Image quality radiographic testing on the making of trabeculae genu phantom by using ingredients surfactant

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Abstract. Exposure to radiation can be dangerous for the body. Hence why we need an effort to minimize the effects of radiation received, especially for students and lectures during practicum that uses source of radiation. One of the efforts that can be done is to use phantom radiology so that there is no need to expose living things. Previous research has done to make phantom radiology by using gypsum instead of human bones and acrylic as a substitute for soft tissue (human flesh). However, this research still has a shortage which is trabeculae cannot be formed in the phantom produced. The purpose of this study was to determine whether the surfactant solution could be used to form trabeculae in phantom genu by using in the concentration of surfactants with a ratio of 2:1. The research was conducted in three stages, namely designing the genu phantom and trabecular phantom, printing genu phantoms and trabeculae, and conducting radiographic quality tests of genu phantom. Trabeculae in phantom genu have been successfully made with a water and surfactant ratio of 2:1. Radiographic quality tests showed good detail, sharpness and contrast. The presence of trabeculae and soft tissue is apparent. Surfactants with a ratio of 2:1 can be used to form trabeculae on phantom genu with good quality in radiographic test results.

1. Introduction

Technological advancement in health sciences improved every year, which include radiology. This require educational sector to take action in preparing radiographers that have high competence in radiology. Effort that can be done to achieve this goal is to provide knowledge about radiology through lectures, practicum and clinical practice in a comprehensive manner [1].

The learning process at radiology educational institutions by utilizing radiation sources as a public facility during practicum in the laboratory aims to produce students who have competence in the field of radiology. The use of ionizing radiation must ensure that the recipient of the radiation dose is as low as possible so that the set dose limit is not exceeded [2].

The dose limit value for students that has been determined by the Indonesian Nuclear Energy Supervisory Agency (BAPETTEN) has imposed a dose limit value equal to the dose limit value for radiation workers. For this reason, it is necessary to make efforts to minimize the effects of radiation received, especially for students and lecturers in carrying out practicum. One effort that can be done is to use radiological phantoms so that there is no need to give X-rays to humans [2].

The use of phantom radiology also creates problems, where the price of phantoms is very expensive, so not all radiology education institutions can afford it. In previous research, it was about making Phantom radiology by using gips as a substitute for human bone and acrylic as a substitute for soft tissue.
The results of this study still have shortcomings where the trabeculae cannot be seen on the results of phantom radiograph images. Based on this, researchers want to carry out further research to perfect the phantom radiology that is made [3].

2. Theoretical basis

2.1 Phantom radiology
Phantom is a human substitute tool that is commonly used as a practice object for photo radiographs. Phantom also has a bone structure covered with a soft gel in the skin which is supported by a hard material.

![Figure 1. Phantom genu [4]](image)

2.2 Gypsum
Gypsum is a soft sulfate mineral composed of calcium sulfate dihydrate, with the chemical formula CaSO4·2H2O. Gypsum generally have white colour, but there are other colour variations too, such as yellow, grey, red, orange and black. This depends on the impurity minerals mixed with the gypsum. Gypsum generally has a soft nature, dense, with hardness of 1.5-2. density of solubility in water 1.8 g / l at 0°C which increases to 2.1gr / l at 40°C, but decreases again when the temperature gets higher [5].

2.3 Acrylic resin
Acrylic resin is a polymeric material (in solution, dispersion or solid) containing acrylic monomers. These monomers are usually esters of acrylic, methacrylic acids or their derivatives, and can be functionalized by introducing different chemical groups (R groups). Others monomers can also be incorporated in the polymer chains in order to obtain resins with different properties or lower cost. In general. Acrylic resins show good chemical and photochemical resistance. They are commonly used in many different applications, from solvent-based and water-based industrial coatings to architectural coatings. Key parameters of an acrylic resin are:
1. Glass transition temperature
2. Average Molecular weight of the polymers, and
3. Polymer molecular weight distribution
These parameters have an impact on the resin properties (viscosity, dispersion) and on the final film/coating obtained (flexibility/hardness) [6].

2.4 Catalyst
Catalyst is a substance that is able to increase the rate of a chemical reaction so that the reaction can run faster. In a reaction, the catalyst is actually involved, but at the end of the reaction it is re-formed to its original shape. Thus, the catalyst does not provide additional energy to the system and cannot thermodynamically affect the equilibrium. The catalyst speeds up the reaction by decreasing the reaction
activation energy, the decrease in activation energy occurs as a result of the interaction between catalyst and reactants.

In heterogeneous catalysts, the solid which acts as a catalyst can bind a certain amount of gas or liquid to its surface based on adsorption. Currently, heterogeneous catalytic processes are divided into two broad groups, reduction-oxidation (redox) reactions, and acid-base reactions. Redox reactions include reactions in which the catalyst affects the homolytic bond breakdown of the reactant molecules to produce unpaired electrons, and then forms a homolytic bond with the catalyst involving the electrons from the catalyst. Meanwhile, acid-base reactions include reactions in which the reactants form heterolytic bonds with the catalyst through the use of lone pairs from the catalyst or reactants. When the ratio of the atomic size to the particle becomes less than 0.1 or 0.1, the cohesion force begins to decrease, which decreases the melting point. [7,8]

2.5 Surfactant solution
Surfactants or surface-active agents are molecules that contain clusters of hydrophilic, and lipophilic on the same molecule. Surfactants are divided into two parts, namely head and tail. The hydrophilic cluster is on the head (polar) and lipophilic on the tail (non-polar). The polar parts of the surfactant can contain positive, negative or neutral molecule. Generally, the non-polar (lipophilic) part is a long alkyl chain, while the polar (hydrophilic) part contains a hydroxyl cluster.

The properties of surfactants are that they can reduce surface tension, interface tension, increase the stability of the dispersed particles and control its type of formulation, be it oil in water (o/w) or water in oil (w/o). In addition, the surfactant will also be absorbed into the surface of the oil or water particles as a barrier which will reduce or slow down the coalescence of the dispersed particles. These properties can be obtained due to the dual nature of the molecule. The addition of surfactants in the solution will cause a decrease in the surface tension of the solution. After reaching a certain concentration, the surface tension will be constant even if the surfactant concentration is increased. When the surfactant is added beyond this concentration it aggregates to form micelles, this concentration of micelle formation is called Critical Micelle Concentration (CMC). The surface tension will decrease until CMC is reached. After CMC is reached, the surface tension will be constant, indicating that the interface becomes saturated and micelles are formed which are in dynamic equilibrium with the monomers.

Based on the content, the surfactants are divided into four groups, which are:

1. Anionic surfactants are surfactants whose alkyl part is attached to an anion. Its hydrophilic characteristics are due to the presence of a large enough ionic group, which is usually a sulfate or sulfonate group for example, anionic surfactants include linear alkylbenzene sulfonate (LAS), alcohol sulfate (AS), alcohol ester sulfate (AES), alpha olein sulfonate (AOS), paraffin (secondary alkane sulfonate, SAS) and methyl ester sulfonate (MES).

2. Cationic surfactants are surfactants whose alkyl portion is bound to a cation. This type of surfactant breaks down in a liquid medium, with the head of the cationic surfactant acting as a carrier for surface active properties. Examples are alkyl trimethyl ammonium salt, dialkyl-dimethyl ammonium salt and alkyl dimethyl benzyl ammonium salt.

3. Nonionic surfactants are surfactants whose alkyl portion is uncharged. Examples are acyl glycerol esters, acid sorbitan esters, acid sucrose esters, polyethylene alkyl amines, glucamines, alkyl polyglycosides, mono alkanol amines, dialkanol amines and alkyl amine oxides.

4. Amphoteric surfactants are surfactants whose alkyl part has a positive and negative charge. For example, surfactants containing amino acids, betaine, phosphobetain. [9,10,11]

2.6. Contrast
Contrast is a degree of difference the density between the two areas on the radiograph image. Contrast between different parts of the image is wrong one quality assessment criterion in a radiograph image. [12]

2.7. Details
Detail, is the capability of the radiograph for displays the differences of each part anatomy. The result of a capable radiograph image showing the small structure of that organ exposed [12].

2.8. Sharpness
Sharpness is the ability of X-rays to show a clear outline. Sharpness is important components that must be fulfilled in the image radiograph. The thing that affects sharpness is the size of the focal spot, the smaller the focal spot, the better [12].

2.9. Trabeculae
Trabeculae bone, also called cancellous bone, is a porous bone made up of trabecular bone tissue. It can be found at the end of the bone, where the bone is not actually solid but is full of holes connected by thin rods and bone tissue. Red bone marrow, where all blood cells are made, fills the spaces between the pores of the trabeculae. Although trabeculae bone has many holes, its spatial complexity provides maximum strength with minimum mass. trabecular bone structures are arranged to optimally withstand the loads generated by activity [13].

2.10. Soft tissue
Soft tissue is all tissue in the body that does not harden due to calcification, such as bones and teeth. Soft tissue connects, surrounds or supports internal organs and bones, and includes muscles, tendons, ligaments, fat, fibrous tissue, skin, lymph and blood vessels, fasciae, and synovial membranes.[14]

3. Method
The tools and materials used in the process of making this phantom trabecula are as follows: Electric Grinder, Electric Drill, Cutter Knife, Pipe Peralon and containers. The main ingredients in the manufacture of this phantom are Acrylic Resin Solutions, Catalysts, Sticky Gels, Glue and Surfactants. Phantom manufacturing

3.1. Design phantom genu

3.2. The making process of phantom genu
3.2.1 The process of molding the bones by mixing the ingredients.
a. After the desired results are formed, the genu bone is pressed with a surfactant solution to make trabecula.
b. Then it is assembled into a genu bone and the process of joining the bones is carried out which can be seen in Figure 3.
3.2.2. **Phantom creation process.** The result of the bone mold that has been made is then carried out by the soft tissue coating process.

3.2.3. **Phantom Testing Procedure.** In the testing procedure, the phantom is placed on an examination table and then exposed using an X-ray aircraft.

4. **Results and discussion**

The phantoms in this study resulted in genu phantoms consisting of genu bone from the material (plaster), soft tissue made from a mixture of resin and catalyst, and trabeculae on the bone using a surfactant solution which can be seen in Figure 4.

![Figure 3. Combined genu bone](image)

After the phantom is formed, a radiograph test is performed. In the testing phase of the radiograph image quality, it is carried out by using a variety of exposure factors to obtain the right exposure factor. After the test results are assessed by respondents consisting of three radiographers who already have 10 years of experience working in the field of radiology, the results obtained are entered in table 1.
Table 1. Variasi factor exposi

| Faktor Eksposi | Hasil Citra Radiograf Phantom |
|----------------|-------------------------------|
|                | kV | mAs | Detail | Ketajaman | Kontras | Soft Tissue | Trabekula |
|----------------|----|-----|--------|-----------|---------|-------------|-----------|
| 1              | 50 | 6   | B      | B         | B       | G           | TB        |
| 2              | 55 | 6   | B      | B         | B       | G           | TB        |
| 3              | 60 | 6   | B      | B         | G       | G           | G         |
| 4              | 55 | 8   | E      | G         | G       | E           | G         |
| 5              | 60 | 8   | G      | E         | G       | G           | E         |

Information:
1. B: Bad
2. G: Good
3. E: Excellent

Phantom radiograph test results show that the genu phantom 5 photo (KV 60 mAs 8) shows that two respondents stated that the details of the radiograph image are good, this is indicated by the appearance of the patellar os well. Testing the sharpness of the radiograph results showed two respondents said it was very good. This is shown by the ability of the radiograph to show the boundaries between the bones. The contrast test shows that the average radiograph is good, this can be seen with the difference in black and white in the area of a good radiograph image. Soft tissue and 3 respondents said the trabeculae is clearly visible from the radiograph image, this statement can be seen in Figure 5.

Figure 5. The test results of respondents (R1, R2, R3) for the quality of the phantom radiograph

From the results of the research conducted, it appears that the surfactant solution can be used to form trabeculae in the phantom genu. The addition of surfactants in the solution will cause a decrease in the surface tension of the solution. The concentration of the surfactant solution used to form trabeculae in the manufacture of genu phantoms obtained a 2:1 ratio of water and surfactants. Based on the radiograph quality test, it can be seen that the KV 60 mAs 8 exposure factor shows the radiograph quality consisting of details, sharpness, contrast, the presence of soft tissue and trabeculae looks the best. From the results of the radiograph, it is also able to provide good anatomical information.

5. Conclusion
The results showed that the surfactant solution can be used to form trabeculae on phantoms by adding the ratio of water and surfactant solution used to make trabeculae on genu phantoms is 2:1 with the results of the radiographic quality test in the form of detail, sharpness, contrast shows good results while the trabecular image and soft tissue has also been seen with excellent results. Further research can be carried out using standardized tools so that the results are more objective.
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