AN EDUCATIONAL APPLICATION OF 3D PRINTING TECHNIQUE USED FOR INSOLE PRODUCTION

Hasan Kemal SURMEN
Department of Automotive Technology, Vocational School of Technical Sciences, Istanbul University

Faruk ORTES
Department of Mechanical Engineering, Faculty of Engineering, Istanbul University

Yunus Ziya ARSLAN
Department of Mechanical Engineering, Faculty of Engineering, Istanbul University

ABSTRACT: In this study, it was implemented a biomechanical application of 3D printing technique for insole production. Basically, in terms of the arch height, there are three foot types including high, normal and flat arch. Moreover, if the alignment of the foot is taken into account, foot types can be classified as neutral, supinated and pronated foot. Each foot class has different shape and foot size. An insole is a device that is placed into the shoes to provide comfort and to correct the alignment of the lower limbs. Design of the insoles could be implemented according to specific foot geometry of subjects. These kinds of insoles are called generally as customized insole and have total-contact characteristics. Total-contact insoles are effective in reducing pain as distributing the pressure and improving the foot function. To produce a total-contact insole, the geometric data of foot plate surface should be known. In order to carry out this task, molding process is widely performed. Advances in scanning technology enable insole designers to obtain 3D CAD (three-dimensional computer-aided-design) model which represents the shape and dimensional data of an object. The model, namely, solid model could be imported to various commercial or educational software and be modified for special purposes. Therefore, molding process is discarded and molding cost is prevented with the method of 3D scan. Many 3D scan devices exist to obtain 3D data that may require high cost for an insole device. Thus, people even not having engineering background could obtain 3D foot model using various free available image capturing programs integrated in a mobile phone. In this educational application, it is aimed to manufacture a customized full-contact insole by means of a 3D printer and a 3D scan mobile application. The scanning software, which combines the photos of the object captured from the different angles, was used to obtain 3D CAD data of the geometrical shape of the foot in this study. Then, the data was imported as a model to a CAD software and modified for a subject shoe. Next, the model was converted into STL file format and imported to a 3D printer device. Finally, the solid model of the insole was printed and placed into the shoe. By taking advantage of new facilities of technological improvements, subject specific insoles could be designed and manufactured. These kinds of educational applications regarding 3D scanning and printing technologies have the potential to increase the prevalence of use of custom made biomechanical instruments which are developed to increase the quality of daily life of human being.

Key words: Insole design, scientific education, 3D printer

INTRODUCTION

Insoles are devices inserted into shoes to support feet and to absorb shock effect in a comfortable manner. The insole is a device to reduce some difficulties due to the defects causing from human foot shapes such as presented in Table 1. Furthermore, the insoles, known generally as custom insoles, should be designed and manufactured according to foot shape and biomechanical needs of individuals. There are many studies investigating the design and effect of insoles [1, 4]. A mold of the foot sole is taken and insole is produced considering this mold geometric shape in the conventional method of the custom made insole manufacturing. Thus, the insole exactly fits to the surface of the foot. A custom made insole has total contact characteristic that reduces the pain and distributes the pressure. Also custom insoles can be modified considering some kind of deformities such as varus/valgus, and, in this way, can improve the posture by supporting the foot in a neutral position. Moreover, complaints such as hip, knee and lower back pains caused by poor foot function could be reduced using custom insoles restoring the natural foot function.

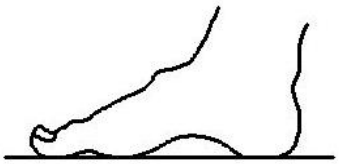
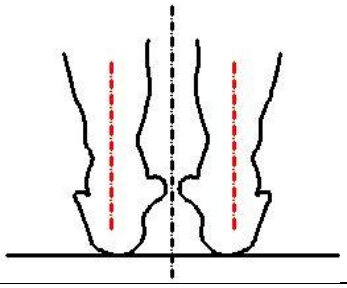
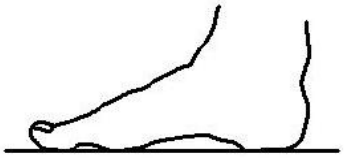
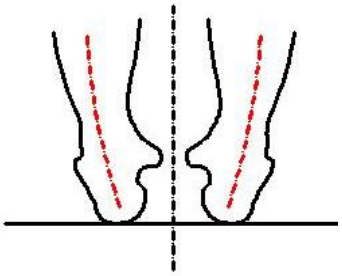
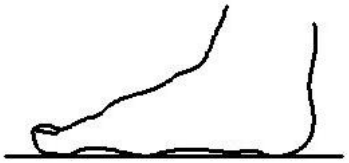
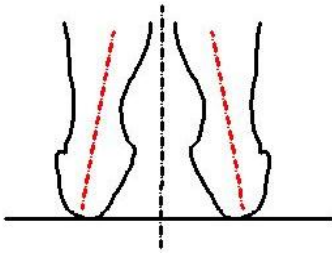
Arc Height		Alignment		Contact Zone
High		Neutral		
Normal		Supinated		
Flat		Pronated		

Figure 1. Human Foot Structures and Contact Zones

With the advancements in 3D printer technology, it is possible to easily and quickly produce the solid objects from 3D CAD data. Comparing with the traditional manufacturing methods, 3D printers that use various additive manufacturing methods lead to shorter and more efficient production especially for the manufacture prototypes and custom-made objects. 3D printer technology has been used for manufacturing the orthotic devices in some novel studies [6]. The insoles designed in a CAD software could be also manufactured by a 3D printer. The customized CAD model of an insole can be derived from a CAD model of the foot sole of an individual. The CAD model of foot sole can be captured by scanning the surface of person foot sole geometry with a 3D scanner system. In this application study, an open source and android based "123D catch" software, which is a free mobile application, was used to capture the 3D scan data of the foot sole. In this method, insoles are produced without the molding procedure and insole model can be modified before manufacturing.

3D printing technology, which is a prominent tool for the last decades, enables to print 3D models of any real objects specifically for customized molds and prototype products [5, 7]. The design and production industry of custom insoles has been highly affected by the advances of 3D printing technology. This method, which is time, labor, cost and source saving, is performed using different kinds of materials such as PLA (Polylactic Acid) and ABS (Acrylonitrile Butadiene Styrene). The method is also known FDM (Fused Deposition Modeling) that implies a production technique employing a moving nozzle that is heated to melt and extrude the material. It builds the objects layer by layer and sustain precise surfaces.

In this study, in order to improve the teaching methods for novel technologies with educational concerns, a subject specific customized mold insole was designed and produced. The study represents an educational application which includes the main steps of insole design and production using up-to date technologies so that people and especially students could adopt to latest developments.

METHODS

This application study involves a series of steps which are critical for production of custom made insoles that is aimed to improve the poor gait and the posture of people. As a starting step, in order to obtain 3-D geometrical data of the subject foot, a series of photos were taken using mobile phone which operates Autodesk 123D Catch open-source software. The photos should be taken in an angle interval of 0 and 360 degrees so that one tour around the object was needed to be completed. The software required a time duration about 60 minutes to process the photos. The model constituted by the software could include some defects originated from environment in which photos or foot were taken. It is necessary to perform a cleaning operation to discard these undesirable defects. The operation could be achieved using various open-source softwares but, in this study, Autodesk Meshmixer which is also open-source software was used to carry out this task. The modified foot sole is still a rough surface. The smoothness operation was performed to refine the surface quality and this step was also implemented using Meshmixer software tool, as well. The outer surface of foot sole and the inner surface of the designed insole should have the same topology to sustain a good adaptation and to satisfy the subject specifity.

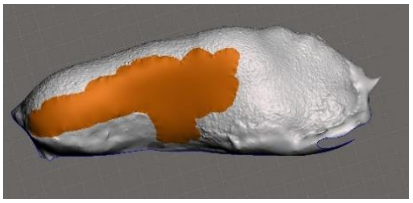
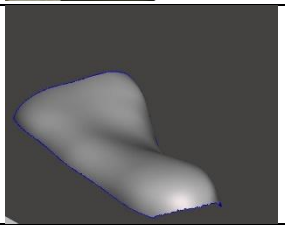
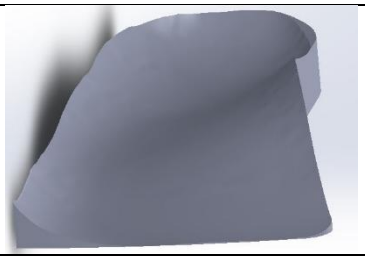
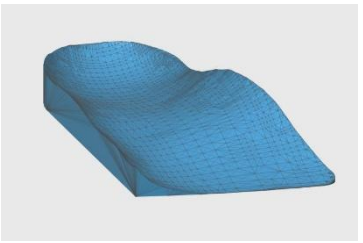
TASK	PROCESS	OUTPUT
TAKING PHOTOS		
CLEANING & SURFACE OPERATIONS		
SOLID BODY OPERATIONS		

Figure 2. Processes and outputs of design steps

In order to obtain the same shape of foot for insole, 123D Design, which is a reverse engineering and also open-source software was used. The output of this step is still a surface in stereolithography (stl) file and must be transformed to a CAD file in order to perform required solid body operations. The surface of the insole which has the same topology with the foot surface, then, converted to a solid body using a conventional solid body modelling program.

After a series of operation, including fillet, radius, extrusion and cutting, the model was ready to print. Aforementioned design steps are shown in *Fig 2*. Manufacturing of the insole model was carried out using a 3D printer device, which is namely Ultimate 2 Extended and based on fused deposition modeling technique. Printing is the last stage of whole process. Schematic representation of work flow is given in the *Fig. 3*.

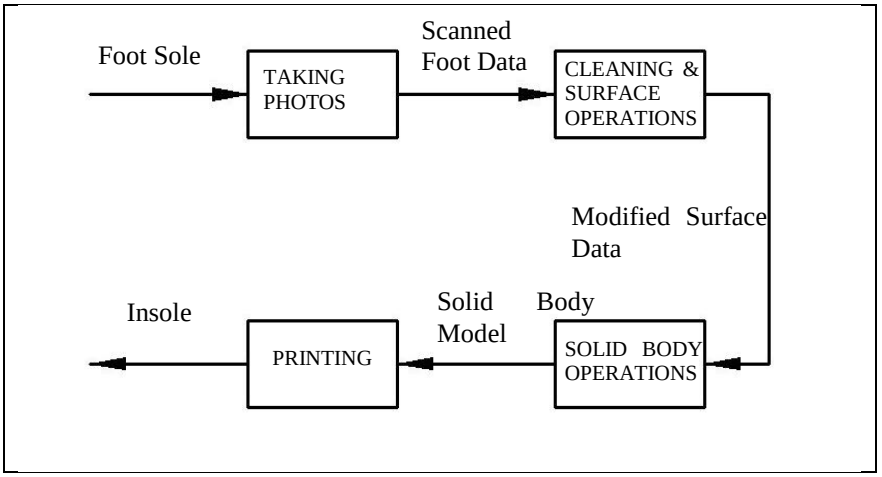


Figure 3. Schematic representation of work flow

The PLA material was fed to the 3D printing device in our laboratory which is extensively used for biomechanical purposes. Produced insole model is shown in Fig. 4.

Figure 4. Fresh insole model after printing process

RESULTS AND DISCUSSION

In this paper, the procedures for design of subject-specific insoles were discussed and the production of insoles by taking the advantages of 3D printing technology was evaluated. Design and manufacturing processes were completed in accordance with the functional requirements such as total contact, customizable, labor and cost effective and easily producible. In addition, the produced insole has shown a good match to the foot surface of the subject. Since adaptation of foot sole to insole surface is critical for comfort in posture and gait, an appropriate match is a crucial result for the study. Moreover, it was also shown that improvements in science and technology would provide effective solutions on production processes of subject specific designs and products.

The study also shows that from stl to CAD part, there are numerous steps must be carefully done using open-source and commercial softwares. The actual geometry of foot could be reflected in the computer model by benefiting from capabilities of those programs.

Additive materials technology has been utilized in the study and it is clearly experienced that this kind of technology is prominent and also promising for biomechanical and educational purposes.

CONCLUSION

This study was undertaken to design and produce a subject-specific insole and to evaluate the benefits of 3D printing technology. Returning to the question posed at the beginning of this study, it is now possible to state that the improvement of science and technology could provide effective solutions on production processes of subject specific designs and products. This study present the main steps in a sequence for design and manufacture of insoles.

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