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Challenges in facemasks use and potential solutions: The case study of Kenya

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ABSTRACT

The emergence of the novel Coronavirus has forced most governments across the world to enact stringent public laws to curb its transmission among the populations. The requirement to wear a facemask whenever in public places is one of such laws. As such, the demand for such masks has escalated across the world and this predisposition has presented a manufacturing challenge to the developing countries, which have limited capacity to meet the demand for their large populations. In developing countries such as Kenya, the citizens are now required to wear facemasks when in public places such as markets, streets, shopping malls, etc.

With limited supply of the proper facemasks in the developing countries, the public is left to improvise them from the available resources. Alternatively, they purchase substandard facemasks from uncertified suppliers and sellers. The purchased masks do not meet the required health standards in most cases. In Kenya, for example, the government has been discouraging citizens from using N95 respirators and instead preserve them for medical practitioners due to their rarity and incapacity to manufacture them. The government has certified several textile industries to produce facemasks for the public from non-woven fabric materials. The challenge with such a move is that there has been an influx of an assortment of facemasks in the Kenyan market and it is not possible for the citizens to identify the safe ones. In this short communication, a brief description of the challenges facing the citizens in terms of access to and quality of face masks in developing countries, with a case study of Kenya is provided. Furthermore, a proposed design solution and a proof of concept of a low-cost and reusable 3D printed facemask for developing economies is herein presented. The adoption of such a design by the governments and manufacturers would solve the challenges of access and quality of the respirators to lower the transmissions of the Coronavirus.

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Introduction

The emergence of the Covid-19 disease has led to change in personal lifestyles and routines, public rules and regulations and government policies on health and security across all nations of the world. With the precognition that there is no cure or vaccine for the Covid-19 disease so far, prevention is the key to slow its transmission [1]. In most countries, there are restricted movements and public gatherings to curb further transmission and hence spread of the disease. In developing countries of sub-Saharan Africa such as South Africa, there has been public lockdown, where the citizens are required to strictly stay at home and only go out for shopping of essential goods such as food. In Kenya, there was the restricted movement of people in high-risk counties of Nairobi, Kilifi, Kwale, Mombasa and Mandera sometimes back although this has been since lifted [2]. Additionally, the Kenyan government has continued to implement dusk to dawn curfew (from 9 PM to 4 AM) to curb movements, social gatherings and promote social distancing [2]. In most countries, public gatherings in places such as bars, hotels and restaurants, churches, mosques and temples have been suspended. According to World Health Organization (WHO), the transmission of the Coronavirus can be minimized by ensuring high standards of hygiene, regularly washing hands with soap or using alcohol-based sanitizers and maintaining a social distance of beyond 1.5 m amongst persons [3]. It is also recommended that surfaces at work, public places and homes should be regularly disinfected to avoid transmission of the virus. To promote this course, most governments have recommended the use of facemasks by all their citizens since these masks prevent transmission of the novel virus amongst individuals in public places.

Despite adopting most of these strategies, the number of infections and deaths have continued to rise in most countries including developed ones. As such, there is a growing strain in the medical facilities (ventilators, oxygen supplies, and intensive care units), personal protective gears for medical practitioners and public preventative facilities (such as sanitizers and facemasks). Although the developed countries have existing technologies to manufacture the biomedical devices and protective facilities for their populations, they are already overwhelmed and can no longer satisfy the demand of their local markets in the wake of this pandemic [4]. Since developing countries such as Kenya largely depend on imports of these devices from the developed countries, the situation has created a large imbalance between demand and supply of medical devices and protective facilities. A case in study is the current situation of facemasks in the Kenyan market, where, traditionally, those masks are not locally manufactured. As such, innovation and development of medical devices and facemasks locally is extensively being encouraged in the country. In developed countries, availability and knowledge of advanced 3D printing technology have been shown to accelerate the development of some of the essential devices for assisting the Covid-19 patients as well as protection of the medical practitioners and the public [5,6]. The purpose of this short communication is to demonstrate the challenge facing Kenya in meeting the demand for quality facemasks with the rising prevalence of Covid-19 cases. The communication also presents a prototype of a simple 3D printing design solution of facemask, which can be adopted to produce low-cost and reusable facemasks for the Kenyan population and developing countries at large.

Challenges of facemasks in Kenya

The directive by the Government of Kenya (GoK) that every citizen must wear a non-medical face mask whenever they visit open places such as shopping malls, streets and markets has led to skyrocketing of their demand in the country's market [7]. It is reported in media that failing to wear a face mask in public places in Kenya can attract a fine of about 6000 Kenyan shillings (about 60 US dollars) [8]. The facemask should cover both the mouth and nose, meet high quality standards and should be purchased from certified manufacturers. They should be manufactured from non-woven 3-ply fabric for effective protective purposes to the users. To meet the high demand of the protective masks for her large population of over 45 million people, the GoK has certified the major textile industries such as the Rift Valley Textile Industry (RIVATEX Ltd), Kitui County Textile Center (Kikotec) Co. Ltd, etc. to manufacture non-woven facemasks [9]. Despite these efforts by the government, the supply does not meet the demand and as such, roadside tailors and unscrupulous business persons are reportedly manufacturing substandard respirators. Therefore, the country is currently faced with the challenge of access to quality protective facemasks for its large population.

The challenge has been exemplified by the 'crazy fashions' and poor quality of the masks worn by the Kenyan public (Fig. 2). For instance, some members of the public have been reported in the mainstream media wearing facemasks manufactured from women pants (www.citizentv.co.ke) [7]. It has also been reported that some dubious and criminal citizens have been washing used facemasks and reselling to the unsuspecting public in the streets of the capital, Nairobi (Fig. 1). The roadside tailors have been reported to produce the masks from normal fabric (Fig. 2) although the Kenyan Bureau of Standards (KEBS) has advised against the use of normal clothing facemasks since they cannot protect against Coronavirus transmission [9].

The poverty levels among the slum dwellers and the most vulnerable households have been cited as the main driver of the low-quality manufacturing of face masks since they cannot afford the standard or certified protective masks. The use of such uncertified masks made from low-quality fabric poses worse health challenges compared to not using the facemasks at all. Although the government and other agencies have been donating masks to these communities, it is not possible to reach everyone and the majority are left depending on the substandard, reused and unhygienic masks. Most users of the cloth-made (roadside tailors) masks reuse them without even washing them and this exposes them to high etiology of contracting other diseases besides the Covid-19 [9,10].

Fig. 1. Women washing used facemasks for resale (www.standardmedia.co.ke) [8].

Fig. 2. Different fashions of face masks manufactured from clothing fabric. It is not clear whether wearing these masks can protect against the transmission of Coronavirus [7].

The sourcing of masks online through online markets has been deemed as the safest method of acquiring them as it reduces physical contact and public interactions [11]. However, in such economies, only a small percentage of the population has trust or experience of online purchases. On the other hand, corruption has been shown to hinder successful delivery of PPE's in Kenya, for example, there were reports that donated PPEs and facemasks were illegally acquired by private investors for resale [12]. According to the media, the Germany officials said that about 6 million facemasks went missing and were

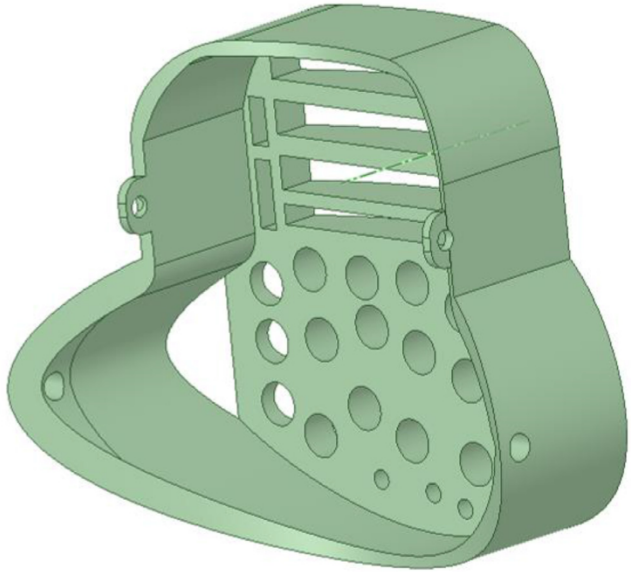

Fig. 3. Three-dimensional CAD model of the design of the reusable facemask.

allegedly stolen at an airport in Kenya. These issues hinder the effective distribution and provision of PPEs to the public and therefore local solutions through innovation are critical.

To solve the above challenges, the government and manufacturers should devise a solution, which achieves the following three important requirements.

i The facemasks should be durable and safe
ii The facemasks should be low-cost
iii The facemasks should be sterilisable, washable and reusable.

In this short communication, we have considered the above factors as the design requirements, and presented a method for manufacturing of a prototype of a 3D printed facemask.

Proposed prototype

Herein, the design of a prototype of a facemask with the following characteristics is presented.

i The prototype is easy to manufacture on a desktop (home) 3D printer as a single component.
ii It is fabricated easily on a cheap, non-heated bed and at low-temperature polylactic acid (PLA), which is a bioplastic filament.
iii It consumes a very small amount of filament material (a maximum of 53 g).
iv The mask is reusable since it is easy to wash in soap and disinfect.
v It uses small amounts of disposable non-woven fabric particularly laminated polypropylene, which the user should dispose of after every use. These fabrics are readily available in the Kenyan markets since they are used as the carrier bags and serve as an alternative to the 2017 banned plastic bags.
vi The design is based on general human anthropometrics and ergonomics and therefore everyone including children above 7 years can use it.

The computer-aided (CAD) modeling was undertaken in Spaceclaim Software (ANSYS® 2019 R2, student version obtained from https://studentcommunity.ansys.com/thread/download-ansys-19-1-1/). The design model was developed using primitive features of the modeller and the 3D CAD model as shown in Fig. 3. The sizing and dimensioning of the design were based on the various anthropometric databases [13-15]. As such, the design can be worn by most people aged between 7 and 70 years, although it has been reported in literature age is not a significant factor of the human face anthropometrics.

Proof of concept

The CAD model (Fig. 3) was exported as a Standard Tessellation Language (STL) file into the slicing software, Cura Ultimaker BV (https://ultimaker.com/software/ultimaker-cura) for print settings and generation of the toolpath. The printing settings were selected as shown in Table 1 after several trials of the process.

Table 1
3D printing parameters for the face mask.

Parameters	Description
Layer height	0.3 mm
Shell thickness	0.8
Fill density	20%
Print speed	50 mm/s
Printing temperature	210 °C
Bed temperature	Non-heated
Support type	Touching build plate
Platform adhesion type	Brim
Filament diameter	1.75 mm
Filament flow	100%
Retraction speed	40 mm/s
Initial layer line width	100%
Dual extrusion overlap	0.15 mm
Infill speed	50 mm/s
Filament material	PLA

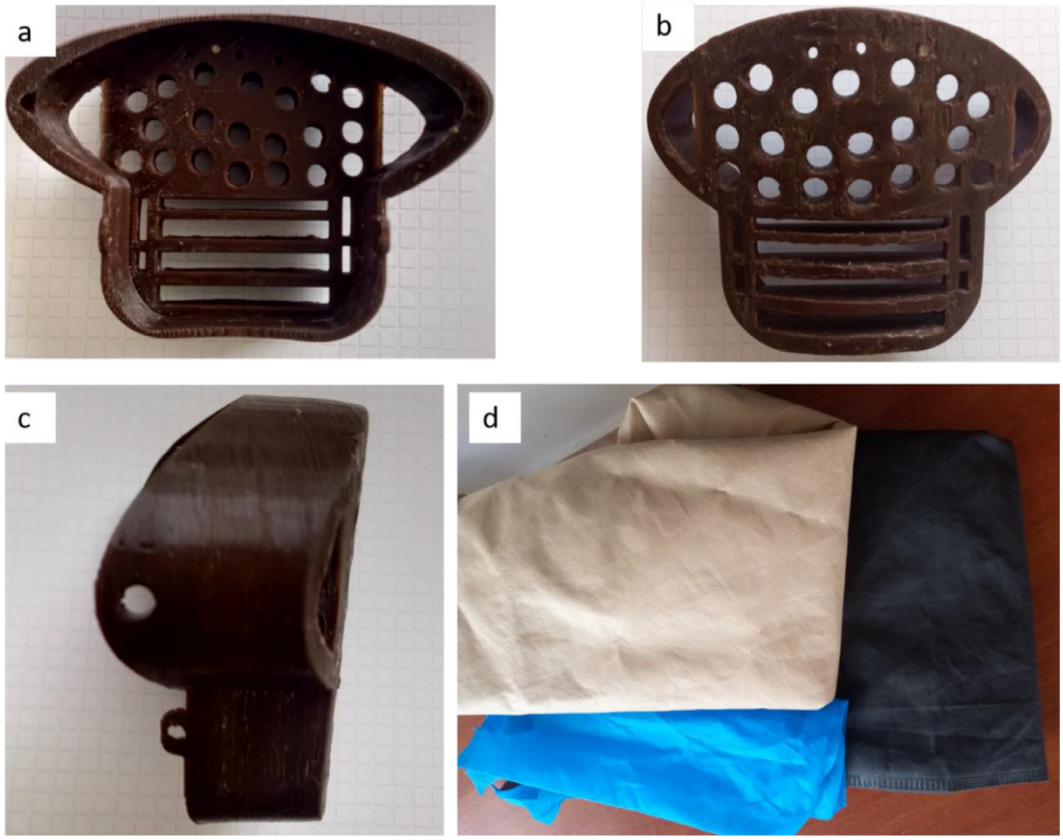

Fig. 4. Images of the 3D printed facemask taken from different directions (a) front (b) back (c) side. Examples of laminated non-woven polypropylene fabrics locally available in the Kenyan market.

The G-code files generated from the slicing software were then exported to the WANHAO Duplicator (D10) desktop 3D printer for manufacturing of the masks. The printing time for the design was about 2 h and 40 min and the printed mask was as shown in Fig. 4.

The next procedure was to prepare the laminated non-woven polypropylene fabric for the masks. The steps are illustrated in Fig. 5. The profile of the internal shape of the facemask was traced with a plain paper and then, the paper used to trace and cut-out profiles on the non-woven fabric. The fabric profiles shown in Fig. 5d should be prepared in duplicate for each mask. Additional two rectangular profiles should be cut-out and assembled as shown in Fig. 5e. Finally, two strands of about 400 mm lengths and 3 mm thick should be cut for head attachment as shown in Fig. 5f.

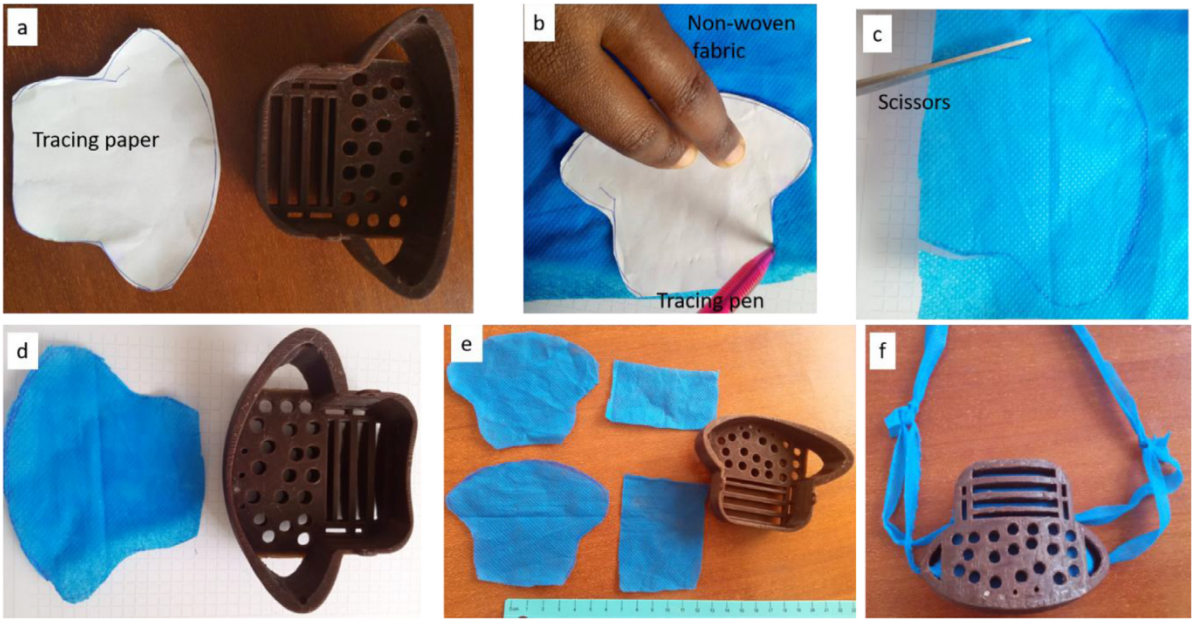

Fig. 5. Steps of preparing the fabrics for the face mask. They represent (a) a tracing paper cut into the internal dimensions of the face mask (b) trace the paper on the non-woven fabric using a tracing marker (c) cut-out the traced profile of the fabric (cut two pieces for each mask) (d) the cut-out profile of the fabric (e) additional rectangular profiles for supporting the fabric and (f) the assembled face mask ready for usage.

The manufactured or printed and fabric-assembled masks were tested for fitting on a child (8 years old), a male adult (35 years) and a female adult of 33 years of age (family of the authors and the images have been omitted for ethical purposes). The reason for using these groups of people is that they represent the most active individuals of the community in the Kenyan society. Additionally, it has been demonstrated that the face anthropometrics of human changes considerably across these groups of people [13]. It was observed that the designed face mask can fit users across different anthropometrics. Additionally, the authors and their close relatives have been using these facemasks since the government announced their mandatory use since February 2020.

The proposed 3D printed face mask exhibits the following properties (i) It is light comparable to the weight of sunglasses, 50 g, (ii) it is biocompatible since it is fabricated from PLA, which is obtained from starch, (iii) it is comfortable to use and can be adopted by users of a wide range of age groups, (iv) it allows the users to breathe freely since it has enough holes for airflow, (v) the masks are easy to clean and re-use except the disposable nonwoven polypropylene material which is readily available in the Kenyan market and (vi) it uses the non-woven polypropylene which is used in N95 respirators, which are deemed the best masks to prevent Coronavirus transmission.

Conclusion

The challenges facing developing countries in terms of access to quality public protective facemasks during the Covid-19 pandemic have been illustrated with a case study of Kenya in this short communication. The lack of manufacturing capacity and poverty levels in developing countries is the main cause of the problem. Herein, a simple prototype of reusable facemasks for the Kenyan population is presented. The facemask design can be easily produced via home, domestic and desktop 3D printers that cost less than $200 with a very small quantity of filament material (~ 58 g). The facemask was then assembled with a non-woven polypropylene fabric, which is readily available in the Kenyan market. The facemask was demonstrated to fit a male child, male and female adults. The fabric is disposable while the mask can be washed or sanitized for reuse. The governments of the developing countries can adopt the design by investing in small 3D printers, which can be distributed to various counties or communities for manufacturing of low-cost or free facemasks for their citizens during this pandemic or for the unforeseen future outbreaks.

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Available files

The STL file of the face mask is freely available for anyone to download and print their facemasks.

Declaration of Competing Interest

The authors declare no conflict of interest.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sciaf.2020.e00563.

References

[1] M.A. Shereen, S. Khan, A. Kazmi, N. Bashir, R. Siddique, COVID-19 infection: origin, transmission, and characteristics of human coronaviruses, J. Adv. Res. 24 (2020) 91–98 Jul..
[2] D. Ayega, Night Curfew Extended For 30 Days, To Start From 9 pm To 4 am, Capital News (2020) https://www.capitalfm.co.ke/news/2020/06/night-curfew-extended-for-30-days-to-start-from-9pm-to-4am/.
[3] World Health OrganizationCoronavirus Disease (COVID-19) Advice for the Public, WHO, 2020 https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public [Accessed on 27.04.2020].
[4] C. Medina Amado, C.J. Minahk, E. Cilli, R.G. Oliveira, F.G. Dupuy, Bacteriocin enterocin CRL35 is a modular peptide that induces non-bilayer states in bacterial model membranes, Biochim. Biophys. Acta - Biomembr. 1862 (2) (2020) 183135 Feb..
[5] G.R.J. Swennen, L. Pottel, P.E. Haers, Custom-made 3D-printed face masks in case of pandemic crisis situations with a lack of commercially available FFP2/3 masks, Int. J. Oral Maxillofac. Surg. (2020) 1–5 Apr..
[6] F.M. Mwema, E.T. Akinlabi, "Basics of Fused Deposition Modelling (FDM), Fused Deposition Modeling. SpringerBriefs in Applied Sciences and Technology, Springer, Cham, 2020, doi:10.1007/978-3-030-48259-6_1.
[7] J. Wachira, Murang'a county residents duped into wearing panties fashioned into facemasks, Citizen Digit. (2020) https://citizentv.co.ke/news/muranga-county-residents-duped-into-wearing-panties-fashioned-into-facemasks-329849/. [Accessed on 20.04.2020].
[8] "No 'cash bail' of KSh6,000 for not wearing mask in Nairobi CBD under Kenya's Covid-19 regulations | Africa Check." [Online]. Available: https://africacheck.org/fbcheck/no-cash-bail-of-ksh6000-for-not-wearing-mask-in-nairobi-cbd-under-kenyas-covid-19-regulations/. [Accessed: 19-July-2020] 2020.
[9] C. Soi, Kenya's coronavirus fight: factories, tailors make cloth masks, Aljazeera News (2020) https://www.aljazeera.com/news/2020/04/kenyas-coronavirus-fight-factories-tailors-cloth-masks-200417095635189.html. [Accesed on 17.04.2020].
[10] B. George, Reusable cloth masks won't prevent COVID-19, MoH and KEBS warn, Standard Digital (2020) https://www.standardmedia.co.ke/article/2001367475/reusable-cloth-masks-won-t-prevent-covid-19-kebs-and-moh-warn. [Accessed on 15.04.2020].
[11] "Jumia Heightens The Fight Against COVID-19 In Kenya, Donates Masks To Community Health Workers | CIO East Africa." [Online]. Available: https://www.cio.co.ke/jumia-protects-kenyan-health-workers-against-coronavirus-donates-facemasks-to-moh/. [Accessed: 19-Jun-2020] 2020.
[12] "Germany says six million coronavirus face masks missing in Kenya - Reuters." [Online]. Available: https://www.reuters.com/article/us-health-coronavirus-germany-masks/germany-says-six-million-coronavirus-face-masks-missing-in-kenya-idUSKBN21B1T0. [Accessed: 19-Jun-2020] 2020.
[13] W. Lee, H. Kim, D. Jung, S. Park, H. You, Ergonomic design and evaluation of a pilot oxygen mask, Proc. Hum. Factors Ergon. Soc. Annu. Meet. 57 (1) (2013) 1673–1677 Sep..
[14] W. Lee, et al., Application of massive 3D head and facial scan datasets in ergonomic head-product design, Int. J. Digit. Hum. 1 (4) (2016) 344.
[15] A. Alrashdan, A. Alkaff, S. Khamis, Head and face anthropometric measurements for Saudi Arabian females, Proc. Int. Conf. Ind. Eng. Oper. Manag. 2018 (March) (2018) 2180–2184.