to the frame as a double gantry guide structure made of aluminum steel,

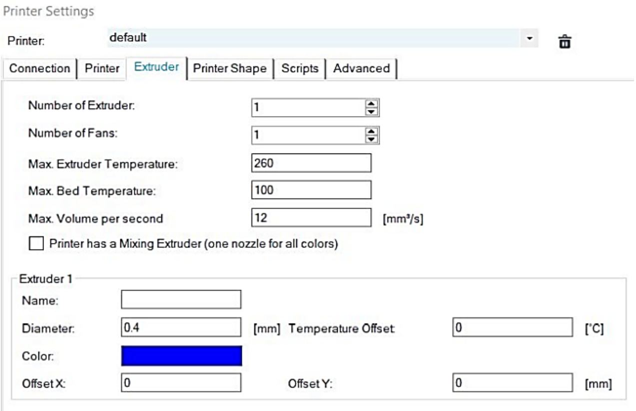
Figure 1. ADIMLab Gantry 3D Printer.



Source: https://www.manualslib.com/manual/1530095/Adimlab-Gantry.html?page=2#manual the second one is an aluminum heating printing platform. This structure presents an object printing size of 310x310x410mm with a 0.4mm nozzle.

The material used for the effector is a PLA (polylactic acid) filament, which is one of the most common materials used for the most commonly used materials for printing mechanical prototypes in research developments. Printing is focused on the extruder configuration, where an adjustment of the maximum temperature of the extrusion head is required since the correct setting of the parameters avoids damage to the printer by overheating. In addition, the extruder diameter or size is set in the lower section of the control software window, Figure 2 illustrates this base configuration.

Figure 2. Extruder configuration.



Printer: default

Number of Extruder: 1

Number of Fans: 1

Max. Extruder Temperature: 260

Max. Bed Temperature: 100

Max. Volume per second 12 [mm³/s]

☐ Printer has a Mixing Extruder (one nozzle for all colors)

Extruder 1

Name:

Diameter: 0.4 [mm] Temperature Offset 0 [°C]

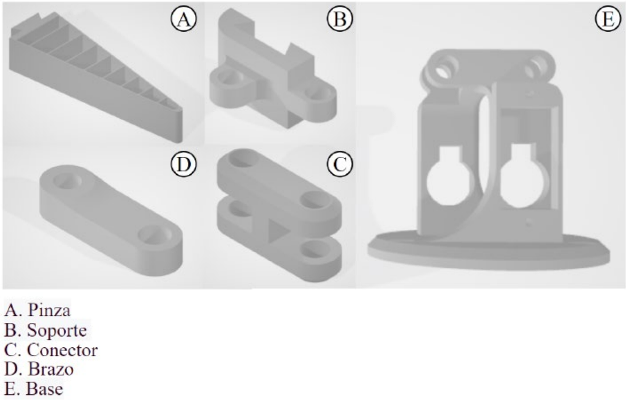
Color:

Offset X: 0 Offset Y: 0 [mm]

Source: Own

The mechanical design of the robotic effector, is inspired by the flexible mechanism exposed by Festo of the MultiChoice Gripper [13], where the grippers play a main role because they flex in order to adapt to the shape of the gripping object. The system consists of 5 CAD parts exposed in Figure 3, whose files were downloaded from the open source platform in order to perform printing tests, varying their configuration.

Figure 3. CAD parts of the Robotic Effector.



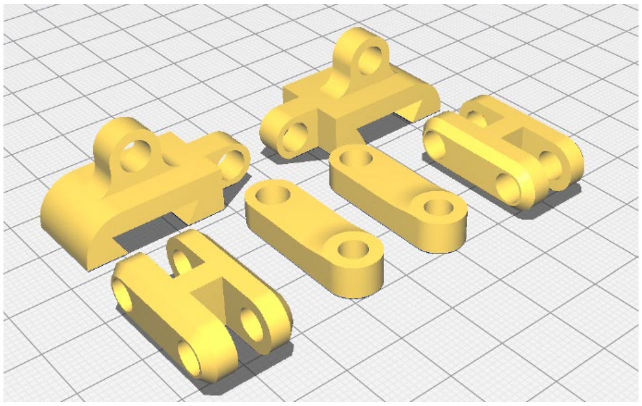
Source: Own

This prototype was printed using gray PLA of 1.75mm diameter Hatchboxun brand, a material known for its resistance to deformation, it is for this reason that the design and printing configuration of the grippers (A in Figure 3) must take into account the direction of the forces at the time of gripping. For this purpose, an alternative rotational to linear motion transmission mechanism known as connecting rod-crank is implemented, where the parts (B, C in Figure 3) play as a crank, while the arm (D) would be the connecting rod because the servomotors were embedded in the base (E) and the shafts generate a rotational motion which will be transmitted by the arm.

Additive manufacturing requires a detailed treatment to obtain good results and an extended lifetime of the machinery. Nowadays, specialized software developments such as Cura [14], are in charge of controlling and configuring everything related to 3D printing, taking into account factors such as extruder temperature, bed speeds, object density, among others. In general terms, a layer height of 0.2mm was implemented in the printing of the effector because this value can fluctuate between 25%-75% of the extruder diameter, thus the feasible working range is 0.1 - 0.3 mm. It is printed with a temperature for the extruder and bed of 203 and 55 degrees Celsius respectively, while the print speed is 40mm/s.

For the manufacture of the effector it was necessary to perform a phased printing process, because certain parts must be parameterized depending on their application and printing methodology. It is for this reason that 3 phases are defined, the first one as shown in Figure 4, the parts (B,C,D) or joints are selected, the second phase is for the clamp or element (A), and finally phase 3 is related to the base or part (E).

Figure 4. Phased printing.

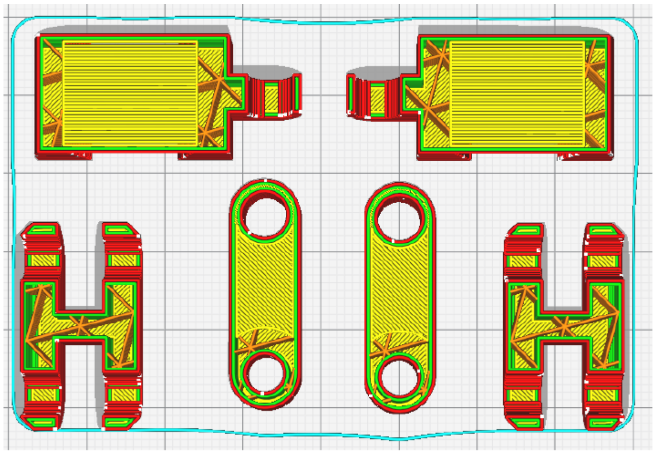


Source: Own

2.1. Phase 1

The first printing set consists of 6 elements which are printed at the same time, i.e. they all increase in layer at the same time. Because of this, the geometries between parts vary, but their configuration is standard among them. As shown in Figure 5, an internal filling pattern of the triangular type was selected since it allows shorter printing times by not going through the same line twice. Likewise, a filling density of 20% was determined since these parts are the ones that allow the transmission of mechanical movement and therefore require greater resistance.

Figure 5. Triangular Internal Filling.

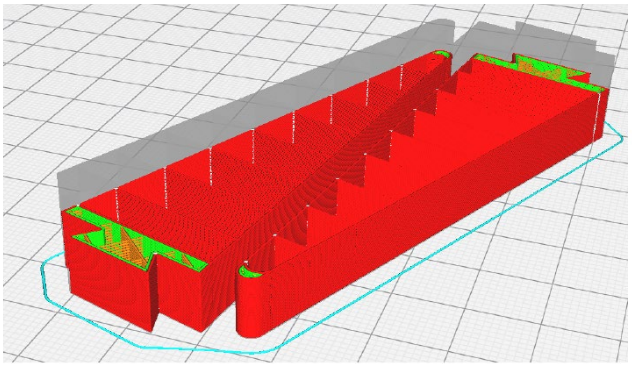


Source: Own

2.2. Phase 2

The second printing set consists of 2 equal grippers as shown in Figure 6, an internal filling pattern of the linear type is selected since it is widely used for parts with low density, in this case this is 8% since the parts must have the least amount of material to be deformed in the grip in order to adapt the shape of the element. It is evident that in the internal fins there is no filler pattern trace, so only the 4 outer layers are being made.

Figure 6. Low Density Elements.

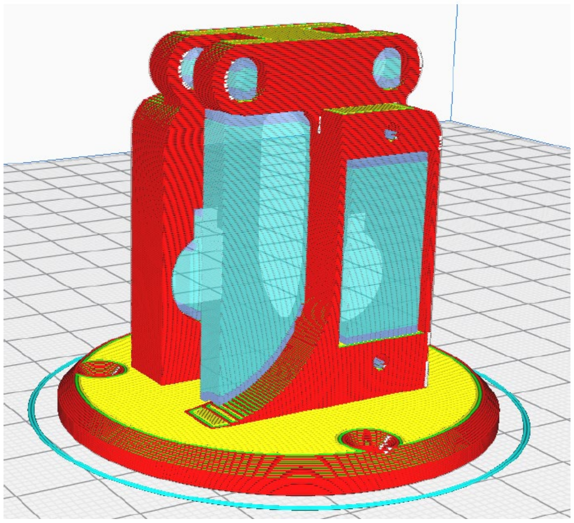


Source: Own

2.3. Phase 3

Finally, the third printing stage consists of a single piece called the base, an internal filling pattern of the triangular type and a density of 15% is selected since the servomotors and the gripper supports are embedded in this element, which requires good mechanical strength. Likewise, supports of the same material are generated due to the geometry of the element, which are illustrated in blue shades in Figure 7, the dark stage describes the limiting layers with the outer edges of the part, while the light phase exposes the hollow support generated.

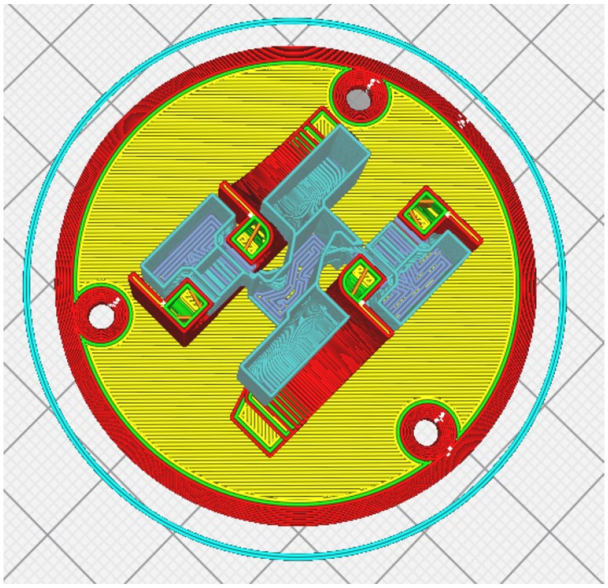
Figure 7. Generation of Supports.



Source: Own

Figure 8 shows the type of support filling in the collinear layer, where concentric was selected due to the ease of extraction that this configuration generates when removing the supports from the part.

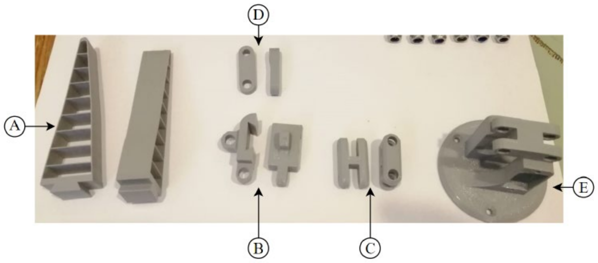
Figure 8. Advanced Support Specifications.



Source:Own

The printed structure is illustrated in Figure 9, which shows the finish of each of the parts (A-E) after a total printing period of 3 hours and 41 minutes.

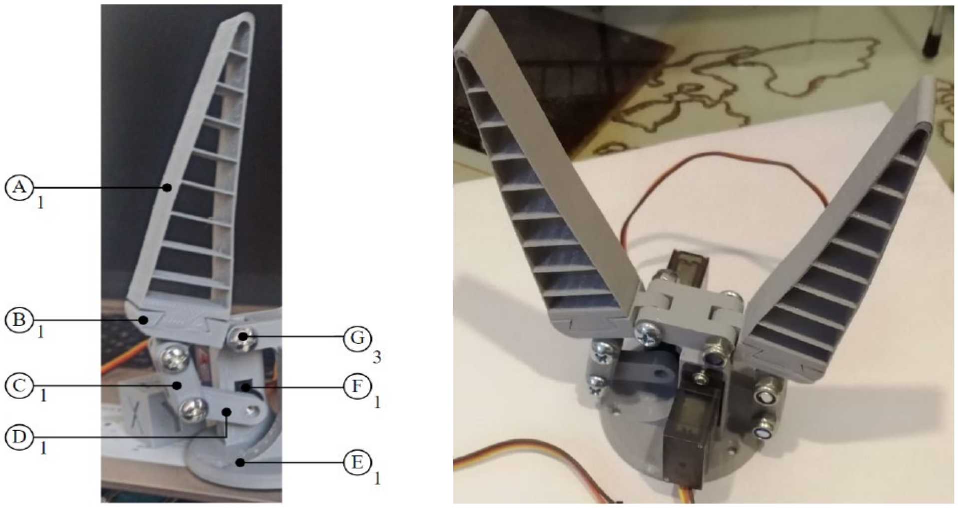
Figure 9. Pieces finally printed.



Source:Own

As shown in Figure 10 (left), the assembly base guide and the final effector are shown, it is worth mentioning that a transversal view of the effector is presented because it is vertically symmetrical, therefore, at the end of the steps shown, the process is repeated on the opposite side.

Figure 10. Assembly guide and end effector.



Source: Own.

Figure 11. Obtained grips.

Source: Own.

The lettered balloons show the part reference while the lower right subscript represents how many units are required in this cross section, only part (G) shows the need for 3 screw-nut pairs to join the 5 printed parts.

On the right side of Figure 10, the assembled flexible effector can be seen.

3. Results and analysis

The flexible robotic effector obtained allows the generation of curvilinear object grips as projected. The separation between the internal lines of the gripper accounts for the stiffness to be achieved; in this case, the tests performed, as shown in Figure 11, show a curvature of up to 2.5 mm per gripper.

In this case, the separation between internal lines was approximately 1 cm, thus achieving the gripping of objects of different densities (see Figure 11), where it was possible to appreciate that depending on the object, the friction generated between the gripper and the object played a relevant factor in the gripping, where cases such as the ball could easily slip out between the grippers, or very heavy objects could slip out of the gripper.

4. Conclusions

It was evidenced that the adjustment of the extrusion parameters allows to take care of the extruder and efficiently manage the 3D printing process. Minimization of printing times is evidenced by setting the triangular printing guides and the spacing between the gripper lines.

The obtained grips give evidence of the versatility of the effector in tasks of gripping curvilinear objects and that for the sample performed allow to conclude its functionality in assistive robotics tasks by having the ability to deliver objects of different density and shape to a user.

Acknowledgments

The authors would like to thank the Universidad Militar Nueva Granada, which, through its Vice-Rectory of Research, finances the present project with the code IMP-ING-3405 (2021-2022) and entitled "Mobile robotic prototype for assistance tasks in residential environments", from which the present work is derived. Likewise to the Universidad de los Llanos for the allocation of time for the participation of the engineer Javier Eduardo Martínez Baquero in the research project.

References

[1] Z. Hu, W. Wan and K. Harada, "Designing a Mechanical Tool for Robots With Two-Finger Parallel Grippers," in IEEE Robotics and Automation Letters, vol. 4, no. 3, pp. 2981-2988, July 2019. https://doi.org/10.1109/LRA.2019.2924129

[2] L. Berscheid, T. Rühr and T. Kröger, "Improving Data Efficiency of Self-supervised Learning for Robotic Grasping," 2019 International Conference on Robotics and Automation (ICRA), 2019, pp. 2125-2131. https://doi.org/10.1109/ICRA.2019.8793952

[3] Y. Domae, A. Noda, T. Nagatani and W. Wan, "Robotic General Parts Feeder: Bin-picking, Regrasping, and Kitting," 2020 IEEE International Conference on Robotics and Automation (ICRA), 2020, pp. 5004-5010. https://doi.org/10.1109/ICRA40945.2020.9197056

[4] J. H. Sanchez, W. Amanhoud, A. Billard and M. Bouri, "Foot Control of a Surgical Laparoscopic Gripper via 5DoF Haptic Robotic Platform: Design, Dynamics and Haptic Shared Control," 2021 IEEE International Conference on Robotics and Automation (ICRA), 2021, pp. 12559-12566. https://doi.org/10.1109/ICRA48506.2021.9561887

[5] S. Ainetter and F. Fraundorfer, "End-to-end Trainable Deep Neural Network for Robotic Grasp Detection and Semantic Segmentation from RGB," 2021 IEEE International Conference on Robotics and Automation (ICRA), 2021, pp. 13452-13458. https://doi.org/10.1109/ICRA48506.2021.9561398

[6] S. K. Rajput, A. Kaushal, R. K. Singh and A. K. Sharma, "A Study and Fabrication of SMA based 3D Printed Adaptive Gripper," 2021 Smart Technologies, Communication and Robotics (STCR), 2021, pp. 1-5. https://doi.org/10.1109/STCR51658.2021.9588838

[7] C. Son and S. Kim, "A Shape Memory Polymer Adhesive Gripper For Pick-and-Place Applications," 2020 IEEE International Conference on Robotics and Automation (ICRA),

2020, pp. 10010-10016. https://doi.org/10.1109/ICRA40945.2020.9197511

[8] S. D. Liyanage, A. M. Mazid and P. Dzitac, "An Innovative Whisker Tactile Sensor for Intelligent Robotic Grasping," IECON 2021 – 47th Annual Conference of the IEEE Industrial Electronics Society, 2021, pp. 1-6. https://doi.org/10.1109/IECON48115.2021.9589765

[9] T. V. Prabhu, P. V. Manivannan, D. Roy and Yathishkumar, "A robust tactile sensor matrix for intelligent grasping of objects using robotic grippers," 2021 International Symposium of Asian Control Association on Intelligent Robotics and Industrial Automation (IRIA), 2021, pp. 400-405. https://doi.org/10.1109/IRIA53009.2021.9588669

[10] G. Hwang, J. Park, D. S. D. Cortes, K. Hyeon and K. -U. Kyung, "Electroadhesion-Based High-Payload Soft Gripper With Mechanically Strengthened Structure," in IEEE Transactions on Industrial Electronics, vol. 69, no. 1, pp. 642-651, Jan. 2022. https://doi.org/10.1109/TIE.2021.3053887

[11] J. Guo, J. -H. Low, X. Liang, J. S. Lee, Y. -R. Wong and R. C. H. Yeow, "A Hybrid Soft Robotic Surgical Gripper System for Delicate Nerve Manipulation in Digital Nerve Repair Surgery," in IEEE/ASME Transactions on Mechatronics, vol. 24, no. 4, pp. 1440-1451, Aug. 2019. https://doi.org/10.1109/TMECH.2019.2924518

[12] C.I. Basson, G. Bright y A.J. Walker. “Testing flexible grippers for geometric and surface grasping conformity in reconfigurable assembly systems.” En: South African Journal of Industrial Engineering, vol. 29, no. 1, 2018, 128 -142.

[13] Festo AG & Co.KG. “MultiChoiceGripper”. En: Variable gripping based on human hand (2018).

[14] Ultimaker, “Introducing the new Ultimaker method”. https://ultimaker.com/es/software/ultimaker-cura