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SHORT PAPER

Development of an Artificial Nose Using 3D Printing Technology for Patients with Tumors

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The authors hereby confirm that they have obtained the consent of the persons depicted in the photographs for publication.

ABSTRACT

A prosthetic nose is an option where the patient can gain an artificial organ for aesthetics. Thus, this study includes the 3D scan and reconstruction of the 3D model of an artificial nose and analyzes different material properties, which are thermoplastic polyurethane (TPU), thermoplastic elastomer (TPE), and nylon 6 (PA). This research aims to fabricate an artificial nose model using 3D printing technology. A 3D scanner can scan the human head before reconstructing the nose. The analysis of different materials on the artificial nose model is to determine the appropriate material for the artificial nose to fit perfectly into the patient's face. The artificial nose will use TPU material with a deformation value of 0.00413mm and a maximum stress value of 0.4930 MPa. This prosthesis nose enables people to interact in their social and family lives, making them happier and more comfortable.

KEYWORDS

artificial nose, stress distribution, finite element analysis, skin cancer, 3D printing technology

1 INTRODUCTION

1.1 Skin cancer

Skin cancer is a condition that develops from the uncontrollable growth of abnormal cells in the epidermis, an outer surface of the skin layer, caused by skin exposure to the sun. It can cause death to the patient if the cancer is not controlled. The most common are three primary skin cancers: basal cell carcinoma (BCC), squamous cell carcinoma (SCC), and melanoma. BCC and SCC can be developed or appear on the head, face, neck, shoulder, and other body parts where the area is sun exposed [1]. Patients with skin cancer, SCC, on the nose not only have tough challenges to manage but also have to deal with the removal of that cancer, which affects every feature of their face [2]. Skin cancer surgery has significantly affected the patient's face, with a big hole in the middle of the face and no nose [3]. Maxillofacial prostheses can generally be categorized as therapeutic or complementary. Reparative prostheses

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replace bone loss or facial contour deformity repair [4]. An esthetic and satisfied maxillofacial prosthesis helps to reduce many of the patient's concerns and improves their quality of life without the surgical risks [5]. The prosthesis nose can be developed by 3D scanning the human head and 3D printing the reconstructed prosthesis nose to fabricate it.

1.2 Artificial nose

Typically, the nose, ear, oculopalpebral, auricular, skullcap, and traqueostomal can be classified as facial prostheses. The prosthesis also exists to regenerate the patient's appearance and improve self-esteem and quality of life. These are artificially reconstructed soft or hard tissues that had previously been lost. An esthetically satisfying facial prosthesis will mimic and replicate the missing shape, size, place, texture, clarity, and color to ensure that the prosthesis is almost barely noticeable to the viewer.

1.3 3D printing technology

Three-dimensional printing is a process additive that makes it possible to create three-dimensional solid objects of virtually any form from a 3D model file. The 3D models can be created or extracted from 3D scanners using computer-aided design (CAD) software to capture images and distance information from natural objects and then pass the data to a computer. The application of 3D printing technologies has become more and more common in many fields [5]. 3D volunteer face scanning was performed with a commercial scanner at a distance range from the model, which is 45cm to 200cm. To capture a 3D image before sending it to the free CAD software for generating the final 3D model. The 3D scanner was panned 360° around the individual's head, allowing the evaluation of the resolution of the different 3D printing technologies. 3D printing is a technique for developing a 3D tactile digital model using three-dimensional CAD data sources. Based on the type of production method used, it is also known as rapid prototyping, solid-free structure, software-controlled, or layered production. The basis of rapid prototyping is to use 3D computer models to visualize a 3D digital model by adding layers of material [6]. The system reads information from a CAD model for additive manufacturing and lays down successive layers of material while making up the model from a sequence of cross-sections.

These layers, which relate to the virtual cross-section of the CAD model join together to form the final shape. Fused deposition modelling (FDM) is one of the styles of 3D printing. FDM is the least expensive option in terms of maintenance, print, and start-up prices [7]. It is not only for many applications, such as designs and models, but also for the practical part of medical applications. The main advantage of additive manufacturing is its ability to create any complicated form or geometric characteristics. The term "rapid" needs to be used comparatively: constructing a model using conventional methods can take hours to days.

In contrast, additive processes for rapid prototyping will usually generate models in a short period of time. The actual construction time depends on the typical approach used, the scale, and the difficulty of the design. The model could be customized to suit the patient exactly, or, in other words, customer-specific. Upon the construction of the nose based on three different materials (thermoplastic polyurethane (TPU), thermoplastic elastomer (TPE), and nylon 6 (PA), the nose model is then imported to

Finite Element Analysis software to analyze the artificial nose at different material properties. It gives the user more ease. The benefit of this technology is that it could be developed anywhere in the world simultaneously, as the 3D printer is available, so people living in rural areas can quickly get their facial prostheses without going to the doctor. This study aims to reconstruct the nose and involves 3D printing the reconstructed artificial nose according to the patient's condition.

2 METHODOLOGY

2.1 Development of a 3D model of an artificial nose

The 3D scanning of the patient's head or face is needed to reconstruct the nose (see Figure 1a). The model will then be imported into a 3D Builder to reconstruct the nose of the model (see Figure 1b). Usually, all the models were in STL format before being converted to CAD format, which is the format in Parasolid, Step, and IGES.

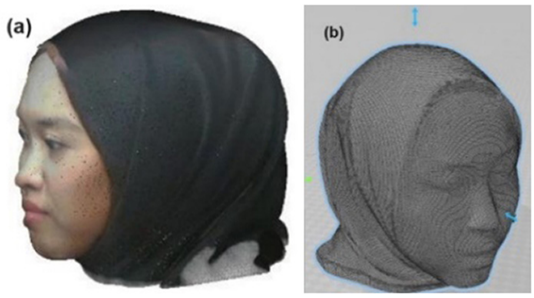

Fig. 1. 3D design process (a) 3D scanning human head using Sense 3D scanner (b) 3D scanned human head imported into 3D Builder software

2.2 Finite element analysis

The design will then be analyzed using Computer-Aided Engineering (CAE) software. The design will undergo only one finite element analysis, the static analysis. The central part that will be used for the analysis is the tip of the nose, which is the most critical part of the prostheses nose as it is the most vulnerable. The materials used are TPU, TPE, and nylon 6 (PA) polyamide 6.

The materials are needed to set up according to Table 1 [8–11]. The number of elements meshing is 2269. The static analysis setting is to withstand a load of 0.51kg [12], which is 5N, on the prostheses, as shown in Figure 2. The loading weight was chosen since it caused a realistic and clinically significant displacement of the nasal tip [12]. The analysis determines the von Mises stress and deformation for different material settings, thus determining the best setting for the fabrication process.

Table 1. Material properties for 3D printed parts [8–11]

Material	Density (Kg/M3)	Young's Modulus (MPa)	Poisson Ratio (MPa)
TPU	1240	2410	0.3897
TPE	960	900	0.4100
Nylon	1.14	493	0.3900

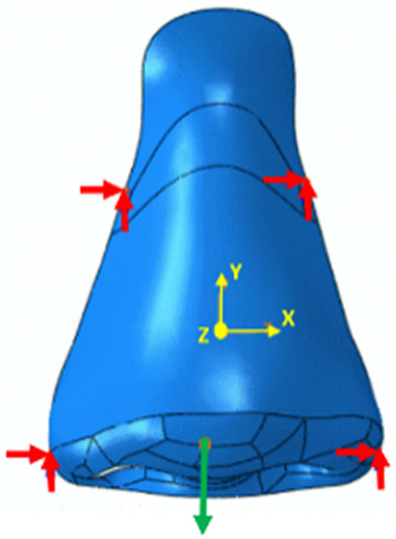

Fig. 2. Static analysis setting; placement of support, placement of 0.51kg load

2.3 Fabrication of 3D model

The best setting for an artificial nose model design will then be exported as a stereolithography (STL) file to slicing software, Flashforge, to generate G-code for a 3D printer. The 3D printer will then read the G-code to print it into a 3D model. The human head without a nose model is also reconstructed a few times to get the proper design. The model depicted in Figure 3 is 3D printed using a polylactic acid (PLA) filament. The best setting for the design will then be exported as an STL file to the slicing software Ultimaker Cura to generate G-code for the 3D printer.

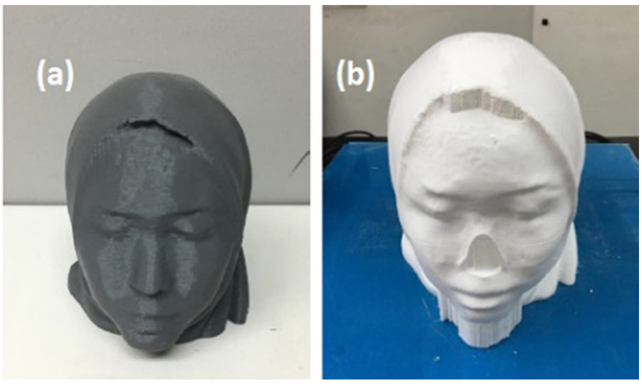

Fig. 3. 3D printed (a) full human head model and (b) human head without nose model

3 RESULTS AND DISCUSSION

3.1 3D scanning and reconstruction of the 3D model

Using the 3D scanning of a human head, the nose reconstruction can be done as shown in Figure 4. The reconstruction was done in 3D Builder software in the STL file. An artificial nose must be reconstructed based on the patient's satisfaction and fit exactly to the area on the face that can give comfort to the patient.

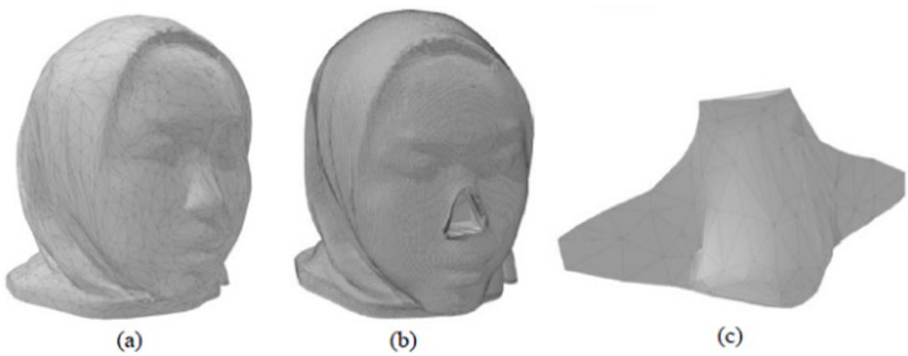

Fig. 4. (a) Human head model after converted into CAD format (b) human head without nose model after reconstruction (c) human nose after reconstruction

3.2 Effect of materials properties of artificial nose

In static analysis, the material employed for the artificial nose will be altered as the manipulated variable in response to both the von Mises stress and the static deformation of the artificial nose.

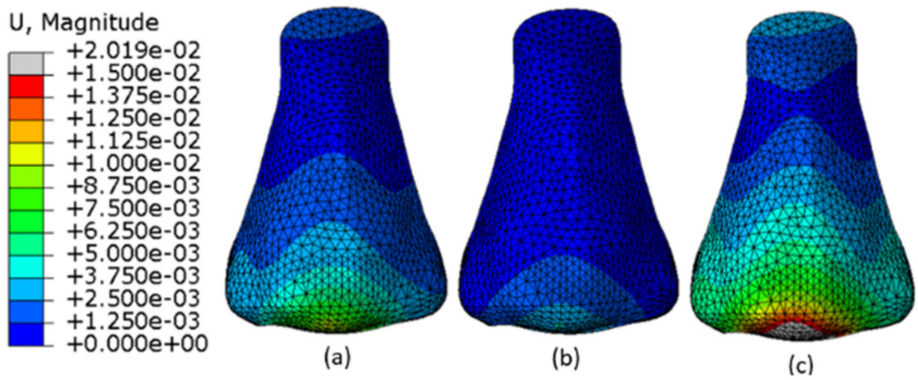

Fig. 5. Deformation on different materials: (a) TPE, (b) TPU, and (c) nylon

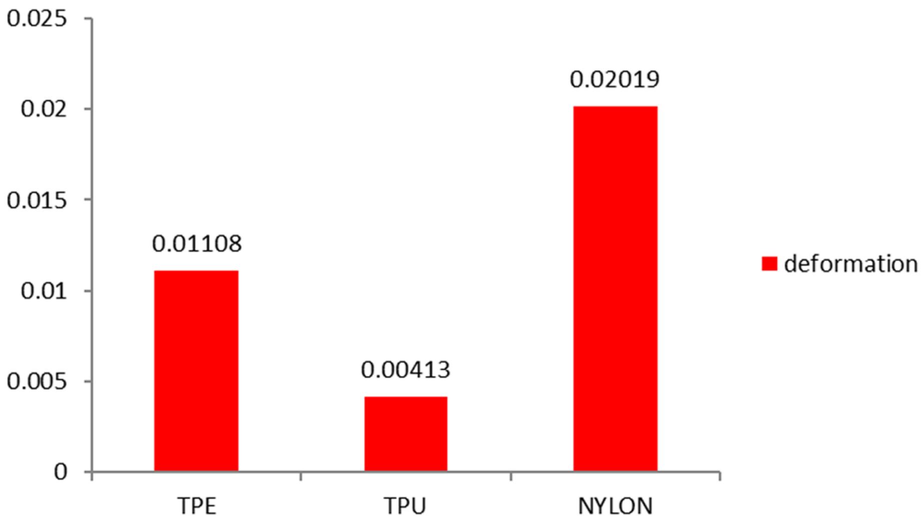

Fig. 6. Comparison of deformation between TPU, TPE, and nylon

The TPE, TPU, and nylon deformations are 0.01108mm, 0.00413mm, and 0.02019mm, respectively. The comparison of deformation between TPU, TPE, and nylon is shown in Figure 6. The results showed that the material with the minimum deformation is TPU, which is 0.00413mm.

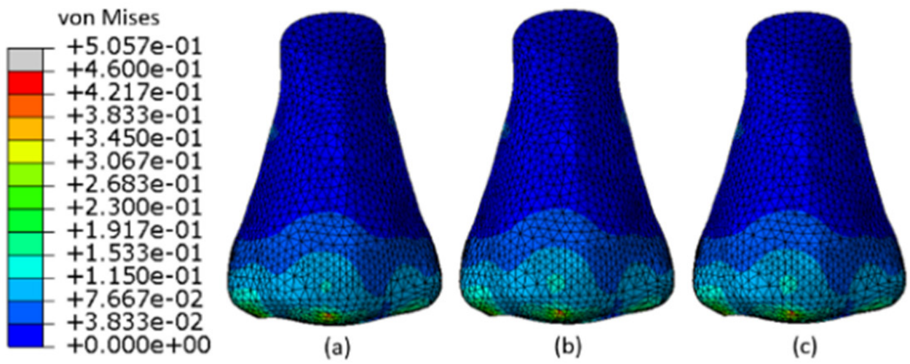

Fig. 7. von-Mises stress on different materials: (a) TPE, (b) TPU, and (c) nylon

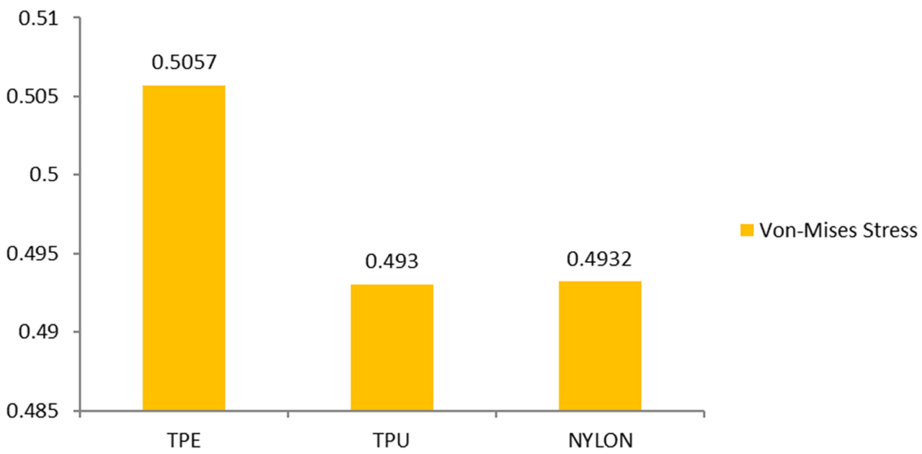

Fig. 8. Comparison of von Mises stress on (a) TPE, (b) TPU, and (c) nylon

The result in Figure 8 shows the von Mises stress for the TPE, TPU, and nylon, which 0.5057 MPa, 0.4930 MPa, and 0.4932 Mpa, respectively. Based on the results from Figures 5 and 7, the appropriate material is TPU, because despite having the lowest value of maximum stress and deformation value compared with TPE and nylon. Low distortion is essential for user comfort because the artificial nose will touch skin or tissue directly. High deformation may cause pain and skin rashes.

3.3 3D printed model of the artificial nose

The design of the artificial nose was reconstructed to fit the respective patient. The fabrication of the artificial nose model is shown in Figure 9 using different materials. In the fabricated nose model, the suitable material can naturally fit the patient's face. All materials can be fabricated, but only one of the materials, TPU material, was suitable for this artificial based on the results obtained in the analysis.

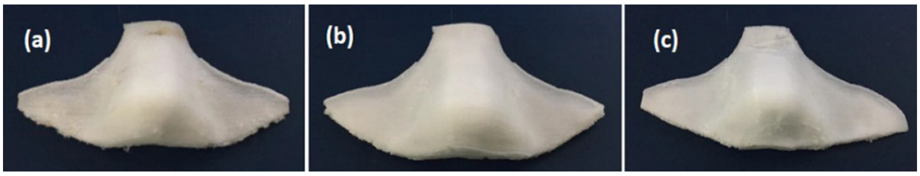

Fig. 9. The 3D printed artificial nose for different materials: (a) nylon, (b) TPE, and (c) TPU

4 CONCLUSION

In conclusion, the artificial nose was successfully printed. All the objectives were achieved, such as using a 3D scanner to scan the human head and then importing the human head model into 3D Builder software to reconstruct its nose into the desired design. By analyzing the artificial nose using different material properties such as TPU, TPE, and nylon, the suitable material is TPU, which has the lowest von Mises stress and deformation, with values of 0.4930 MPa and 0.00413mm. After that, the reconstructed model was printed using the 3D printer based on the setting of each material used. The project can be improved by doing further research on every flexible filament material so that the best result can be obtained. The study would also open up more possibilities for implementing 3D printing technology in the medical field, not only in the engineering field.

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6 REFERENCES

[1] S. Kraft and S. R. Granter, "Molecular pathology of skin neoplasms of the head and neck," *Arch. Pathol. Lab. Med.*, vol. 138, no. 6, pp. 759–787, 2014. https://doi.org/10.5858/arpa.2013-0157-RA

[2] C. Ricotti, N. Bouzari, A. Agadi, and C. J. Cockerell, "Malignant skin neoplasms," *Med. Clin. North Am.*, vol. 93, no. 6, pp. 1241–1264, 2009. https://doi.org/10.1016/j.mcna.2009.08.011

[3] EMBODI3D, "Man's cancer eaten face receives donated 3D printed face from son," 2015. website: https://www.embodi3d.com/blogs/entry/155-man%E2%80%99s-cancer-eaten-face-receives-donated-3d-printed-face-from-son/. [Accessed 12.04.22].

[4] F. P. de Caxias, D. M. dos Santos, L. C. Bannwart, C. L. de Moraes Melo Neto, and M. C. Goiato, "Classification, history, and future prospects of maxillofacial prosthesis," *Int. J. Dent.*, vol. 2019, pp. 1–7, 2019. https://doi.org/10.1155/2019/8657619

[5] N. Ariani *et al.*, "Microbial biofilms on silicone facial prostheses," *Biofouling*, vol. 28, no. 6, pp. 583–91, 2012. https://pubmed.ncbi.nlm.nih.gov/22703052/

[6] D. Radenkovic, A. Solouk, and A. Seifalian, "Personalized development of human organs using 3D printing technology," *Med. Hypotheses*, vol. 87, pp. 30–33, 2016. https://doi.org/10.1016/j.mehy.2015.12.017

[7] A. M. Abdullah, D. Mohamad, T. N. D. T. Din, S. Yahya, H. M. Akil, and Z. A. Rajion, "Fabrication of nasal prosthesis utilising an affordable 3D printer," *Int. J. Adv. Manuf. Technol.*, vol. 100, pp. 1907–1912, 2019. https://doi.org/10.1007/s00170-018-2831-y

[8] Y. Le Tan, C. H. Huang, Z. X. Guo, and J. Yu, "Morphology and mechanical properties of polyamide 6/polystyrene blends prepared by diffusion and subsequent polymerization of styrene in polyamide 6 pellets," Materials (*Basel*), vol. 11, no. 5, p. 776, 2018. https://doi.org/10.3390/ma11050776

[9] A. Zolfagharian, M. R. Khosravani, and A. Kaynak, "Fracture resistance analysis of 3D-printed polymers," *Polymers*, vol. 12, no. 2, p. 302, 2020. https://doi.org/10.3390/polym12020302

[10] N. Sabyrov, Z. Sotsial, A. Abilgaziyev, D. Adair, and M. H. Ali, "Design of a flexible neck orthosis on fused deposition modeling printer for rehabilitation on regular usage," *Procedia Computer Science*, 2021, vol. 179, pp. 63–71. https://doi.org/10.1016/j.procs.2020.12.009

[11] H. Lee, R. I. Eom, and Y. Lee, "Evaluation of the mechanical properties of porous thermoplastic polyurethane obtained by 3D printing for protective gear," *Advances in Materials Science and Engineering*, vol. 2019, pp. 1–10, 2019. https://doi.org/10.1155/2019/5838361

[12] C. T. Manuel, R. Harb, A. Badran, D. Ho, and B. J. Wong, "Finite element model and validation of nasal tip deformation," *HHH Public Access*, vol. 176, pp. 139–148, 2017.

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