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engB075

3D-Printing to Fight COVID-19

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Abstract: *In the context of the COVID-19 pandemic, there was the need to develop solutions to minimize the spread of the disease in public spaces. Some commonly shared surfaces include doors, public transportation, vending machines, payment stations, and hand-sanitizer dispensers. 3D printing, which allows for very fast manufacturing of prototypes was the chosen method to create these devices in a short period to prevent a possible second-wave of the disease after lockdown measures were lift. The developed devices include: a personal hook, a fix door hands-free (forearm) door opener, a hands-free and also electronics-free hand sanitizer dispenser also elbow activated and also, a finger cover for button pressing which is stored in a personal hook. These devices are easy to manufacture, durable, effective, inexpensive and some of them are built in anti-bacterial polymers. With these solutions, it is expected that surface contact with the virus is minimized and possibly reducing the number of infected individuals.*

Keywords: *Additive Manufacturing, Covid-19, Product Development*

1. INTRODUCTION

By December of 2019, the first cases of an unknown respiratory infection were found in the city of Wuhan, Hubei, China. A few months later, first cases were discovered in Portugal. Readily, several institutions and individuals with access to additive manufacturing equipment, moved by the worrying news of PPE shortages, took matters by their own hands and began nearly mass producing these devices. All over the world, additive manufacturing revealed to be a powerful tool in mitigating PPE shortages as well as producing other PPE for the general population (Choong et al. 2020; Tino et al. 2020; Ishack and Lipner 2020) being that face shields for medical professionals are one of the most investigated and improved designs (Bishop and Leigh 2020; Celik et al. 2020; Erickson et al. 2020; Flanagan and Ballard 2020; Amin et al. 2020), as well as 3D-printed masks (Swennen, Pottel, and Haers 2020; Tarfaoui et al. 2020). Moreover, in *open sources* such as *thingiverse* (Makerbot, n.d.) and other platforms, many examples of readily available devices can be replicated and printed. The work here proposed is more focused on developing devices that do not require medical approval or certification to facilitate daily lives in the “new normal” reality where touching any surface that other people may have touched can cause a real hazard to one’s health. It has been studied that the novel coronavirus, SARS-CoV-2 can persist in plastic or stainless steel surfaces for up to 72 hours (Van Doremalen et al. 2020). The contagion occurs when the dirty hand from touching any infected surface, touches the nose, mouth or eyes, thus allowing the virus to enter the respiratory system, infecting the individual. Doorknobs, elevator buttons, handrails are some of the most touched surfaces. If these are adapted to avoid being touched with the hands, contagion can be reduced, since it is not as common to touch the face with the forearm or elbow. Therefore, some devices are proposed to reduce touching only of these surfaces with one’s hand. Besides replacing hand touch with arm or elbow, hand touch is also replaced with a personal hook in case the user finds a door without any installed device. It is important that these devices are ergonomic, visually pleasant, and intuitive, as well as durable and effective in their purpose.

2. MATERIALS AND METHODS

The 3D printing process chosen was Fused Filament Fabrication (FFF), which is a material extrusion process where the printing head with Oxy movement extrudes the filament layer by layer. The selected equipment was an i3MK3s printer by Prusa Research (Prusa, n.d.). The material used for printing the parts was PLA from FilamentPM (FilamentPM, n.d.) and anti-bacterial TPU from copper 3D (Copper3D, n.d.), for the finger covers. The properties of these two materials are shown in Table 1. According to the TPU supplier, this material can remove more than 99.99% of bacteria and virus after 24h. Additionally, a previous study concluded that the addition of copper to protective masks could effectively deactivate the influenza virus (Borkow et al. 2010).

Table 1 - Material properties for the PLA and anti-bacterial TPU (FilamentPM, n.d.; Copper3D, n.d.)

	Supplier	Density [g/cm^3]	E [MPa]	σ_{ut} [MPa]	σ_y [MPa]	Impact str. [kJ/m^2]	Viscat soft. temp.[ºC]
PLA	FilamentPM	1.24	3500	53	-	16	55
TPU	Copper3D	1.16	150	-	50	NB	138

2.1. Hands free door opener – *Handgenic*

To avoid transmission in doorknobs, a device was designed to open doors without using one’s hand. This device was designed to fit the standard doorknobs found in FEUP which are double curved tubular doorknobs. The initial idea for the fixation of the door was a tweezer-like mechanism. From this mechanism idea, the first sketch (Figure 1a)) for a prototype was developed. This first prototype was quite large (Figure 1b)) and pulled the door handle through a lever mechanism. The tweezer mechanism required the most refinement, and after a few iterations, the part shown in Figure 1c) was finalized. Furthermore, the parts’ ergonomics must be improved, so the initial shape was transformed into a more comfortable shape for the arm as can be seen in Figure 1d). Moreover, the level part was integrated in the tweezers for sturdiness of the model. The final model after all the necessary improvements is shown in Figure 1e). In the final model, a smaller tweezers’ mechanism can be found which increases the stability of the part during its use, curvatures with less stress concentration, a bigger and more ergonomic surface to accommodate the forearm, a more adequate inferior geometry that prevents the rotation of the entire part.

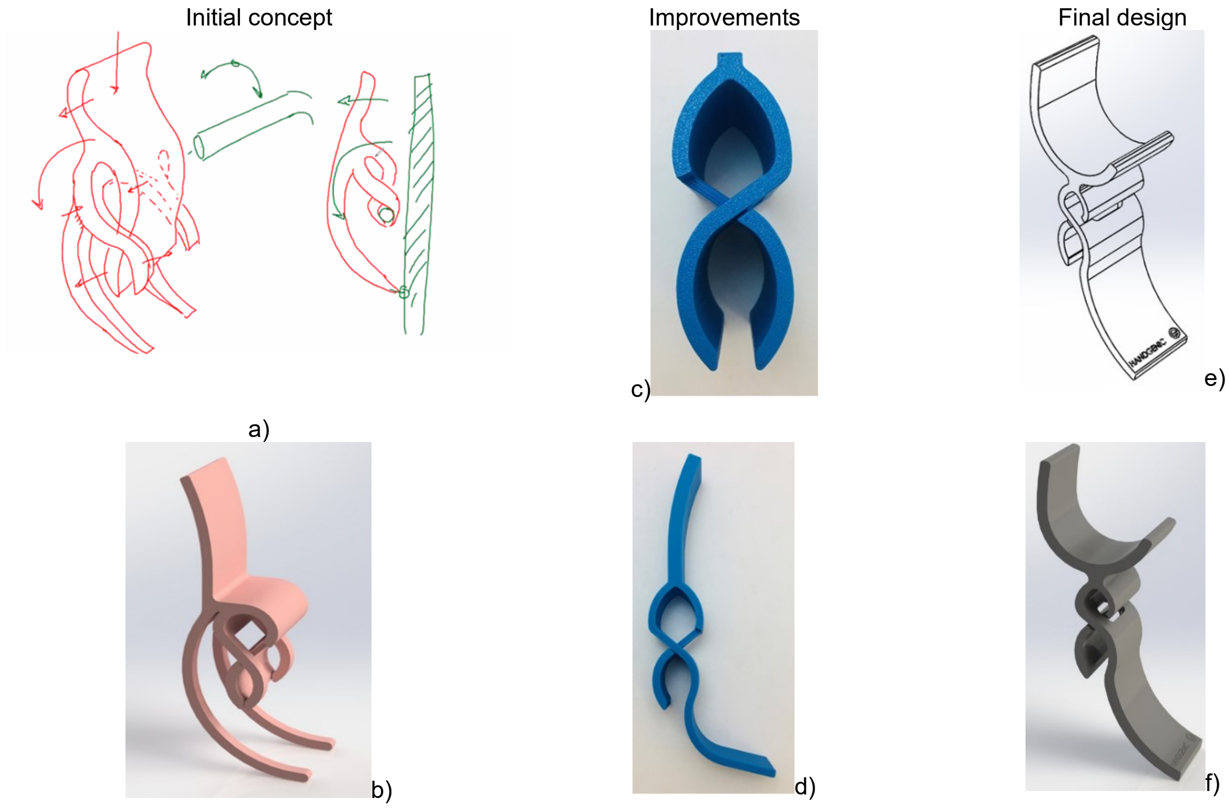


Figure 1 – Handgenic development: a) initial sketch; b) initial design based on the first sketch; c) improvement of the tweezer mechanism to fit 20mm diameter doorknobs; d) new design with lever mechanism integrated in the tweezer; e, f) final design with improved ergonomics to fit the arm when opening the door

2.2. Finger cover and hook - *HYTIP/HYHOOK*

The HYTIP/HYHOOK is a two-part component which includes the finger cover and a hook device for storage and opening doors. The finger cover suffered several iterations as indicated in Figure 2. The finger cover is to be manufactured in anti-bacterial flexible polymer, MDFlex by cooper 3D. It has a protective casing as shown in Figure 2 f)-I). This casing has recesses to fit the flaps of the finger cover which can be seen in Figure 2 c)-e). The hook component and the casing are made in PLA. The hook should be capable of opening doors and be used in public transportation to avoid touching surfaces, for example handrails. Its iterative evolution is shown in Figure 2 j)-m). This part includes a hole where the finger cover casing will fit. The hook and the casing are printed together and through rotation of the casing inside the hook, any interior supports will break thus allowing full freedom of rotation. The final assembly of the HYTIP/HYHOOK is shown in Figure 2 n)-o) where it can be seen that the casing has full freedom of rotation in the hook. The finger cover is therefore kept in the hook for a very compact design.

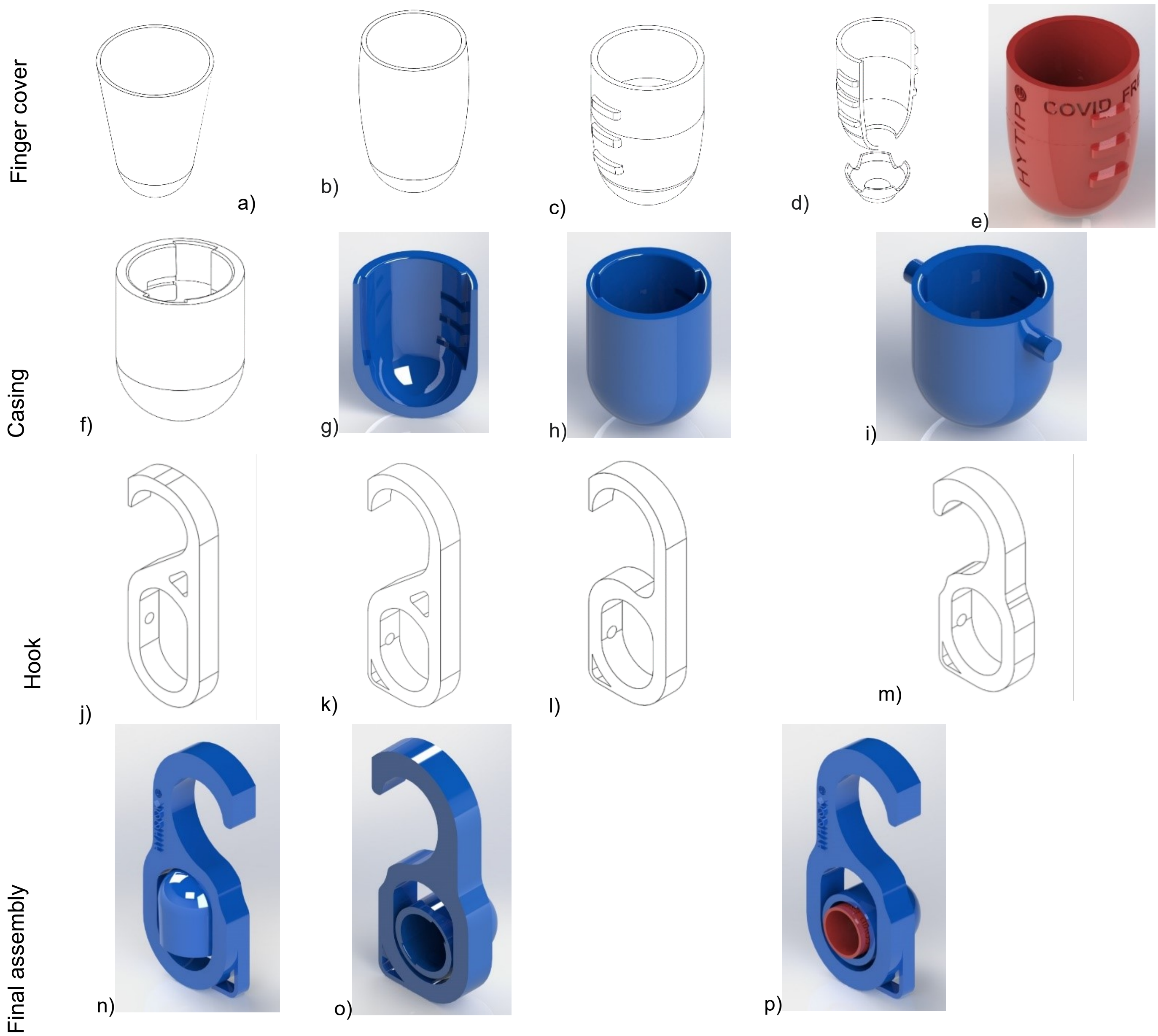


Figure 2 - HYHTIP/HYHOOK development, a) initial finger cover design; b) ergonomic finger cover, c) inclusion of flaps to fit in the casing, d) inclusion of a tip in conductive polymer which is assembled in the finger cover; e) rendered image of the finger cover; f) finger cover assembled in the casing; g) inside view of the casing with recesses where the finger cover flaps fit; h) outer view of the casing; i) inclusion of pins in the casing to assemble in the hook; j) initial hook design with holes to fit the casing; k) inclusion of a ring to add a keychain; l) removal of the inside cavity to increase the hook size; m) increased thickness in the hook; n, o) rendered view of the assembly; p) full assembly with the finger cover

2.3. Elbow activated hand-sanitizer dispenser

This device was thought as a solution to avoid contact with the hand sanitizer dispenser, which can also be a source for contagion, especially if the container is empty. Several solutions were considered. A first idea consisted on a pedal activated dispenser (Figure 3a)) which would require a large assembly. An automatic option using electronics (Figure 3b)) was considered but abandoned due to cost. Therefore, the chosen idea is a support, fixated to the wall where a container of sanitizer is placed (Figure 3c)). Moreover, and most importantly, this concept is touchless to use. Figure 3 shows the evolution of all prototypes. Having chosen the elbow activated concept, the following iterations, shown in Figure 3d), were made. The final device which includes a casing on the base is shown in Figure 3e).

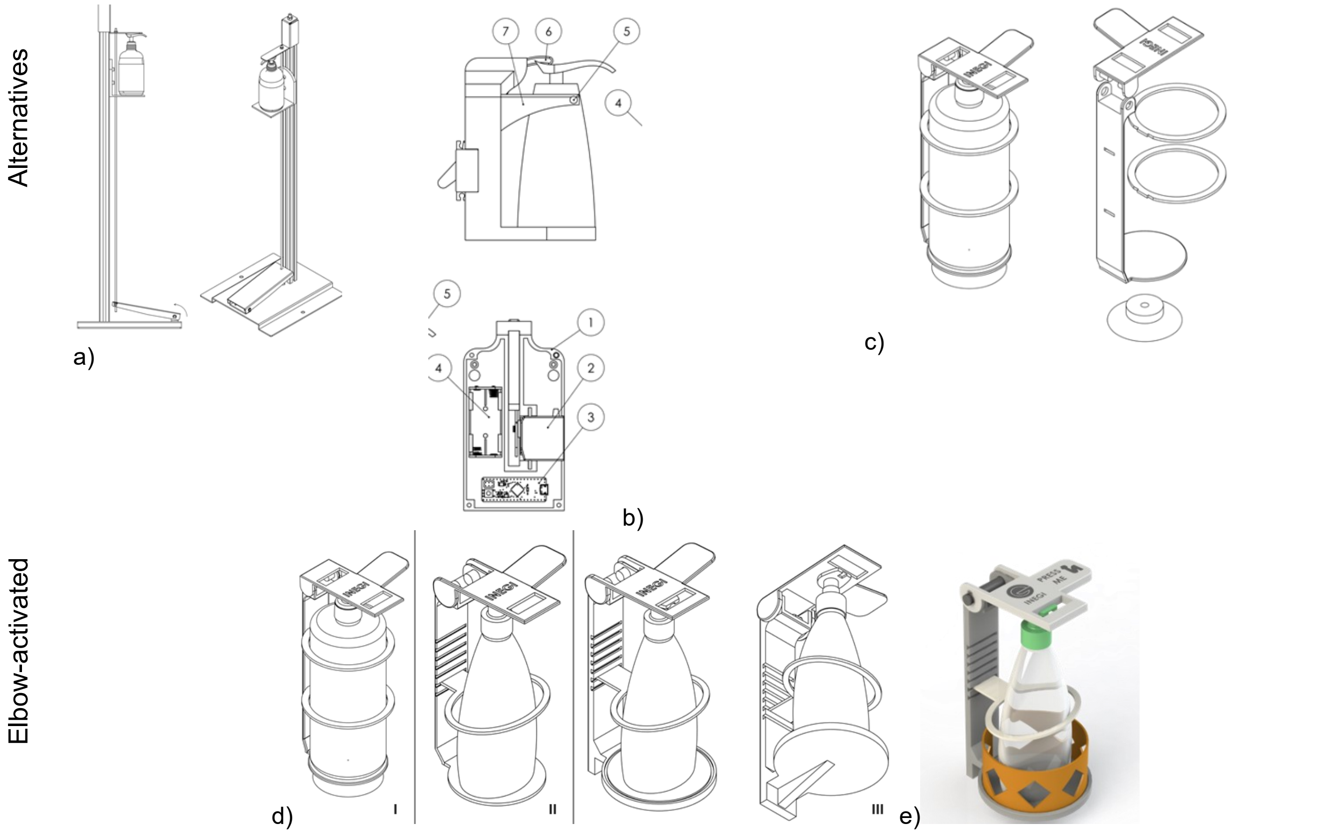


Figure 3 – Hands-free sanitizer dispenser: a) pedal activated; b) electronic solution; c) elbow activated; d) iterations on the elbow-activated design; e) final design

3. RESULTS AND DISCUSSION

Regarding printing, each part had its printing parameters optimized for the best results. The printing parameters used as well as final unit cost for each part are shown in Table 2.

Numerical simulation was conducted to attest the capability of each device as well as defining its maximum admissible load. The parts which are subject to higher loading are made in PLA (E = 3500, ν=0.3). The parts were analysed in the elastic domain.

Figure 4 shows the boundary conditions and stress results for each component. For most applications, the parts can withstand the necessary load without deforming. The door handle solution proposed is quite different from other solutions (François et al. 2020; Chen et al. 2020; Muirhead et al. 2017). It can be transformed into an antibacterial device if PLA is switched by anti-bacterial PLA, however with a much higher cost. Regarding the HYHOOK, even though it is larger, this solution presents a double purpose, unlike any other solution found in *open sources*. The elbow activated dispenser presents the important advantage of being less expensive than commercially available solutions which present an average cost of 20€.

Table 2 - Summary of the most relevant printing parameters and cost of all developed components

	Material	Parts	Mass [g]	Printing time	Layer [mm]	Infill	Speed [mm/s]	Temperature [°C]		Unit cost [€]
								Extruder	Bed	
Handgenic	PLA	3	350	24h	0.2	100% rect. (4 per.)	25-80	215	60	4.16
Hook + casing	PLA	1	38	3h42m	0.16	100% rectilinear	40-60	195	50	1.50
Finger cover	Clean TPU	1	3.10	35m	0.1	100%	15-25	225	50	0.54
Dispenser										11.77

Structure (top and base)	PLA	1	340	11h42m	0.3	100% rect.	30-80	210 (215 first layer)	60	8.9
Others	PLA	1	38	5h34m	0.2	100% rect	15-50	210 (215)	60	2.2
Rings	TPU	2	19	3h35m	0.2	100%	15-20	225	60	0.67

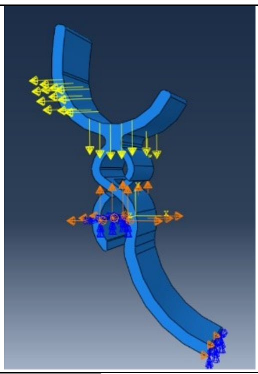
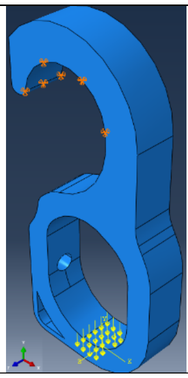
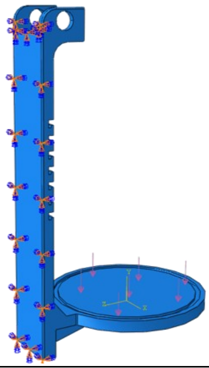
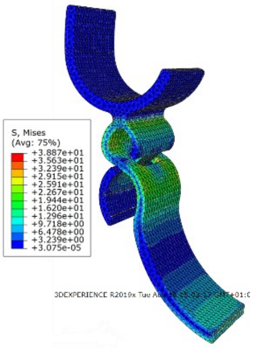
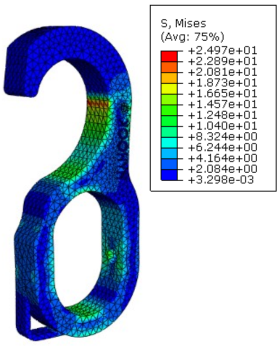
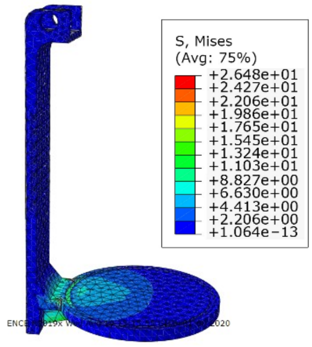
	Handgenic a)	*HYHOOK* b)	Elbow activated sanitizer (base) c)
Boundary conditions			
Results			
Max. load	Vertical load 44N Horizontal load 22 N	Load 320 N	Load 284N

Figure 4 - Numerical simulation results in Abaqus: a) Handgenic; b) HYHOOK hook; c) Base of the elbow activated hand sanitizer

4. CONCLUSIONS

The presented devices show different approaches to avoid surface contact and present interesting solutions to the university buildings and avoid surface contagion. Additive manufacturing allowed to fully develop all of these solutions in a short period, before the beginning of the school year. The sanitizer dispenser, besides being elbow activated, presents a lower unit cost than commercially available solutions. The hook solution is a compact and effective solution to distribute among students and university personnel. Finally, the doorknob solution proved effective and ergonomic, and sturdier than some solutions found online, as well as being a single part instead of an assembly.

5. Acknowledgements

The authors truly acknowledge the funding provided by Ministério da Ciência, Tecnologia e Ensino Superior Fundação para a Ciência e a Tecnologia (Portugal), under project UIDB/50022/2020.

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