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Development of mask design as personal protective equipment through 3D printing

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Abstract

This project aimed to develop an innovative mask design, aided by 3D printing technology that was able to protect its wearers against virus infection. The project was motivated with the intention of helping to fight Covid-19, but that its use was extensive as an option to N95 and similar masks, already on the market, even after the pandemic. Whose main design objective was that the mask had a sealing efficiency based on a half-face mask and that it could be used in conjunction with masks made of antiviral fabrics, such as, for example, a surgical mask that has its filtering capacity already tested and approved and, which would be the filter element of the mask. The mask was also intended to be reusable so that it could be washed for cleaning, with only the fabric filter element being disposable.

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1. Introduction

The use of masks as an essential mechanism in reducing the transmission of SARS-CoV-2, with the transmission of the virus by aerosol, must be recognized as a key factor against the spread of infectious respiratory diseases. Due to their smaller size, aerosols can exacerbate the spread of COVID-19, as virus-containing aerosols easily penetrate the lungs. Therefore, it is essential that control measures are introduced to reduce aerosol transmission, including the use of masks. [12].

Another recent study by the University of Cambridge published in the journal The Royal Society concluded that the massive use of masks can prevent or minimize the waves of contamination of covid-19. [13].

However, due to the higher level of protection, there is a worldwide demand for masks such as the N95, N99 and KN95, causing a shortage of these products. [4] Likewise, due to greater sealing capacity and consequently greater efficiency against viruses, several countries in Europe have started to require N95-type masks. (BBC News, 01/28/2021) Therefore, projects that will serve as an option for these types of masks with the same efficiency will be useful.

In order for a mask to be used as a replacement, the N95 must have the same characteristics in its face sealing efficiencies and high filtering capacity. [3]

Thus, a project was proposed for the Development and Production of PPE (personal protective clothing and equipment) for general use and also for health professionals.

In this way, the design of the mask was based on the form of sealing on the face of half-face masks, which already exist on the market and are proven to be efficient because they have a design that easily molds the face to a face with a variation of shape, for example, see Fig. 1a.

In addition, the mask was designed to be used in conjunction with fabric masks that would act as the filter element. The intention was to use a filter element that had its filtering capacity proven by certification bodies, such as, for example, in surgical masks, which have a filter layer, resistant to the penetration of airborne fluids, see Fig. 1b. In particular, surgical masks made with two layers of TNT fabric and a layer between them of meltblown that prevents the passage of microorganisms.

The conclusions of a study by the Institute of Physics of the University of São Paulo (USP) recently published in the journal (Aerosol Science and Technology) corroborate the choice of surgical masks. The efficiency of 227 models found in stores and pharmacies in Brazil were tested and the research came to the
conclusion that surgical masks have an average of 89% efficiency in filtering fluid particles in aerosols in the air. [18]

Advantages of using snap-on masks:
- It can be reused and is washable;
- Use fabric or fabric mask as a filter element.
- Easy use and handling of the fitting.

2. Justification and discussion

Contagion by the Covid-19 virus can occur through several flaws in masks and potentiated by excessive manipulation in use. Masks must be used, however they are part of a broader strategy, considering that the accessory alone does not protect from the virus. People should also clean their hands frequently and keep a distance of at least one meter from each other, according to WHO guidelines.

Corroborating the recommendations, a WHO-commissioned study published in The Lancet concluded that for the general public, evidence shows that physical distancing of more than one (1) meter is highly effective and that face masks, surgical or cotton of multiple layers, improve protection. [2].

In Germany, a study evaluated the effectiveness of face masks, as masks became mandatory at different times in German regions, it was possible to compare the increase in infections in regions with masks and regions without masks. Twenty days after face masks became mandatory, it was found that the number of new infections was reduced by about 45 percent. As the economic costs are close to zero compared to other public health measures, masks appear to be a cost-effective means of fighting COVID-19. [8].

3. Methodology and design development

The project’s innovation is due to the fact that it is a mask that has the sealing qualities of a rubber mask, and can be used in conjunction with fabric masks, but also because of the way of fixing and locking the fabric used as a filtering element that is given by a rigid structure, which fits on the outside of the mask.

The mask design therefore has two parts:
- A part that is in contact with the face and that promotes sealing with the face;
- The other part fits on the outside and through compression and friction (with the part in contact with the face) locking the fabric so that it is pulled and locked between the two parts of the mask, as seen in Fig. 2 and Fig. 3.

This feature of fitting between the structures makes it possible to dismantle the mask for the disposal of the fabric and also allows the hygiene of the two parts of the mask.

The material of the part that is in contact with the face must be moldable to the face to avoid air leakage, it is understood that it must be produced with flexible, comfortable and antiallergic material.

Two versions were developed for structures, the difference of which lies only in the design of the front part of the mask, however the studies for the design of the part of the mask that is in contact with the face were based on some studies and also on references from half-face mask projects, that have certification and guarantee of sealing effectiveness.

3.1. Methodology

For the development of the design, scientific contributions of a theoretical nature were used, in order to obtain information about...
the dimensions and shape of the face and later information of an applied design was used to know existing projects that have a defined design regarding the use of mechanisms, mask seal in relation to the face of the face.

From the theoretical and applied scientific information, of a practical nature, two design versions were conceived, developed in Rhinoceros virtual modeling software, which served as a basis for preliminary analyzes and to provide the 3D printing of the physical models of the mask, in order to carry out tests with some users participating in the project, within a qualitative approach to obtain information on ergonomic aspects to define the final shape of the mask.

According to Koehler (2014), who developed a face seal (FS) concept for a filter facepiece respirator (FFR). This is based on facial anatomical analysis relevant to the respirator contact areas that allow the face seal to leak inward [5].

The new respirator was evaluated in a pilot study using a quantitative fit test, followed by a Simulated Workplace Protection Factor measurement performed in an operation where electrocautery smoke was generated using standard surgical instruments. The fit effect was mainly attributed to geometry.

The results of this study suggest that the design offers a considerable advance in protecting users from aerosol hazards, particularly surgical smoke in operating rooms. (Fig. 4).

User comfort and fit are two other important indicators of PFF performance. Comfort refers to both the comfort of the wearer’s face and the comfort of the breathing process. Fit refers to the degree of fit between the wearer’s face and the edge of the PFF. It is mainly related to the wearer’s face size, respirator material, strap tension, edge shape and respirator size. Due to the variation in size and shape, a respirator may not match the human face. If the respirator and face do not fit properly, the system may not be effective at blocking contaminated air [1].

For the design of the mask, the facial measurements table with the technical and ergonomic specifications of ISO 16976–2 was used. The ISO table has a spectrum of five types of faces, as seen in Fig. 5 and Fig. 6, which must be considered in order to develop an effective seal serving the largest number of faces in the population.

Although the ISO measures have in the spectrum of the five different face size options, it was also foreseen in the project that the mask would have a gradation to meet the largest number of people and according to [17] there are three percentiles (5 %, 50 % and 95 %) which should be the basis to reach a wider coverage of the population from the smallest person to the largest, in this case in relation to the face. In this way, it was established that the mask will have sizes (small, medium and large) referring to percentiles.

In order to achieve a gradation of frame sizes to ensure a wider spectrum of users with different face sizes, it was necessary to evaluate specific standards such as ISO, antomometric studies and ergonomic aspects to reach a conclusion of an average mask size and also the gradation of sizes that will be necessary to ensure sealing on different face sizes. Analyzing the characteristics of the design and filtering type of the mask with structures and antiviral material [10], for the purposes of normative classification, tests and tests will be necessary to verify the levels of sealing and filtering against particles and aerosols.

### 3.2. Design development

The five ISO mannequins (Fig. 5) have 3D virtual examples (Fig. 7) and facilitate the verification of the seal at the time of the virtual design of the mask and if it is continuous throughout the perimeter of contact with the face.

From the analysis and testing to verify the seal in all five ISO virtual models, the proposed design was continued, which was a two-part snap-on mask. In addition, the assistance in the design of ISO’s virtual models made it possible to make several changes before 3D printing, avoiding wasted time and material [6].

Regarding the measurements of the mask, the average size model of the ISO was used as a parameter, and the width and height measurements were used, as shown in Fig. 8.

In order to meet a greater variety of face sizes, a variation of three sizes was designed, (P, M, L) (Fig. 9) following the size variation (cheese-nose) of the ISO standard and the manufacturers of semi-facial masks (which served as an ergonomic basis for the project) varying 5 mm more in size G and 5 mm less in size P, with the other measures being proportional to height.

Two models were developed in Rhinoceros software, whose part in contact with the face has the same measurements, only changing the design of the front part and the fitting on the outside, but in both sealing characteristics they are identical. The design variation was thought to define which shape would be most appropriate for users and also to use different materials to verify their behavior applied to the mask [9].

One front design has a vertical rod to structure the inner part of the mask, seen in Fig. 10a, and the other design has a hollow structure, seen in Fig. 10b.

Masks with structures (Fig. 10 (a and b)) were designed to be used with surgical masks and allow the fabric of homemade masks
to keep away from the face, increasing the ventilation area for breathing, promoting greater comfort and, as they have the shape of the face, increase the fence.

To increase safety and sealing, an internal membrane facing the entire contour of the frame in contact with the face has been included in the design, so that the seal is not altered by variations in face profiles.

These membranes have been used in models of respirators that have been widespread and marketed for many years as a way to facilitate sealing, even with variations in sizes and face shapes. This model, with greater sealing efficiency, was developed to be used with antiviral fabric with nano particles that attack the virus that causes Covid-19 and, in this way, have its effectiveness potentiated.

4. 3D printing of prototypes

The prototypes of the masks were made by two types of 3D printing technologies to know the behaviors that the different materials provide in the use of the masks. To facilitate the identification of each one, each version will be named version A and version B.

Version A, with hollow structures (Fig. 10b), was produced by the 3D printing process using FDM (Fusion and Material Deposition) additive manufacturing technology, in which the inner part of the mask was built with TPE (thermoplastic elastomer) filament, which prints the masks with both elasticity and resistance, as shown in Fig. 11.

The external part is also produced using FDM technology, but with PLA (thermoplastic polylactic acid) filament, which prints parts with greater mechanical strength, as shown in Fig. 12.

The printing configuration of this mask model was included a tree-like support in the Cura program (Fig. 11) to improve the printing process of membranes that are thinner and have a large variation of angulation.

The Version B, which has a rod on the front, the inner part of the mask was produced by SLS technology that solidifies an elastomer powder through a laser beam generating the mask, as shown in Fig. 14.

For the production of the external part, the material PA 12 (nylon) was used, which is more rigid and printed parts that are more resistant to traction, as shown in Fig. 15.

In both versions, the external part is tractioned by the elastics, which fix the mask to the head and are produced in a more rigid material so as not to suffer variations in shape and not allow gaps between the parts and the entry of contaminated air.

In the inner part of the mask, flexible material was used, because in this part there is a need for sealing and the flexible material is better molded to the face, increasing the seal, in addition, in this part that is in contact with the face, the flexible material is the most appropriate because it provides greater comfort in use.

Below are the results of the 3D printing of the two versions of the Masks, the version with a vertical rod on the front, as shown in Fig. 16a and the version with a hollow front structure, as shown in Fig. 16b (See Fig. 17 Fig. 18. Fig. 19. Fig. 20.).
For the visual checks of sealing and coupling the mask with the face, the mannequins of the ISO 16976–2:2015 standard were printed, in the face sizes S (Fig. 11), M (Fig. 12), L (Fig. 13) and Wide (Fig. 14).

In a first measurement, a visual verification was carried out to verify the seal between the mask and the faces of the mannequins, for later measurements to be carried out through standardized instruments and processes.

In addition to the visual verification and use tests, preliminary air flow and volume tests were carried out for a preliminary verification of the seal on ISO 16976–2:2015 mannequins. Adaptations...
were carried out on the mannequins of all sizes for the coupling of ventilation devices (Fig. 21), according to the specific regulations in force in which the mask to be tested fits. (Fig. 22). The tests were carried out in accordance with the specific standards that govern tests for face masks of the Brazilian Association of Technical Norms - Brazilian Norms (ABNT-NBR). Specifically, the standards NBR 13698:2011 [16] item 5.7 of Breathing Resistance and NBR 13698:2011 [16] item 5.8 Penetration through the filter @ NaCl.

No leaks were detected in the preliminary tests following the pressure and air volume test standards with an ISO dummy (Fig. 23), provided by the certifying company, according to the technical literature. (Fig. 24).

It is worth explaining that Filtering Facepieces (PFF1, PFF2 or PFF3) are maintenance-free respirators and are considered disposable. In this case, the facepiece itself is the filter element. It must be changed whenever it has passed its validity, torn, punctured or dirty.

In masks classified as PFF, the entire body of the mask is a filtering element and therefore must be completely disposable after use, unlike, for example, respirators with filters that have a mask body made of non-filtering material, plastic or rubber, being the filters coupled and disposable external elements and follow NBR 13697 [15].

According to the Falcão Bauer Laboratory, NBR 13698 [16] is indicated for the verification test and PFF classification equivalent to N95. They are also equipped to carry out tests to assess particle retention according to NBR 13697 [15] for particulate filters.

5.1. Sealing and coupling verification with users

The mask production project involved eleven participants and professionals from some areas who, spontaneously, volunteered to test the mask. Two more young people aged between 16 were added with the sole purpose of generating criticism about the mask's design.

The intention of this verification was to create parameters for analysis and criticism regarding the sealing of the mask to the face and if there was any evident discomfort.

Tests regarding the seal were performed with users forcing their breath for a few seconds and comfort was performed with use for 30 min.

The verification participants were distributed as described in Table 1.

These tests were preliminary and in order to obtain the best design of the mask through observation and analysis of ergonomic aspects and were carried out by the professionals who were part of the project. The tests generated a lot of constructive criticism for the improvement of the project for the development of a new model that meets the sealing needs in faces of different sizes and shapes.

All users who tested the membrane masks cited difficulty moving the chin during speech and discomfort with the part that is in contact with the face being more rigid than version (B) with the horizontal rod on the front (Fig. 25b), because the rubber is less malleable and more abrasive than the TPE rubber version (A), which is more malleable and has a smoother surface (Fig. 25a). The conclusion, by critics in general, was that the design was correct for all users and that the material of the mask would have to be very malleable so as not to cause discomfort with use. Thus, the recommended materials would be silicone and TPE, as they
Fig. 16. (a) produced version (B) of SLS technology; (b) version (A) produced in FDM technology, author 2021.

Fig. 17. (a) Front detail; (b) zoom fit side; (c) zoom fit part of the chin: Seal check on face size mannequin S of ISO 16976–2: 2015.

Fig. 18. (a) Front detail; (b) zoom fit side; (c) zoom fit part of the chin: Seal check on face size mannequin M of ISO 16976–2: 2015.

Fig. 19. (a) Front detail, (b) zoom fit side and (c) zoom fit part of the chin: Seal check on face size mannequin L of ISO 16976–2: 2015.
Fig. 20. (a) zoom fit side; (b) zoom fit part of the chin: Seal check on face size mannequin Wide of ISO 16976–2: 2015.

Fig. 21. Drilling adaptation for preliminary ventilation tests on dummy size M of 16976–2:2015, author 2021.

Fig. 22. Types of tests to verify the seal to be carried out based on the standards in which the mask fits, provided by the certifying company Falção Bauer, 2021.

| Essay                        | Methodology                  | Testing accredited by Cgcre? |
|------------------------------|------------------------------|------------------------------|
| Breathing Resistance         | ABNT NBR 13698:2011 - Item 5.7 | Yes                          |
| Penetration through NaCl filter | ABNT NBR 13698:2011 - Item 5.8 | Yes                          |

Fig. 23. Preliminary tests carried out on a size P dummy of ISO 16976–2:2015 with the couplings of the apparatus for the pressure and air volume tests, side view (a), top view (b), author 2021.
are less abrasive and very malleable and are the same materials used in masks that are available and commercialized in the market.

6. Conclusions

Regarding the designs of the two versions, there was no objection regarding comfort, especially because the part that molds to the face is identical. However, there was a preference in the design of the mask with the vertical rod and that it should be produced in TPE material (or similar material such as silicone) which was the

![Air pressure and volume parameters](image)

**Fig. 24.** Air pressure and volume parameters to be tested for sealing measurement, certifying company Falção Bauer, 2021.

| Breathing Parameters | Men | Women |
|----------------------|-----|-------|
| TV 168.6 mL          |     |       |
| MV 2,023 LPM         |     |       |
| PIP 23.5 LPM         |     |       |
| PEF 28.94 LPM        |     |       |
| BF                   |     |       |
| MAP 8.6 cmH2O        | Comp 46.2 mL/cmH2O |
| PIP 11.3 cmH2O       | O2 -2.7 % |
| PEEF 7.4 cmH2O       | Baro P mmHg |
| IPP 11.3 cmH2O       |     |       |
| Min P 7.5 cmH2O      |     |       |
| Ast P 0.0 cmH2O      |     |       |

**Table 1**

| Professions and performances | Men | Women |
|------------------------------|-----|-------|
| Doctors                      | 1   | 1     |
| Designers                    | 4   | 2     |
| Physical therapists          | 1   | 1     |
| Ergonomists (Human Factors)  | 0   | 1     |
| Students (16 years old)      | 1   | 1     |
material chosen by all as the most appropriate for the manufacture of the mask, because it was identified as a more malleable material that produces a smoother surface and, consequently, more comfortable to use.

In this way, the objective with the project was achieved, which was to develop a mask for a target audience of professionals, who, due to the nature of their work, regardless of the covid-19 pandemic or not, are in constant contact with people and need it. wear a face mask for your protection.

The professionals who can benefit from the mask are those in the medical area (doctors, nurses, attendants) and professionals in the area of commerce in general (supermarkets, shopping centers, banks, offices, stores etc).

Based on research with project professionals, the best design of the mask was version (B), which has a vertical stem on the front, and is now made with the TPE material (or similar material such as silicone) that was used in version (A), as seen in Fig. 26.

It is worth noting the inestimable importance of 3D printing models of masks. 3D printing provided the quick construction of physical models that provided the various ergonomic and design analyses, facilitating decision-making.

In addition, it facilitated the making of new prototypes from new designs that were based on the changes suggested in the tests.

The next steps should be the production of prototypes with design and material configuration, as described above, to carry out tests by certifying companies in order to assess the level of safety in relation to sealing by processes provided for in the relevant standards and tests for verification the physical and mechanical integrity of the mask structure and the materials used, which must comply with the standards.

The definitions of the normative and legal aspects, mentioned above, will be added to the development process, with a view to making production and commercialization viable, so that the benefits generated by the mask are enjoyed, not only by the health area, but also by the entire community in the fight against infectious diseases spread by aerosolized particles. Mainly to Covid-19 and Influenza A, whose viruses are circulating in our society causing so much harm to people's health and also affecting daily life and quality of life in every way.

With the production project and regulatory authorizations completed, the mask may be presented to companies interested in its production and commercialization. However, the project can evolve with the development and use of new materials and other characteristics to meet new applications of demands in environments and specific groups of users.

Data availability

Data will be made available on request.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Carlos Mauricio da Costa Ramos reports financial support, statistical analysis, and writing assistance were provided by CAPES - Coordination for the Improvement of Higher Education Personnel from Brazil. Carlos Mauricio da Costa Ramos reports financial support, article publishing charges, equipment, drugs, or supplies, statistical analysis, travel, and writing assistance were provided by
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References

[1] Cai, Mang et al. Customized design and 3D printing of face seal for an N95 Filtering Facepiece Respirator. Journal of Occupational and Environmental Hygiene, 2017. Available at: <https://doi.org/10.1080/15459624.2017.1411598>. Accessed on: 03/16/2021.

[2] Chu, Derek K. et al. Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis, The Lancet Magazine, 07/01/2020. Available at: <https://www.thelancet.com/action/showPdf?pii=S0140-6736(20)31142-9>. Accessed on: 03/17/2021.

[3] M. Gierthmuehlen, Evaluation and discussion of handmade facemasks and commercial diving-equipment as personal protection in pandemic scenarios, Plos One 15 (8) (2020), Available from: ResearchGate database. Accessed on 12/04/2020.

[4] A. Imbrie-Moore, Quadrupling the N95 supply during the COVID-19 crisis with an innovative 3D-printed mask adaptor, Healthcare 8 (3) (2020) 225, Available from: ResearchGate database. Accessed on 04/13/2020.

[5] Koehler, Richard H. A Novel Face Seal Design for Filtering Facepiece Respirators: Development and Pilot Testing In a Hospital Operating Room. Journal of the International Society for Respiratory Protection, 2015. Available at: <http://dx.doi.org/10.13140/RG.2.1.1964.1844>. Accessed on: 03/21/2021.

[6] M. Kunkel, Additive manufacturing and injection molding process for mass-production of face shields during COVID-19 pandemic: a comparative study, Res. Aquare (2020), Available at: ResearchGate database. Accessed on 04/15/2020.

[8] Mitze, T et al. Face masks reduce COVID-19 cases in Germany. Proceedings of the National Academy of Sciences of the USA (PNAS), 2020. Available at: <https://www.pnas.org/content/117/51/32293>. Accessed on: 03/21/2021.

[9] B. Oladapo, Review on 3D printing: fight against COVID-19, Mater. Chem. Phys. 258 (7) (2020), Available from: ResearchGate database. Accessed on 14/04/2020.

[10] Prather, Kimberly A. Reducing transmission of SARS-CoV-2. Science Magazine, 2020. Available at: <https://science.sciencemag.org/content/368/6498/1422>. Accessed on: 03/16/2021.Semifacial Reusable Respirator Technical Bulletin, 2018. 3M. Available at: https://multimedia.3m.com/mws/media/8283580/boletim-tecnico-respirador-3m-6000.pdf Accessed on 11/04/2020.

[11] Prather, Kimberly A. Reducing transmission of SARS-CoV-2. Science Magazine, 2020. Available at: <https://science.sciencemag.org/content/368/6498/1422>. Accessed on: 03/16/2021.Semifacial Reusable Respirator Technical Bulletin, 2018. 3M. Available at: https://multimedia.3m.com/mws/media/8283580/boletim-tecnico-respirador-3m-6000.pdf Accessed on 11/04/2020.

[12] Stutt, Richard O.J. H. A modelling framework to assess the likely effectiveness of facemasks in combination with 'lock-down' in managing the COVID-19 pandemic. The Royal Society Publishing, 10/06/2020. Available at: <https://doi.org/10.1098/rspa.2020.0376>. Accessed on: 03/15/2021.

[13] Zambini.org. ABNT NBR 13697-2010: Respiratory protection equipment- Filters for particles. ABNT NBR 13698-2011. ABNT. Available at: <https://www.zambini.org.br/pdfs/ABNT%20NBR%2013697-%202010.pdf>. Accessed on: 04/20/2021.

[15] Zambini.org. ABNT NBR 13698-2011: Respiratory protection equipment - Half-face filter piece for particles. ABNT NBR 13698-2011. ABNT. Available at: <https://www.zambini.org.br/pdfs/ABNT%20NBR%2013698-%202011.pdf>. Accessed on: 04/20/2021.