

A Study on the Compression Paddle Materials to Reduce Exposure during Mammography

Dong-Hee Hong¹, Hong-Ryang Jung^{2*}, Cheong-Hwan Lim², Jun-Gu Choi¹ and Gha-Jung Kim¹

¹Department of Radiology Science, Far East University, Eumseong-gun - 369-700, Chungcheongbuk-do, Korea; hansound2@hanmail.net

²Department of Radiology Science, Hanseo University, Seosan-si, Chungcheongnam-do - 356-706, Korea; hrjung@hanseo.ac.kr

Abstract

During mammography, it is necessary to press the breast with a compression paddle to increase the concentration and contrast of images and to obtain images with high diagnostic value by using reduced exposure dose. This study is related with the compression paddle that is used for the evaluation of materials in terms of the values of radiolucency, and each pixel in existing polycarbonate, plastic series was compared by using Image J. The radiolucency dose of compression paddle material was measured as 8.552m Gy after removing the compression paddle; and the value for the materials was 6.308 mGy for PC, 5.766 m Gy for PET, 6.488 m Gy for Nylon-6, 7.067 m Gy for LLDPE, 7.174 m Gy for LDPE, 7.147 m Gy for Block-PP, 7.207 m Gy for Homo-PP, 7.140 m Gy for HDPE, 7.181 m Gy for CO-PP, and 5.550 m Gy for Acetal. The pixel value of the dose that passed each material was 975.795 after removing compression paddle without radiation attenuation by using Image J; and the pixel value for each material was 829.104 for PC, 794.679 for PET, 844.857 for Nylon-6, 891.851 for LLDPE, 888.347 for LDPE, 889.081 for Block-PP, 892.62 for Homo-PP, 887.416 for HDPE, 890.228 for CO-PP, and 780.324 for Acetal.

Keywords: Breast, Compression Paddle, Mammography, Material

1. Introduction

Due to the increase in Breast Cancer, there has been an increase in the use of mammography¹. Therefore, when obtaining an image of the breast, the amount of exposure of the breast is important, and attempts are made to obtain maximum image quality with minimum exposure. Breast compression when taking a picture causes pain to the patients but increases the image quality by approximating the film and breast. Also, because the thickness of the breast decreases, the clarity of the image decreases and by redistributing the breast tissue it shows delicate structure anatomically². Therefore, the application of pressure to the breast became mandatory. It uses low energy than other imaging techniques; hence, the quality of the

material used for pressure application cannot influence the penetrating power of radiation. Also, the thickness of the compression paddle material increases the amount of radiation which the patients do not need such a high dose. Therefore, compression of the breast to obtain the image is the mandatory requirement for assessing the quality of the material for compression paddle. Presently, the most appropriate material is Polycarbonate (PC) which is widely used clinically, and it is heat resistant, weatherproof, self-digestible, and transparent, which is a type of plastic³.

Plastics are also called synthetic and are divided into thermosetting and thermoplastic. Thermosetting plastics include PS, PE, PP, PA, POM, PVC, PC, and PMMA, and thermoplastics include PE, EP, MF, PDAP, UF, and SI⁴.

* Author for correspondence

PC is the most commonly used material for compression paddle. It is a thermosetting plastic that is clear and amorphous. Other crystalline plastics are unclear but they are similar to PC or better than PC in strength and have gross penetrability. In this study, we attempt to compare these materials with PC and suggest new material.

2. Materials and Methods

2.1 Materials

2.1.1 Equipments

We compared the quality of image and radiolucency of amorphous plastic PC and crystalline plastic PET, Nylon-6, LLDPE, LDPE, Block-PP, Homo-PP, HDPE, CO-PP, and Acetal.

We used digital X-ray mammography (Alpha ST, GE and Germany). The Target/Filter combination of the equipment was Mo/Mo, and we used the FOV 18x24 cm CR (Computed Radiography) type Figure 1.

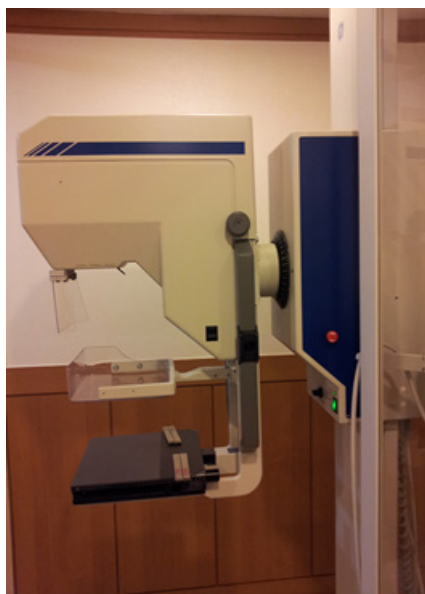


Figure 1. CR mammography device.

2.1.2 Dosimetry

To measure the amount of radiolucency, we used a semiconductor dosimeter (Xi prestige, Unfors, Sweden) that was used for a regular check up 2014. 7 is shown in Figure 2.

To evaluate each factor as similar as possible to the first time, we used the ACR phantom and to minimize

the amount of distraction, we placed a lead plate that has a hole measuring 4.5 cm and we measured it in Figure 2.



Figure 2. Unfors Xi dosimetry and Pb plate.

2.2 Methods

2.2.1 Evaluation of Exposure and Beam Quality

For obtaining the same condition as clinical breast filming, we placed the ACR phantom on the nipple area with a compression paddle. Then, we exposed it in the AEC mode 3 times having a perfect condition and used is as the measuring condition. The kVp and mAs that we obtained from here were acquired 3 times each in the same position and the average was calculated. We limited the quality of the material of the compression paddle to same as the clinical paddle which was 2 cm, and during radiation exposure, each material was placed in the middle of the ACR phantom and the radiation dosimeter was placed in the middle of the nipple area while taking measurements shown in Figure 3.

2.2.2 Evaluation of Image Quality by Image

To compare the quality of each image, we analyzed the DICOM file image that was acquired while measuring transmission in Image J. We performed the measurement of pixels 3 times and then calculated the average. To choose the ROI position in the DICOM file, we used the JPG file image. First, by placing ROI in the position where there was no artifact lesion inside the ACR phantom in the JPG file image, and by copying the ROI position and placing it in the DICOM file image J in Figure 4.

3. Results

3.1 Evaluation of Exposure and Beam Quality

To compare the quality of the breast compression paddle material according to the radiolucency and half- value



Figure 3. Measurement procedure for the 10 materials. Radiolucency measurement and acquisition of raw images.



Figure 4. ACR phantom images for measurement of mean value of pixels by image j. Processed image and raw image.

layer, we performed the experiment under the same condition which is 28 kVp and 80 mAs. This was the result of AEC condition having the ACR phantom, and to perform the experiment under the same condition, we performed done it manually.

To determine the only value without using the paddle, we performed the measurement without using the paddle and obtained the result of 8.552mGy, and according to the quality of the material, the values were measured as 6.308 mGy for PC, 5.766mGy for PET, 6.488 mGyfor Nylon-6,

7.067 mGy for LLDPE, 7.174 mGy for LDPE, 7.147 mGy for Block-PP, 7.207 mGy for Homo-PP, 7.140 mGy for HDPE, 7.181 mGy for CO-PP, and 5.550 mGy for Acetal. The materials showed high radiolucency in the order of Homo-PP, CO-PP, LDPE, Block-PP, HDPE, LLDPE, Nylon-6, PC, PET, and Acetal.

With respect to the half-value layer, it was measured as 0.375 mm Al for PC, 0.388mm Al for PET, 0.371mm Al for Nylon-6, 0.368mm Al for LLDPE, 0.359mm Al for LDPE, 0.360mm Al for Block-PP, 0.360mm Al for Homo-PP, 0.360

mmAl for HDPE, 0.360 mmAl for CO-PP, and 0.394mmAl for Acetal, and the materials had high radiation quality in the order of Homo-PP, CO-PP, LDPE, Block-PP, HDPE, LLDPE, Nylon-6, PC, PET and Acetal (Table 1).

Table 1. Comparison of radiolucency dose value among the 10 materials

Materials	Radiolucency(mGy)	HVL(mmAl)
No-PADDLE	8.552	0.344
PC	6.308	0.375
PET	5.766	0.388
Nylon-6	6.488	0.371
LLDPE	7.067	0.368
LDPE	7.174	0.359
BLOCK-PP	7.147	0.360
HOMO-PP	7.207	0.360
HDPE	7.140	0.360
CO-PP	7.181	0.360
Acetal	5.550	0.394

3.2 Evaluation of Image Quality by Image J

After checking every JPEG file that was obtained from each different material, and checking the position where there was no artifactual lesion within the ACR phantom, we analyzed the pixel average of radiolucency amount of each material by Image J in the same area as the DICOM file.

Table 2. Comparison with mean pixel value among 10 materials

Materials	Min	Max	Mean±SD
No-PADDLE	939	1015	975.795±11.361
PC	803	859	829.104±10.504
PET	761	837	794.679±10.449
Nylon-6	814	877	844.857±10.214
LLDPE	857	926	891.851±10.976
LDPE	848	924	888.347±10.781
BLOCK-PP	855	924	889.081±10.484
HOMO-PP	856	935	892.620±10.894
HDPE	855	927	887.416±10.857
CO-PP	852	930	890.228±11.044
Acetal	749	814	780.324±10.214

The image that was taken without the paddle and no attenuation was 975.795, the pixel value for each material was 829.104 for PC, 794.679 PET, 844.857 for Nylon-6, 891.851 for LLDPE, 888.347 for LDPE, 889.081 for Block-PP, 892.62 for Homo-PP, 887.416 for HDPE, 890.228 for CO-PP, and 780.324 for Acetal, and they were in the order

of Homo-PP, LLDPE, CO-PP, Block-PP, LDPE, HDPE, Nylon-6, PC, PET, and Acetal (Table 2).

3.3 Statistical Significance Test

For the evaluation of radiation penetrability according to the material of compression paddle, we used the SPSS (ver.22, Chicago, IL, U.S.A.) Program. The analysis for the material was performed using ANOVA which is the equivalent of the Kruskal-Wallis test, and the result was statistically significant ($\chi^2 = 16.596$, $p=0.005$), (Table 3).

Table 3. Kruskal-Wallis test for statistical analysis

Materials	Mean	X2	P-Value
No-PADDLE	8.552	16.596	0.005
PC	6.308		
PET	5.766		
Nylon-6	6.488		
LLDPE	7.067		
LDPE	7.174		
BLOCK-PP	7.147		
HOMO-PP	7.207		
HDPE	7.140		
CO-PP	7.181		
Acetal	5.550		

** Post-analysis showed a significant difference $p = 0.009$.

4. Discussion

The compression paddle material that is normally used is PC. This is the material that is used instead of acrylic, which has high strength and does not transform easily. Also, because it has 90% light penetration ability, the use of this material is accompanied by a high expectation of reduction in the exposure dose. However, because of the development of technology, many materials, which are better than PC in strength and light penetration, are being developed^{5,6}. Therefore, in this research, we performed the measurement of the quality of the image and the amount of the radiolucency of the currently used materials for compression paddle which include PC and other plastic types.

Hourdakis CJ and others used 3 ionization chambers and 4 solid-state detectors to assess the usefulness of dosimetry. Based on that study, Unfors Xi, a solid-state detector which showed energy dependence of $\pm 2\%$ and was found to be useful, was also used in this research⁷.

Bengt Hemdal thought that because of the forward-back scattered radiation from the compression paddle, the average glandular dose to the breast will increase,

and they performed the experiment with 2 different compression paddles. The study showed that the paddle which was the thickest (2.72 cm) emitted the maximum forward-back scattered radiation⁸⁻¹⁰. This indicates that because the paddle presses the breast, it decreases the thickness of the breast and helps to decrease the exposure dose, but because of the thickness of the paddle itself, scattered radiation occurs and the radiolucency decreases and increases the exposure dose to the breast. Also, due to the Compton effect and the photoelectric effect caused by the atom number in the paddle material, the absorbed dose for the paddle will differ and the lower is the absorbed dose, it will help form a breast image^{11,12}.

In this research, we compared and evaluated the amount of radiolucency of the clear PC and unclear plastics which include PET, Nylon-6, LLDPE, LDPE, Block-PP, Homo-PP, HDPE, CO-PP, and Acetal. As a result, compared to the PC which is used currently, radiation penetrability of Homo-PP, LLDPE, CO-PP, Block-PP, LDPE, HDPE, and Nylon-6 was found to be better, and this will provide a better material than PC and by performing more research, we can lower the amount of exposure dose.

5. Conclusion

This research is about the quality of the material of compression paddle that is used to obtain an accurate test result of mammography. We evaluated the radiolucency of plastics that are crystalline materials and have similar properties to PC. For accurate evaluation of the quality of the material, we studied penetrability and pixel amount of 6 different materials by Image J.

First, with respect to the radiolucency amount of the paddle material, when there was no compression paddle it was 8.552 mGy, and the radiolucency amount for material was 6.308mGy for PC, 5.766mGy for PET, 6.488 mGy for Nylon-6, 7.067 mGy for LLDPE, 7.174 mGy for LDPE, 7.147 mGy for Block-PP, 7.207 mGy for Homo-PP, 7.140 mGy for HDPE, 7.181 mGy for CO-PP, and 5.550 mGy for Acetal.

Second, the half-value layer was 0.375mmAl for PC, 0.388mmAl for PET, 0.371mmAl for Nylon-6, 0.368mmAl

for LLDPE, 0.359mmAl for LDPE, 0.360mmAl for Block-PP, 0.360mmAl for Homo-PP, 0.360mmAl for HDPE, 0.360 mmAl for CO-PP and 0.394mmAl for Acetal.

Third, the compared amount of pixel which is the amount that penetrated the paddle material, by the image J, when there was no paddle, the mean pixel value was 975.795, and the pixel value for each material was PC 829.104, 794.679 for PET, 844.857 for Nylon-6, 891.851 for LLDPE, 888.347 for LDPE, 889.081 for Block-PP, 892.62 for Homo-PP, 887.416 for HDPE, 890.228 for CO-PP and 780.324 for Acetal.

Based on these results, compared to the material that we are using currently, PC, Homo-PP, LLDPE, CO-PP, Block-PP, LDPE, HDPE, and Nylon-6 were found to be the materials that can replace PC as they have better pixel of penetrability and half-value layer, and radiolucency. More research is needed on this matter.

6. References

1. Hourdakakis CJ, Boziari A, Koumbouli E. The effect of a compression paddle on energy response, calibration and measurement with mammographic dosimeters using ionization chambers and solid-state detectors. *Physics in Medicine and Biology*. 2009; 54:1047-59.
2. Pelc NJ, Nishikawa RM, Whiting BR. The effect of breast positioning on breast compression in mammography: A pressure distribution perspective. *Physics of Medical Imaging*. 83134M.
3. Hyeon CS. Newton Korea. 2010.
4. Kim KH. Lastic theory and application. Moon-Un Dang. 2010.
5. Kim JW. Plastic materials. Koo-Min Sa. 2000.
6. Available from : <http://www.lottechem.com>
7. Hemdal B Forward-scattered radiation from the compression paddle should be considered in glandular dose estimations, *Radiation Protection Dosimetry*. 2011; 147(1):196-201.
8. Available from :<http://www.mammopad.com>
9. Malkov S, Wang J, Kerlikowske K, Cummings SR, Shepherd JA. Single x-ray absorptiometry method for the quantitative mammographic measure of fibroglandular tissue volume. *Med Phys*. Dec 2009;36(12):5525-36.
10. Vachon CM, Van Gils CH, Sellers TA, Ghosh K, Pruthi S, Brandt KR, et al. Mammographic density, Breast Cancer risk and risk prediction. *Breast Cancer Res*. 2007;9(6):217. doi: 10.1186/bcr1829.