

Digital Quality Control Phantom for X-ray Mammography Image

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Introduction

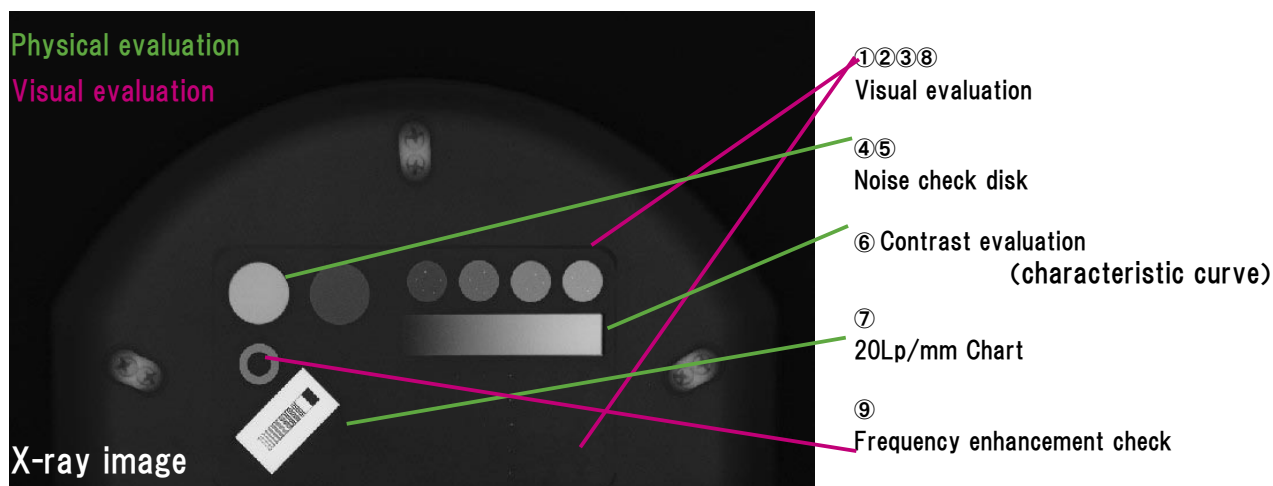
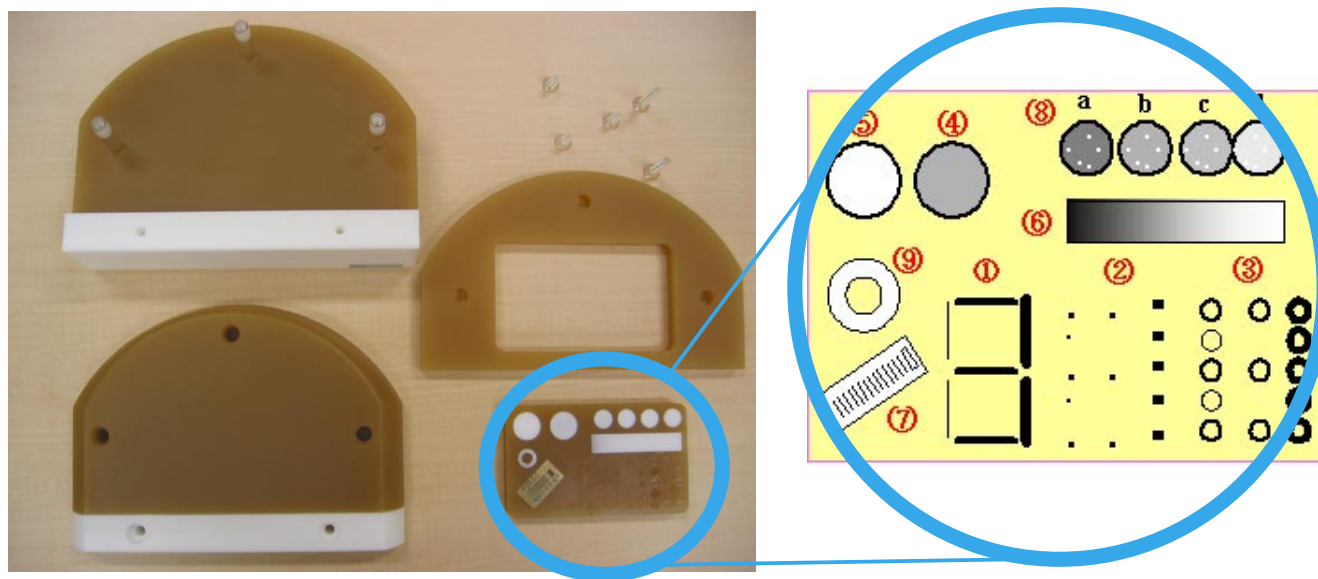
Recently, in Japan the incidence of breast cancer has been increasing, but the chances of survival can be improved by early detection. Therefore, more and more mammography screening is being administrated nationwide. So far, the mammography has carried out by analog medium, screen and X-ray films, and diagnoses have been made on the images.

Current development in digitalization of medical imaging is significant, and the advantageous digital techniques such as image processing, data transfer and automatic diagnostic system are being used in diagnostic imaging. Those digital techniques have begun to being applied even to mammography, the field which requires the most delicate imaging. Thus there has been pressing need to create new evaluation tools for digital quality control in mammography in order to support reliable diagnosis.

It is to meet the above requirements that we have developed an innovative Digital Mammography Phantom that provides comprehensive visual evaluation with one exposure, and also produce an overall source for quality control by quantifying the evaluation result.

The difficulty in developing a digital imaging phantom is to quantify the graininess and granularity in images. It depends on recording latitude, output resolution and frequency enhancement. We approached the problem from several different angles, e.g. an Aluminum Ring for the evaluation of frequency enhancement, a Teflon Ruler to see contrast and resolution, and a Bar Wave Chart to check sharpness, and then integration of those evaluation results through an original point-system.

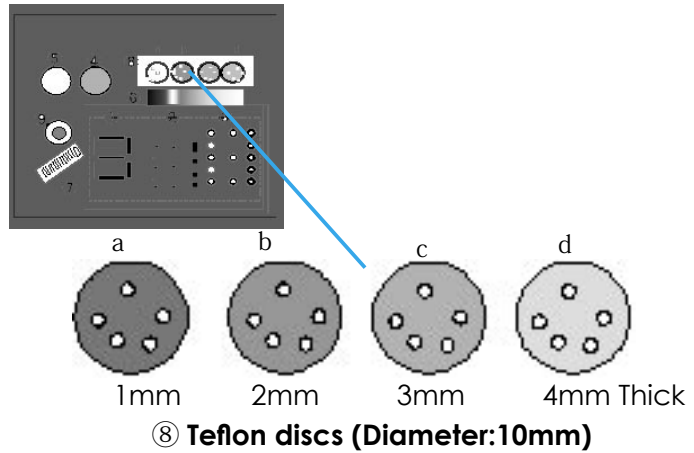
We also carried out a performance assessment study of the phantom and the point system, comparing the phantom image and clinical image.



I -2 Contrast Disk Including Simulated Calcifications (300 μ Aluminum oxide)

It is important for the mammary image to catch all the fine calcifications found in actual mammary glands. Check the four disks including five calcifications each.

Point system
When 5 calculi appear in every 4 disks ...
= 1 point
Otherwise...
= 0 points
Standard Score : 1 Point



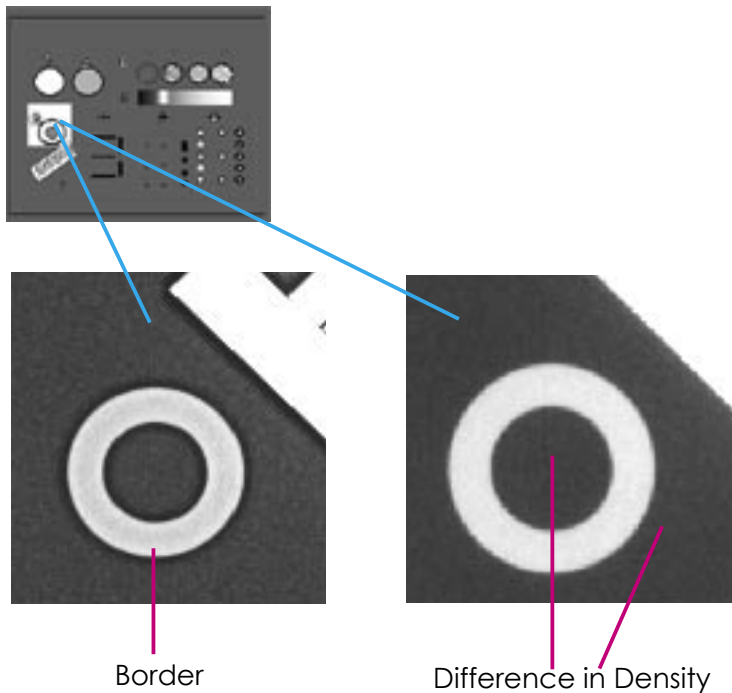
I -3 Aluminum Ring: Frequency enhancement check

Evaluation of the frequency enhancement processing (Frequency band and degree of enhancement) is important for checking the mammary image of patients who have breast implants.

Point system
When a black border appears around the ring...
= 0 points
Without a black border...
= 1 point

When the density differs between inside and outside of the circle by more than 0.05 D...
=0 Points
Without density difference...
= 1 point

Standard Score : 2 Points



Evaluation Method

Basical conditions: scanning & output

Phantom body is made of tissue-equivalent material which is the same as ACR156. We used a molybdenum target and a molybdenum filter, and fixed the scanning condition as voltage 28kV and exposure 50mAs. The images were output through printers and image analyzers that each collaborating laboratories had, adjusting the density at the center of image at 1.4 more or less 0.05.

I Visual Evaluation

I-1 Simulated fibroid tissue, Simulated calcification and Simulated lump

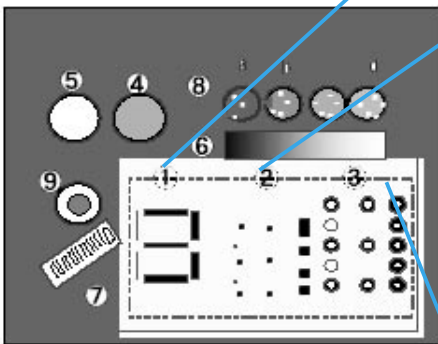
Each simulated tissues are arranged in a figure of "8", which is designed to change visibility gradually from left to right.

Point system

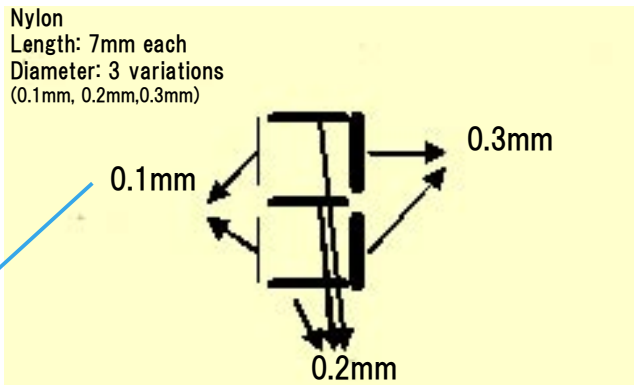
When it looks like...

- "8" = 5 points
- "3" = 3 points
- "1" = 1 point
- None of them = 0 points

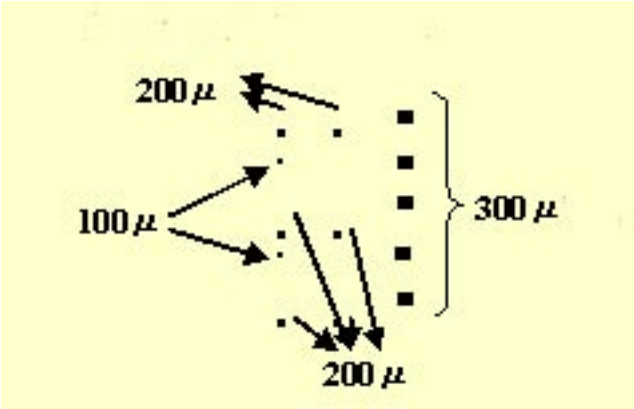
Standard Score : 9 Points



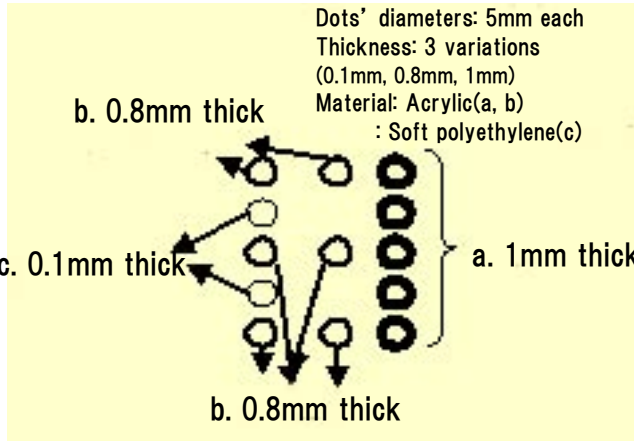
① Simulated fibroid tissue



② Simulated calcifications (Aluminum oxide)



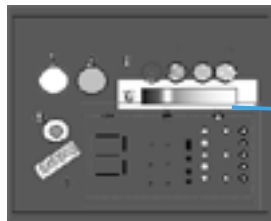
③ Simulated lump



II -2 Contrast evaluation (characteristic curve)

Since the contrast curve of a digital image is controllable, management of contrast gradation is important.

When something seems to be wrong with equipment, scanner, image analyzer or output printer, this device allows one to find out where in the contrast gradation the problem is happening.

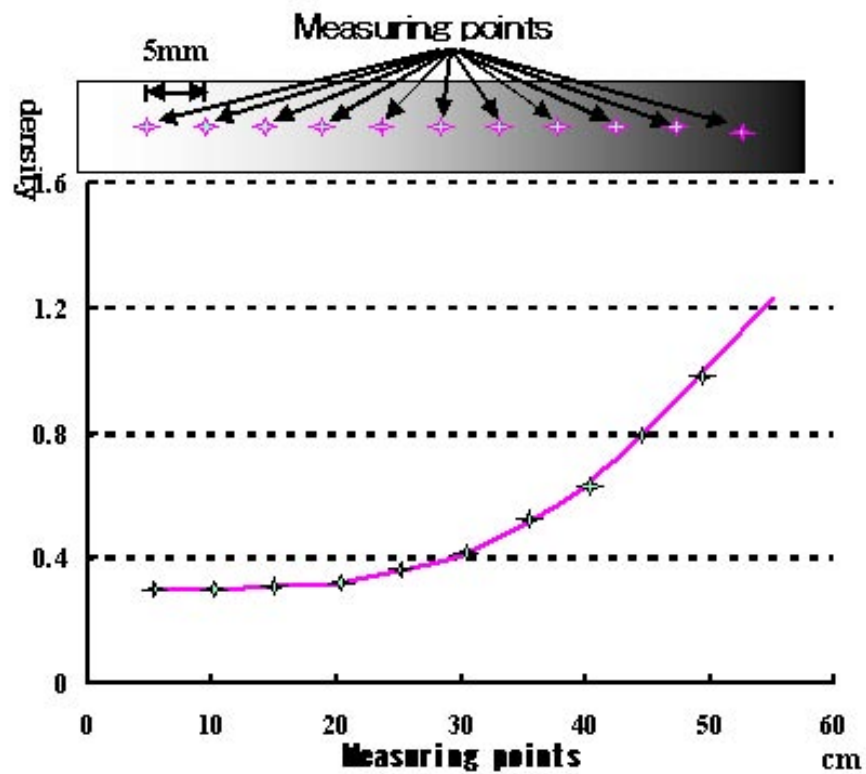


Measurement Method

Measure on the image of Teflon Ruler at every 5mm from low density area to high density area with a diffuse densitometer. Then check the resultant contrast curve.



Point system
No point system here.



II Physical Evaluation

II -1 Image Granularity Check Disk

Measure the image noise in two disks in order to evaluate the scanning radiation insufficiency, often caused by damaged scanner, and the effects of frequency enhancement.

Radiation insufficiency: This phantom designed to suit 28kV and 50mA, though radiation dosage at 50mA depends on scanning equipment.

Frequency enhancement: Frequency enhancement processing will enhance the noise at certain degree.

Measurement Method

1, Scan the film with a microdensitometer

Aperture width: 0.1mm

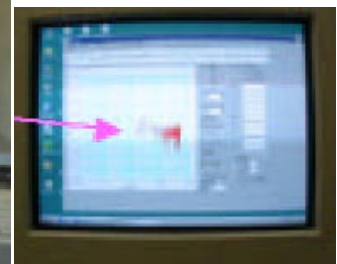
Aperture height: 1mm

Scanning speed: 0.1mm/sec

2, Analysis the noise by special software



Scan the film with a microdensitometer



Analyze the noise

Point system

Standard image granularity at the range of 1-5 cycle/mm is from 10^{-3} to 10^{-4} .

Score is counted at each disk as follows.

When the granularity is no less than 10^{-2} ...

= 0 points

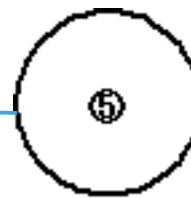
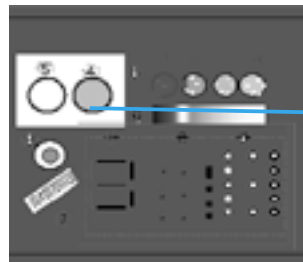
When the granularity is within the standard range...

= 1 point

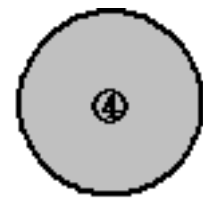
When the granularity is no more than 10^{-5} ...

=3 Points

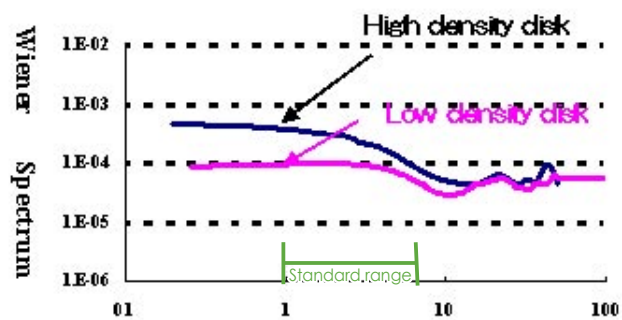
Standard Score : 2 Points



Low density disk



High density disk



III Total Evaluation

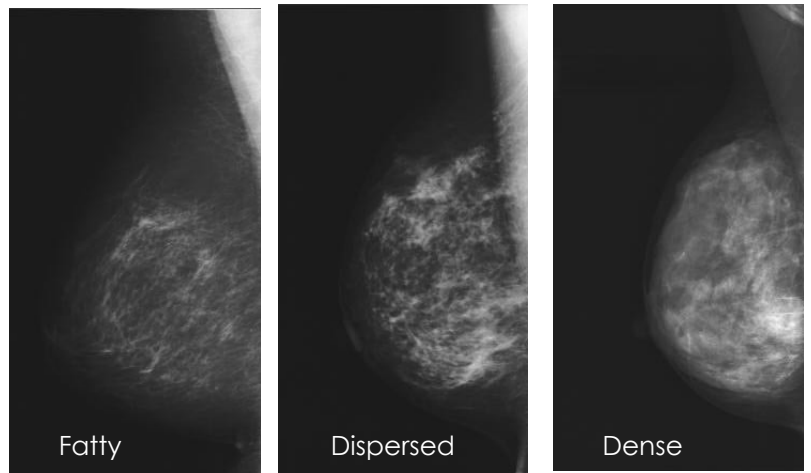
	Evaluation of phantom image	Standard points
Visual	① Fibroid tissue	3
	② Calcification	3
	③ Lump	3
	⑧ Teflon discs	1
	⑨ Aluminum Ring, Border	1
	⑨ Aluminum Ring, Contrast	1
Physical	④ High density granular disk	1
	⑤ Low density granular disk	1
Total standard score		14

Performance assessment study of the Digital Mammography Phantom and the point system

We studied the relation between the phantom image and clinical image, based on the actual clinical samples at 9 facilities.

Evaluation method of clinical images

We made X-ray films of 3 kinds of clinical samples, dense, dispersed and fatty mammary glands and evaluated their graininess, sharpness and contrast.



Point system

Excellent = 5 points

Good = 3 points

Poor = 0 points

Standard average score

=3 points

	Fatty	Dispersed	Dense	
Graininess				
Sharpness				
Contrast				
average score				average

II -3 Contrast Transfer Function

Check the sharpness of images affected by degradation of X-ray tube ,focus, etc.

Sharpness is evaluated by CTF, Contrast Transfer Function, because it is better adapted to evaluate image films processed and outputted by diverse equipment than MTF.

Measurement Method

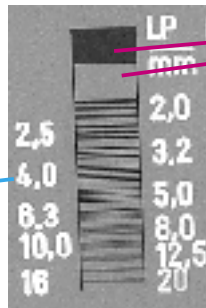
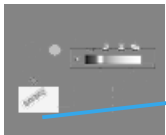
1,Scan the film with a microdensitometer and record the rectangular wave amplitude with pen recorder.

Aperture width: 0.01mm

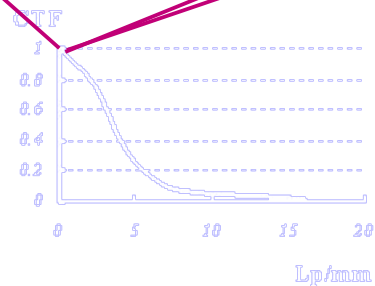
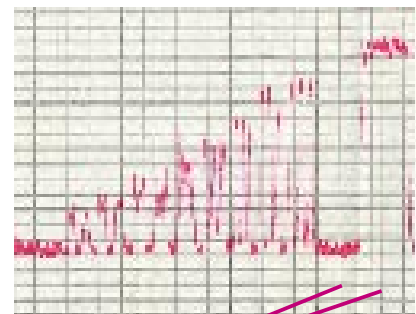
Aperture height: 1mm

Scanning speed: 0.1mm/sec

2,Measure the ratio of wave amplitude at each frequency bands. Compare them with the standard contrast ratio, which can be seen in the top two windows of the chart, as "D=1".



standard contrast:
D=1

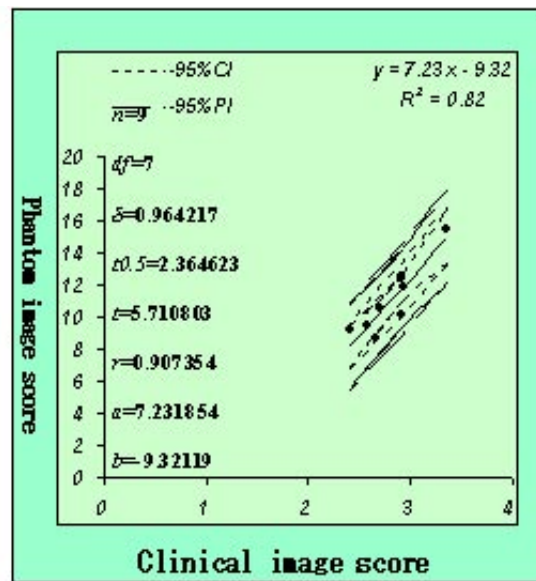


Point system

No point system here.

Relation between Phantom image and clinical image

Facility	Clinical image score	Phantom image score
A	2.94	11.816
B	3.36	15.45
C	2.43	9.17
D	2.92	12.368
E	2.92	10.183
F	2.71	10.549
G	2.58	9.45
H	2.92	12.546
I	2.67	8.628
Standard score	3	14



$r=0.90735$ 0.666383 $P<0.05$ significant correlation*

$r=0.90735$ 0.797681 $P<0.01$ significant correlation**

There is a significant relation between phantom image and clinical image.

Equipment which are applied in the assessment study

Scanner

1. MAMMOMAT 3000T
2. LORAD M-IV
3. Senograph 500T
4. Performa
5. Sepio
6. senograph 2000D

Image analyzer

1. Fuji Computed Radiography AC-3HQ (Sampling Size : 100μ)
2. Fuji Computed Radiography 5000MA (Sampling Size : 50μ)
3. Konica Regius 150 (Sampling Size : 87.5μ)
4. GE senograph 2000D (Sampling Size : 100μ)

Output printer

1. Fuji Computed Radiography CR-DP 3543T
2. Fuji Computed Radiography Dry Pix 7000
3. Fuji Computed Radiography CR-DPL
4. Konica Computed Radiography Dry Pro 752

Conclusions

Today, with remarkable improvement of medical equipment, various kinds of equipment for scanning and processing mammography images are being developed. This innovative Digital Mammography Phantom makes it possible to standardize the image quality of digital mammography and to keep up the quality which is required for making clinical diagnosis.