

Manufacture and Useful Evaluation of Educational Mammography Phantom

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Abstract

Background/Objectives: The purpose of this study is to manufacture a new phantom in variety material and evaluate its usefulness.

Methods/Statistical analysis: Based on the modeling, pectoralis major muscles and mammary glands were printed; in order to express the soft material of the breast, we used the molding method. The assessment was conducted by 3 radiographers who have been in real clinical settings for more than five years.

Findings: The mammary gland tissue and pectoralis major muscles were printed using the SLA method and Polyjet method. At this time, the spheres with a diameter of 1 cm were printed and located at both sides of the mammary gland to test the degree of compression, which is the essential part of mammography and contributed to the phantom for a higher quality of education.

Improvements/Applications: After accessing the manufactured phantom at the clinical level, all of the evaluators concluded that the phantom may be applied for education.

Keywords: *Phantom, Education, Mammography, Manufacture, 3D printer*

Introduction

With an increase in the interest in women's cancers among the public, there is also a rising importance in the early diagnosis of breast cancer. Therefore women are regularly receiving mammograms, leading to a steady increase in the number of mammogram screening cases. A growing desire for a healthy life has triggered an increase in awareness and needs for screening for early detection of breast cancer. In accordance with this trend in Korea, the national health screening center has designated a mammogram as one of the essential tests and is recommended for those over 40 years old.

The most important thing in mammography is the fact that the use of radiation for medical purposes carries both significant medical benefits and the risk of radiation exposure; hence, improper care can lead to fatal side effects

for the patients [1-4]. For this reason, radiographers should refrain from having the patients retake a mammogram and exposing them to unnecessary radiation. It is also advisable that radiographers are fully trained in mammography and improve their practice skills before performing mammography in a real clinical setting.

Mammography is the most optimized test for early detection and diagnosis of breast cancer. Mammography is performed on symptomatic or asymptomatic women through basic examinations with the Cranio-Caudal and Mediolateral-Oblique (MLO) directions [5-9]. Therefore, radiographers should be fully aware of all screening methods for mammography and practice for a variety of patients in advance.

The main purpose of screening mammography is to detect any symptoms of diseases in advance by minutely screening the shape and size of breast masses, mammary gland expansion, and calcification. It can possibly detect lesions, but high-quality images with an appropriate amount of radiation are still required.

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During mammography, breast compression is applied using a compression paddle, which is to compress breasts to a film and reduce breast thickness, resulting in a decline in exposure to radiation while improving image quality [10]. As patients have different shapes and sizes of breasts, it is necessary for radiographers to practice on various types of breasts.

However, less than half of medical schools in Korea do not have a regular mammography curriculum for radiology majoring students. Even if a few does have one, practice is not being carried out properly. The reason is that breasts are a private part of the human body, and there are few phantoms available for practice. Mammography phantoms made in Japan are expensive and lose their shape after several practices. Moreover, it does not show parenchymal tissues in the breasts, and thus, radiographers cannot judge whether they are screening the object in a right position. Therefore, most of the current radiographers strive for mammography practice and training.

3D printers, which has been on the rise these days, have the advantages of reducing time for producing, customized manufacturing and saving the costs for producing, etc [11]. It makes a product from various materials by various methods according to a modeled design map [12]. In the case of breasts, as it is impossible to use hard materials, mammography phantoms should be manufactured with different or new materials. In a prior study, a phantom was manufactured with soft materials which led to a discovery of a transparent material which enables the internal structure to be identified. Therefore the purpose of this study is to manufacture a new phantom in this material and evaluate its usefulness. 3D printer technology has lately been utilized for various purposes, and in particular, it is actively used in the healthcare industry, which leads in a need of a variety of materials[13-14].

Materials and Method

1. Modeling

As seen in Figure 1, the breast images used in this study were based on MRI DICOM Volume data and obtained by 0.1 mm Volume Scanning from GE Signa HDxt 3.0T(GE Healthcare, Milwaukee, WI, USA) device. The obtained images were edited on TeraRecon, a 3D program in order to convert the file format into STL format. STLView (Module Works GmbH) was used to separate and obtain modelling of different structures. Through mesh tools provided by Rhinoceros (McNeel North America, USA), mammary gland, canal, and pectoralis major muscles were edited using a modeling

structure to distinguish more stably and clearly. The pectoralis minor muscle when modeled for the first time was manufactured without any differentiation from pectoralis major muscles and modeling was processed with pectoralis major muscle as the main object.

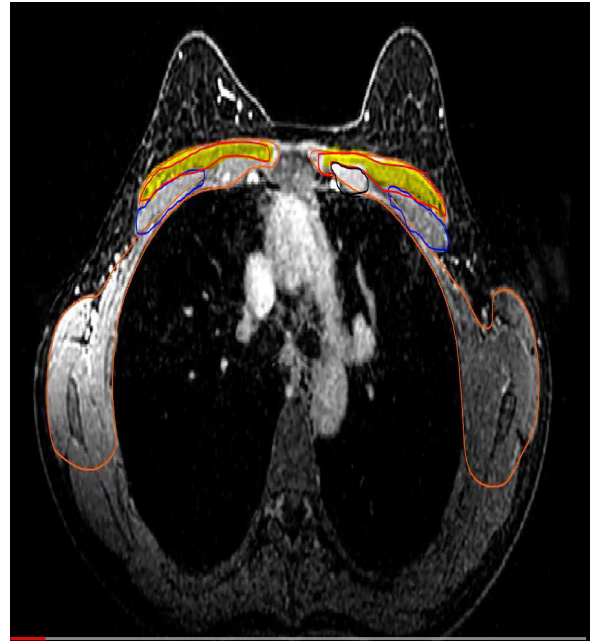


Figure 1. MRI DICOM file for breast, duct, muscle modeling
2. 3D Printing

Based on the modeling, pectoralis major muscles and mammary glands were printed; in order to express the soft material of the breast, we used the molding method. The molding method is to model and print the outer surface of the breast and fill the inside with silicone, which needs to be done carefully to prevent air bubbles. In addition, as seen in Figure 2, after mammography, contrast agents were mixed and printed to identify pectoralis major muscles and mammary glands in the images. Spheres of 1 cm in diameter were also printed to see how much compression has been applied when screening.



Figure 2. Made by mixing the colorant / contrast agent (barium) with silicone

The printer resources used for each printing are as follows:

In order to manufacture breasts using the molding method, when printing the outer surface of the breast, Projet660, a CJP (ColorJet Printing) printer, was used, which is an additive manufacturing technology involving two components – core and binder. It took 4 hours in total, and the printer material used was VisiJet PXL, which is like plaster.

Pectoralis major muscles, as show in Figure 3, were manufactured using Form 2 SLA (Stereolithography) and took 6 hours in total. Clear resin was used as printing materials.

Mammary glands were manufactured using Object 500 Connex 3 in the PolyJet method, which uses UV cured acrylic resins, and it took 2 hours. The spherical prints which enable radiographers to see the degree of compression were manufactured using a sponge material, and they were also printed by using the same method.



Figure 3. 3D printer model Form2 by SLA method

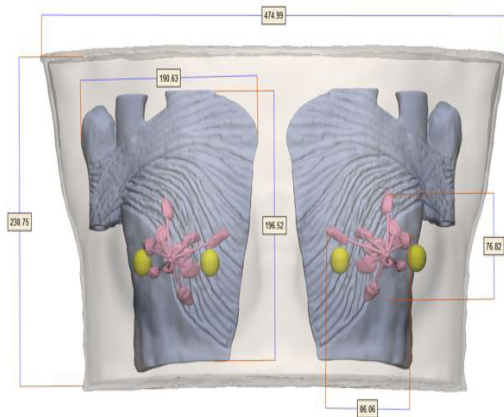
3. Useful evaluation

To assess the usefulness of mammography training phantom manufactured using a 3D printer, various assessments were conducted with mammography device currently used in hospitals. The following were assessed: whether pectoralis major muscle and mammary glands are clearly distinguished from each other in mammogram images; whether they show the appropriate concentration; whether the spheres were useful to check the degree of compression; and whether the quality of the materials were similar to actual breasts during mammography. The assessment was conducted by 3 radiographers who have been in real clinical settings for more than five years.

Results

1. Modeling

As seen in Figure 4, the modeling was based on MRI dicom images where the breast was scanned in 1 mm. The light gray colored outer surface of the breast was modeled by 474.99 x 238.75 mm in size, and the dark gray colored pectoralis major muscles were modeled by 190.63 x 196.52 mm in size. The pink colored mammary glands were modeled by 86.06 x 76.82 mm in size whereas the spheres for checking the degree of compression were colored in yellow and modeled by 10 mm in size.



(a)



(b)

Figure 4. (a) Frontal view of modeling and size of intramammary mammary gland and pectoral muscle and compression check circular sphere. (b) Lateral view of modeling and size of intramammary mammary gland and pectoral muscle and compression check circular sphere

As seen in Figure 4, the front and back sizes of the surface of the breast was modeled by 348.22 mm and those of mammary glands were modeled by 62.57 mm. the spheres for checking the degree of compression were placed in parallel to both ends of the mammary tissue so that they do not interfere with the breast image.

2. 3D Printing

As seen in Figure 5, the phantom was manufactured using silicone in the molding method to enhance the reality of parenchyma of the breast. To achieve this, the outer surface of the breast was modeled and printed for 14 hours in the additive manufacturing method and made it 2 cm thick to support the weight of silicone. The silicone was poured and hardened several times

in order to prevent air bubbles. The amount of silicone was readily controlled to be hardened while regulating the location of each component, and this was done repeatedly as this must be done at the final stage and all the tissues, pectoralis major muscles, mammary glands, and the spheres for checking compression should be placed inside the breast tissue.



(a)



(b)



(c)

Figure 5. (a) In order to produce a molding method by printing the outside of the breast. (b) Pectoral muscle of breast printed by SLA method. (C) Mammary gland tissue of breast printed by Polyjet method

As seen in Figure 5, the pectoralis major muscles in the breast were printed in the SLA method, which took 6 hours. To enhance the reality of the muscle, the comp pattern was modeled and printed at its top. Two were printed to place each on the left and right sides, and to reflect the end of the muscle as being adjacent to the humerus according to bone anatomy, the part of the bone was modeled and printed.

As seen in Figure 5, the mammary glands in the breast were printed for 2 hours in the Polyjet method using UV cured acrylic resins. To express the mammary tissue, the duct connecting the acini to the nipple was printed together, and as it may fall back during

mammography, each tip of the nipple and the duct were tied and fixed using a thread. Also, a colorant was used to produce a red color in order to visually identify the mammary gland tissue in the breast.

3. Useful evaluation

In order to assess the usefulness of the mammography training phantom manufactured by a 3d printer, a mammogram was taken using a mammography device currently used in hospitals. As seen in Figure 6, the results showed that pectoralis major muscles and mammary glands were distinguished from each other with showing adequate concentrations. Also, the spheres manufactured to check the appropriate degree of compression were pressed along with the breast when screening and it showed that there is an appropriate degree of compression when the phantoms were pressed up to the red borders from the quality control assessment. These were assessed by the 3 radiographers with more than five years of experience, and they all had the same opinions.

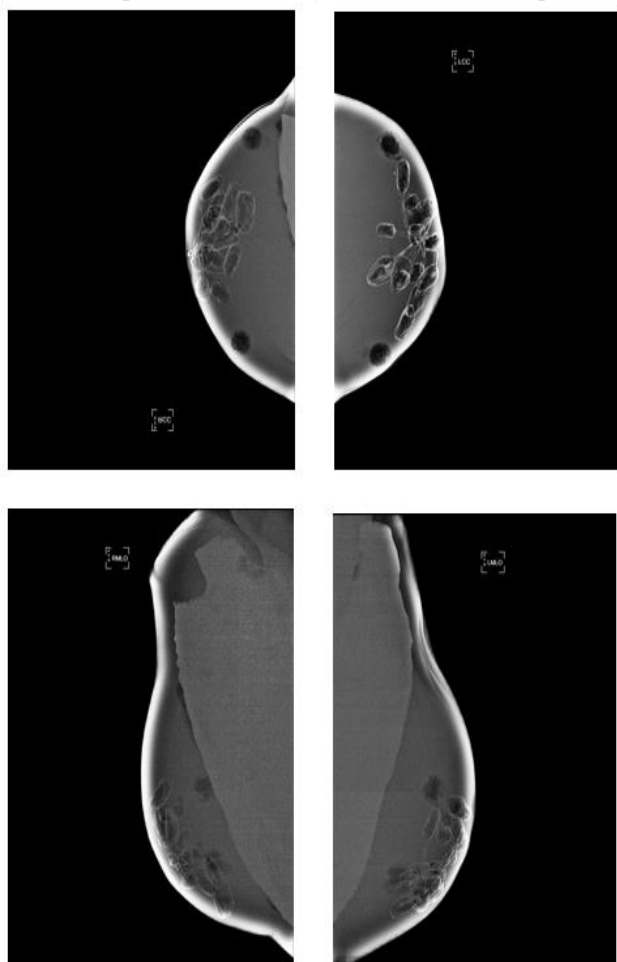


Figure 6. Radiographic image of 3D printed educational mammography phantom

Discussion

Mammography is a structure that must be represented in the image in Cranio-Caudal and Medio-Lateral views, but it must be practiced continuously using anatomically separated phantoms to express it. To achieve this, 3D modeling was implemented by retrieving MRI images to completely separate mammary gland, ductal and pectoral muscle tissue and to apply techniques to express them on radiographic images [15].

In a previous study, we developed a 3D printer system for the production of customized bone models of surgical patients based on open source [16]. Although the usefulness has been proved to be used in making a human bone model as described above, the usefulness of a soft material such as fat of breast is not proven.

In the previous study, we studied the materials and design for making phantom for mammography education. It is expected to contribute greatly to future research and education [17].

Conclusion

A mammography training phantom was manufactured using a 3D printer. The inside of the breast was filled with silicone and manufactured by the molding method in order to express the soft material of the breast. The mammary gland tissue and pectoralis major muscles were printed using the SLA method and Polyjet method. At this time, the spheres with a diameter of 1 cm were printed and located at both sides of the mammary gland to test the degree of compression, which is the essential part of mammography and contributed to the phantom for a higher quality of education. After accessing the manufactured phantom at the clinical level, all of the evaluators concluded that the phantom may be applied for education.

Ethical Clearance: Not required

Source of Funding: This work was supported by the National Research Foundation of Korea (NRF) grant (No. NRF-2017R1C1B5017119) funded by the Korea government (MSIP).

Conflict of Interest: Nil

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