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<원저>

Reduction of Exposure Dose of Mammography by Comparison of Compression Paddle Material

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압박대 재질 비교를 통한 유방촬영의 피폭선량 감소 방안

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Abstract This study compared the radiation transmission and image quality of polymethylmethacrylate (PMMA), polycarbonate (PC), and carbon, which are common components of the compression plates currently used during breast imaging. In addition to measuring the transmitted dose and the intensity without the use of a compression paddle, the four different compression paddles were evaluated according to the material and thickness of each paddle. Radiation transmittance, maximum intensity, and plot profile type were all evaluated for each material, and for each factor evaluated the following order was noted, from best to worst: carbon 4 mm, PMMA 3 mm, PMMA 4 mm, and PC 4 mm. It is necessary to study a variety of materials and thicknesses in order to find the optimal combination of material and thickness, because not only does the material have a large influence in reducing the radiation exposure during mammography, but the thickness of the compression plate also has a great influence.

Key Words: Mammography, Intensity, Exposure Dose, Image Analysis, Compression Paddle
중심 단어: 유방촬영, 신호, 피폭선량, 영상분석, 압박대

Ⅰ. Introduction

Breast cancer is the second most common cancer diagnosed in women, with the highest incidence being reported among women in their 40s [1]. Breast cancer in particular requires an early diagnosis because it can present without symptoms, and distant metastasis may have already occurred by the time of diagnosis. Early diagnosis is achieved through regular health check-ups, particularly through regular screening mammograms, which are performed as an essential test for cancer screening in women age 40 and older [2].

Mammogram views are commonly performed on both the left and right breasts, in craniocaudal (CC) and mediolateral oblique (MLO) orientations [3]. Patients receive a total of four radiation exposures minimum, and the potential effects of radiation exposure must be considered.

In 2003, the International Commission on Radiological Protection (ICRP) recommended the measurement of radiation doses to patients during mammography, as the United States and the United Kingdom were already measuring (Diagnostic Reference Level). The ICRP therefore recommended abroad that the average

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glandular dose (AGD) be set to 3 mGy or less at 4.2 cm (50% fat and 50% mammary tissue) breast thickness. On the other hand, in Korea, the Ministry of Food and Drug Safety (MFDS), which is surveyed nationwide, suggests that the average radiation dose received by a patient during mammography is 1.16 mGy [4].

In other countries, radiation exposure related to mammography has increases, and since specific radiation techniques provide optimal resolution and contrast with minimal exposure, indiscriminate exposure may cause pathological disease in patients [5–6].

Breast compression, which is essential for mammography, plays a big role in not only reducing the dose of radiation to the breast by reducing the breast thickness but also in achieving high resolution and contrast images.

Conventional plates are 3 – 4 mm thick plastics, which provide good radiation transmittance. However, previous studies have assessed more than 10 plastics, and there is a wide difference in radiation transmittance among them [7]. In addition to carbon, other carbon-based materials show an extremely high radiation transmittance, thus it is necessary to consider the breast compression plate in an effort to reduce the radiation dose. Therefore, this study evaluated the radiation transmission and the image quality differences based on a comparison of the existing compression plates used for mammography.

Ⅱ. METHODS and MATERIALS

1. Equipment

A digital X-ray mammography machine (Alpha ST, GE, Germany) was used, and the target/filter combination was Mo/Mo〈Fig. 1〉.

The compression plates used were polymethylmethacrylate (PMMA) 3 mm, PMMA 4 mm, polycarbonate (PC) 4 mm, and carbon 4 mm, and the semiconductor dosimeter (Xi Prestige, Unfors, Sweden) was regularly calibrated in July 2019 to measure the radiation dose and image quality of each material. Evaluation of the acquired images was performed by using ImageJ, a digital image analysis program provided by the National Institute of Health (NIH).

Fig. 1. Computeriaed imaging reference systems(CIRS) phantom and mammography for analyzed the radiation transmission

2. Methods

In order to reproduce clinical conditions comparable to those used during breast imaging, a 4.5 cm American College of Radiography (ACR) phantom, used for image quality control, was placed in the center of the breast support and the compression band was then pressed onto the phantom.

In order to reproduce the same intensity, the four compression plates were measured three times each at the same location with the same technique to calculate an average value.

Images of the radiographic dose and intensity measurements for each compression exposure were obtained as digital image communicated of medicine (DICOM) and joint picture export group (JPEG) file images for analysis in the ImageJ program 〈Fig. 2〉. For each image, a plot profile was obtained from ImageJ for comparison.

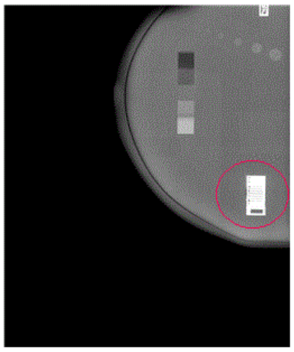

Fig. 2. Computeriaed imaging reference systems(CIRS) phatom image for intensity evaluation(red)

Ⅲ. Results

1. Radiolucency

In order to compare the radiopacity and the semipermeable layer based on the composition of the compression plates, the experiment was conducted using the same exposure technique of 28 kVp and 80 mAs. This technique is the result of exposing the ACR phantom using the automated exposure control (AEC), and was therefore selected in manual mode to maintain constant conditions for the experiment.

In order to have a base dose calculated without a compression plate, the plate was removed and the dosimeter was measured, providing a dose of 8.353 mGy. The dose measured for each material was as follows: PMMA 3 mm − 6.608 mGy, PMMA 4 mm − 6.608 mGy, PC 4 mm − 4.925 mGy, and carbon 4 mm − 7.218 mGy.

Comparing the radiation transmittance, PMMA 3 mm allowed about transmission 79%, while PMMA 4 mm allowed 69%, PC 4 mm allowed 59%, and carbon 4 mm allowed 86%, with carbon being the highest, followed by PMMA 3 mm, PMMA 4 mm, then and PC 4 mm 〈Table 1〉.

Table 1. Comparison of radiolucency and radiation dose values with and without compression plates

Paddle	Radiolucency (mGy)	Penetration ratio (%)
NO-PADDLE	8.353	100
PMMA 3 mm	6.608	79
PMMA 4 mm	5.772	69
PC 4 mm	4.925	59
Carbon 4 mm	7.218	86

2. Image quality evaluation

After confirming the intensity measurement point in the JPEG file, the images acquired were compared according to the compression plate material, and the same area of the DICOM file for each material was compared using the plot profile of each material in ImageJ.

The test of bar pattern stage consisted of 13 stages, and up to 13 different stages could be distinguished. Carbon 4 mm was most clearly distinguished by the material profile of each press bar, and in the order of PMMA 3 mm, PMMA 4 mm, PC 4 mm, the profile was clearly distinguished 〈Figure 3〉.

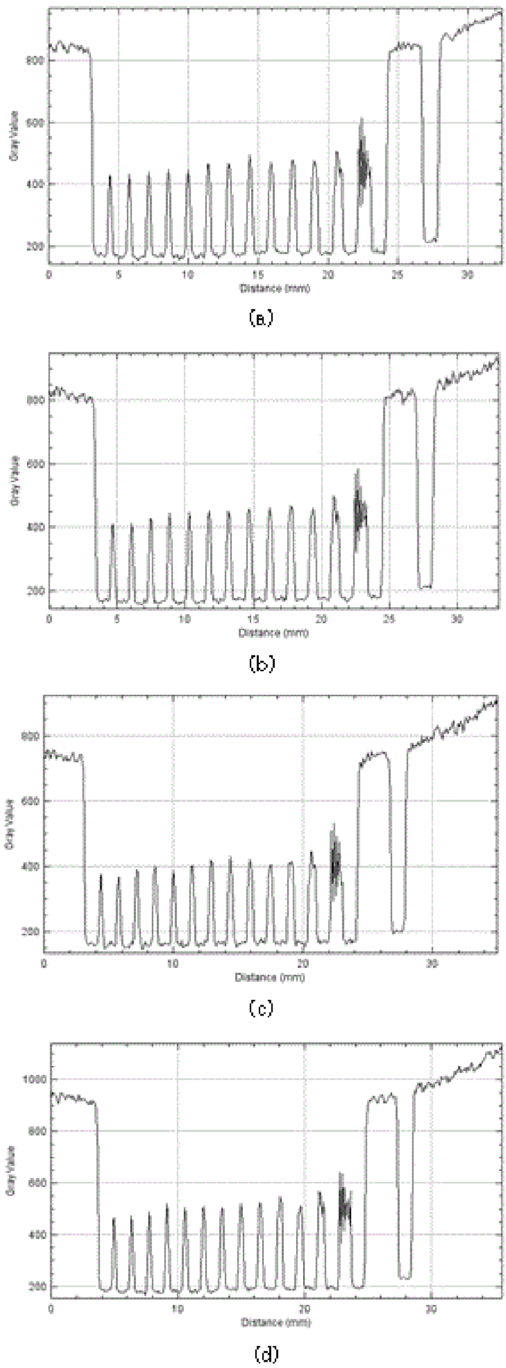

Fig. 3. Plot profile by compression paddle material when measuring intensity. (a) PMMA 3 mm (b) PMMA 4 mm (c) PC 4 mm (d) Carbon 4 mm

As a result of analyzing the intensity for maximum penetration strength at each step, the values of carbon 4 mm – 466.841, PMMA 3 mm – 426.904, PMMA 4 mm – 409.872, and PC 4 mm – 375.352 were found in the lowest step (1); for the middle step (7): carbon 4 mm – 506.397, PMMA 3 mm – 465.617, PMMA 4 mm – 448.410, and PC 4 mm – 418.458; and for the last step (13): carbon 4 mm – 640.365, PMMA 3 mm – 613.583, PMMA 4 mm – 582.718, and PC 4 mm – 530.283. 〈Table 2〉

Table 2. Maximum penetration strength by compression paddle material when measuring intensity for bar pattern test

Level	PMMA 3 mm	PMMA 4 mm	PC 4 mm	Carbon 4 mm
1	426.904	409.872	376.532	466.841
2	431.878	411.513	368.218	472.849
3	439.574	428.821	389.235	488.365
4	448.574	443.051	400.203	518.079
5	443.757	446.436	387.213	505.111
6	464.748	452.026	401.587	509.175
7	465.617	448.410	418.458	506.397
8	492.983	444.077	427.123	517.833
9	469.730	460.000	419.789	526.00
10	477.287	467.538	405.000	547.571
11	474.817	460.308	416.146	511.294
12	504.322	496.154	445.645	568.286
13	613.583	582.718	530.283	640.365

Ⅳ. Discussion

Breast cancer is on the rise, and detection rates are also rising due to an increase in the number early cancer screenings being performed. However, frequent tests also increase the likelihood that a patient will be exposed to radiation, and should therefore be tested with a minimal dose of radiation to minimize exposure [9–10].

The compression plates used in mammography are composed of various materials. In particular, many plastics with a high radiation transmittance are used. Among them, PMMA and PC are most commonly used. Because the radiation transmittance of carbon is close to 90%, images can be obtained with minimal attenuation resulting from the compression plate [10–11]. However, the radiation transmission rate of carbon compression plates, which are carbon-based rather than plastic, is very high, and it is considered to have a great effect on reducing the exposure dose if it is used in the actual pressure zone.

In a previous study, the average radiation dose was expected to increase with the thickness of the pressure rod, and the experiment was conducted with different rod thicknesses. The highest dose was reported in the thickest (2.72 mm) pressure rod [12–13]. This means that compressing the breast reduces the exposure dose, but due to the thickness of the pressure rod, the radiation dose might be increased to provide adequate imaging of the breast.

In the same study, the radiation transmittance of the 2.4 mm thick PC rod was 73%, but the transmission decreased significantly to 59% as the thickness of the rod was increased to 4.0 mm [14–17].

It was found that carbon materials can produce better image quality while reducing exposure when compared to PMMA and PC as used in clinical practice. It was also found that the compression plate thickness as well as the material composition have a great influence on the transmitted radiation dose and image quality.

Ⅴ. Conclusion

This study compared the radiation dose and image quality of PMMA, PC, and carbon, which are common components of the compression plates used during breast imaging.

In addition to measuring the transmitted radiation dose and the intensity without the use of a compression plate, the four different compression plates were evaluated according to the material and thickness of each plate. The results are as follows:

First, the dosimeter was measured without the use of a compression plate, measuring 8.353 mGy and the doses for each material were measured as follows: PMMA 3 mm - 6.608 mGy, PMMA 4 mm - 6.608 mGy, PC 4 mm - 4.925 mGy, and carbon 4 mm - 7.218 mGy.

Second, the radiolucency was measured for each compression plate, with carbon 4 mm being the most transmissible, followed by PMMA 3 mm, PMMA 4 mm, and then PC 4 mm.

Lastly, the maximum intensity was measured in the following order: carbon 4 mm, PMMA 3 mm, PMMA 4 mm, and PC 4 mm in the first, seventh, and 13 steps.

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