Research Article
Cytotoxicity of Cricula triphenestrata Cocoon Extract on Human Fibroblasts

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Objectives. The aim of this paper was to evaluate the cytotoxicity of Indonesian silkworm cocoon extract of Cricula triphenestrata on human fibroblasts.

Methods and Materials. The cocoon shells of the silkworm Cricula triphenestrata were degumming. The shell were mixed with an aqueous solution of 0.3% Na2CO3 at 98°C for 1 hour. The solution was then dialyzed in cellulose membranes against deionized water for 3 days. The cocoon shells extract powder was collected via rotary evaporation and dried under freeze dryer. Cell culture medium was exposed to Cricula triphenestrata cocoon extract (0.01–100 μg/mL) for 24 hours. The primary human gingival fibroblasts were exposed to the treated cell culture medium for 24 hours. Cytotoxicity evaluation was done by MTT method. The data were analyzed by one-way ANOVA.

Result. The result revealed no significant cytotoxicity of Cricula triphenestrata cocoon extract against human fibroblasts at a concentration up to 100 μg/mL (P > 0.05).

Conclusion. Cricula triphenestrata cocoon extract was not cytotoxic on human gingival fibroblast cells.

1. Introduction

Many acute and chronic injuries require bone graft substitutes. Current options for bone graft substitutes include autograft, allograft, and synthetic materials. Each of the options has limitations, such as the need for second site of surgery, limited supply, inadequate size and shape, and the morbidity associated with donor site [1]; thus, there remains a need for the new option.

Synthetic hydroxyapatite is widely used as a bone substitute material because it can bond directly to the living bone and has excellent biocompatibility and bioactivity. However, hydroxyapatite does not have enough mechanical properties to act as substitute in loading-bearing parts of the human skeleton. Hydroxyapatite shows a higher Young’s modulus and lower toughness than cortical bone [2]. It has been desired to develop a material that has mechanical properties analogous to those of natural bone. It is known that human bone has a three-dimensional woven apatite-polymer structure made of inorganic apatite crystals and organic collagen fibers [3]. Bone consists of an organic-inorganic hybrid with a characteristic structure that leads to specific mechanical properties such as high fracture toughness and flexibility. It is a good strategy to mimic bone structure in the design of bone-repairing materials. From this point of view, the fabrication of hybrid materials consisting of apatite and natural organic polymer can be expected to be a good strategy to obtain bone repairing materials that have both a bone bonding ability and mechanical properties similar to those of natural bone.

Previous study [4] reported that apatite-coated silk scaffolds can combine the osteoconductive properties of bioceramics with the mechanical resilience of polymer. Silk scaffolds combined with apatite promoted cellular attachment and bone formation in vitro, providing an appropriate osteogenic environment for tissue engineering.
In vivo research on mongrel dogs by Zhao et al. [5] showed that apatite-silk scaffolds could be successfully used to repair mandibular critical size border defects. The premineralization of the porous silk protein scaffold provided an increase osteoconductive environment for the cells to regenerate sufficient new bone tissue.

Silks are fibrous proteins with remarkable mechanical properties produced in fiber formed by silkworms and spiders [6]. Previous studies reported silks contained two natural macromolecular proteins namely, sericin and fibroin. Sericin comprised granular and high-molecular, water soluble glycoproteins and it acted as a protein glue to fix fibroin fibers together in the cocoon [7]. In silk textile processing, sericin is usually removed, resulting in fine silk fibers. The resulted fibroin fibers can be used to make fabrics.

Sericin is useful because of its properties. The protein which resists oxidation is antibacterial, UV-resistant, and absorbs and releases moisture easily. Sericin can be cross-linked, copolymerized, and blended with other macromolecular materials, especially artificial polymers, to produce materials with the improved properties. The protein is also used as an improving reagent or a coating material for natural and artificial fibers, fabrics, and articles. Sericin composites are useful as degradable biomaterials, biomedical materials, polymers for forming articles, functional membranes, fibers, fabrics, and articles [8, 9]. Sericin has a potential to facilitate apatite deposition and can be useful as polymer material in the fabrication of hybrid materials analogous to bone through biomimetic processes [10].

Research regarding the potentials of Indonesian silk is still limited. Indonesia is well known for its silk textile derived from wild silkworm cocoon of *Cricula triphenestrata*. *Cricula triphenestrata* is one of the world wild species of silkworms which only habitats in Java island. *Cricula triphenestrata* produces golden silk floss which is very luxurious and amazing [9]. The use of discarded sericin of *Cricula triphenestrata* cocoon extract from the waste of silk textile industry as biomaterials will be beneficial for the local silk textile industry and also the development of natural biomaterials as bone substitute.

Biomaterials may have low, medium, or high potential risk to human safety depending on the type and the extent of patient contact. One of the International Standards [11] recommends the appropriate steps for the biological assessment of medical devices in vitro assessment of cytotoxicity of new biomaterials. In this primary screening, we aimed to evaluate the cytotoxicity of *Cricula triphenestrata* cocoon extract on human gingival fibroblasts.

2. Materials and Method

2.1. Materials. The cocoon shells of the silkworm *Cricula triphenestrata* (Figure 1) were obtained from PT Yarsilk Gora Mahottama Textile Industri at Yogyakarta, Indonesia. The cocoon shells were taken from Karang Tengah Forest at Kabupaten Bantul, Yogyakarta, Indonesia. The medium of RPMI 1640, Dulbecco’s Modified Eagle’s Minimum Essential medium (DMEM), penicillin, streptomycin, amphotericin, and trypsin were obtained from Gibco (Carlsbad, CA, USA).

All other chemicals were analytical or pharmaceutical grade and obtained from Sigma-Aldrich Chemicals (Bornem, Belgium).

2.2. Preparation of *Cricula triphenestrata* Cocoon Extract. The cocoon shells of the silkworm *Cricula triphenestrata*, were mixed with an aqueous solution of 0.3% Na₂CO₃ (w/v) at 98°C for 1 hour. The solution was then dialyzed in cellulose membranes (MW = 3500 g/mol) against deionized water for 3 days by changing the water daily to remove the ions and other impurities. The cocoon extract powder was collected via rotary evaporation and drying under freeze dryer [12].

2.3. Cell Culture. Human gingival fibroblasts were obtained from biopsies of the attached gingival of sound permanent molar teeth of healthy persons. Informed consent based on an appropriate protocol was obtained from the donors. The biopsies were stored at 4°C for at most 24 hours in culture medium (RPMI 1640 supplemented with penicillin 100 U/mL, streptomycin 100 mg/mL, and amphotericin 2.5 mg/mL) prior to amplification.

The gingival tissues were cut into 1 to 2 mm³ pieces then washed three times by RPMI 1640. After that, the cut biopsies were placed into 25 cm² tissue culture flasks. The explants were incubated with culture medium consisting of DMEM 90%, 10 mM HEPES, glucose (4.5 g/L), NaHCO₃ (3.7 g/L), penicillin (100 U/mL), streptomycin (100 mg/mL), and amphotericin (2.5 mg/mL), supplemented with 10% heat-inactivated fetal calf serum (FCS). The tissue samples were grown at 37°C in a humidified atmosphere of 10% carbon dioxide in the air. When outgrowth of cells was observed, the medium was replaced twice weekly until cells reached confluence. Cells were detached from the monolayer by a brief treatment with trypsin-EDTA (0.25% trypsin, 0.02% EDTA) and recultured in 75 cm² tissue flasks until confluent monolayer was reobtained [13].

2.4. MTT Cytotoxicity Test. The MTT cytotoxicity test is based on ISO 10993-5 [14] of Biological Evaluation of Medical Devices, Part 5: Tests for In Vitro Cytotoxicity. Cells (1 × 10⁵ cells/mL) in DMEM of 50 μL were seeded into 96-well plates and maintained in culture for 24 hours to form a semiconfluent monolayer. They were then exposed
to the *Cricula triphenestrata* cocoon extracts (50 μL) over a range of 0.01–100 μg/mL concentration. After 24-hour exposure, the formazan formations were determined for each treatment concentration by ELISA reader at a wavelength of 570 nm. The relative viability of the treated cells as compared to the control cells were expressed as the % cytoviability, using the following formula:

\[
\text{% Cytoviability} = \frac{100 \times \text{OD}_{570 \text{ treated}}}{\text{OD}_{570 \text{ control}}},
\]

where \( \text{OD}_{570 \text{ treated}} \) is mean value of the measured optical density of the treated cells; \( \text{OD}_{570 \text{ control}} \) is mean value of the measured optical density of the control cells.

The data were presented as means ± standard deviation (SD). Statistical analysis was performed using analysis of variance (ANOVA) to determine the effect of cocoon extract concentration on the fibroblast cells cytoviability.

### 2.5. IC50 Determination

This study used IC50 determination by the standard curve method. A standard curve was performed based on the extract concentrations numbers versus the cytoviability percentage value. The extract concentrations used were 100, 50, 25, 12.5, 6.25, 3.125, 1.563, 0.781, and 0.010 μg/mL. Each concentration was performed in four replicates. The determined cytoviability value was plotted in the standard curve. This research used the cytoviability values that only fall in the linear range of the standard curve to reduce error. A linear regression analysis was performed regarding to the corresponding concentration numbers and cytoviability values. The regression formula was \( Y = aX + b \). The IC50 value was estimated using the fitted line of the linear regression as \( \text{IC50} = (0.5 - b)/a \).

### 3. Results

The result of relative viability of the fibroblast treated cells as compared to the control cells was expressed in Table 1.

Table 1 shows the effect of *Cricula triphenestrata* cocoon extract on human gingival fibroblast viability measured by MTT test. MTT is a yellow water-soluble tetrazolium dye which is reduced by live cells to a purple formazan product insoluble in aqueous solutions. The amount of formazan generated is directly proportional to the number of viable cells [12]. As can be seen from Table 1, the cocoon extract exposure of 0.01–100 μg/mL during 24 hour of incubation induces the cytoviability of the fibroblast to be 71.184–64.486% in comparison to the control. The highest inhibition effect is induced by 100 μg/mL extract concentration and the weakest is on 0.01 μg/mL one. Although further statistical analysis shows no significant difference among the concentrations, but it is proved that there is an increasing cytoviability on the decreasing of the extract concentration exposure. It means that more concentration exposure tends to lower the fibroblast cytoviability.

The half maximal inhibitory concentration (IC50) is a measure of the effectiveness of a compound in inhibiting biological or biochemical function. This quantitative measure indicates how much a particular substance is needed to inhibit a given biological process by half. In other words,
it is the half maximal (50%) inhibitory concentration (IC) of a substance (50% IC, or IC$_{50}$) [20]. The score of IC$_{50}$ represents the concentration of a drug that is required for 50% inhibition in vitro [21]. In this study, the determination of IC$_{50}$ by the formula of $Y=67.630-0.390X$ is 172 $\mu$g/mL. It means that the highest treated concentration of 100 $\mu$g/mL cocoon extract reveals no significant cytotoxicity against human fibroblasts (less than 172 $\mu$g/mL).

Previous study reported that the IC$_{50}$ of Bombyx mori silkworm cocoon extract on Vero cells was 230 $\mu$g/mL [22]. Comparing to the IC$_{50}$ of Cricula triphenestrata cocoon extract in this study, the Cricula triphenestrata cocoon extract is lower than the Bombyx mori. It means that the Cricula triphenestrata cocoon extract is more cytotoxic than the Bombyx mori. Previous study reported that there was a correlation between environmental condition and the protein production of cocoon [23]. Cricula triphenestrata is a wild silkworm found only in Java island forest in Indonesia. It can be found in guava leaf, cashew leaf, and hardwood leaf. Bombyx mori silkworms are usually growth by the farmers to produce silk fabrics. They were usually fed with only mulberry leaves. The difference between the environmental condition and food consumption may influence the cocoon characteristic including the cytotoxicity.

In the present study, the cytotoxicity of Cricula triphenestrata cocoon extract which is aimed to be used as bone substitute is analyzed using a cell culture model of primary human gingival fibroblasts. Like other tissues, normal fibroblast function is critical to maintain the periodontal tissue function for optimal healing. Gingival fibroblasts are chosen due to their availability and culturing characteristics [13].

5. Conclusion

Biomaterials may have potential risk to human safety. Accurate biological assessment of the proposed medical biomaterial is needed. Based on the research of the cytotoxicity of Indonesian silkworm cocoon extract of Cricula triphenestrata on human fibroblasts, it was concluded that Cricula triphenestrata cocoon extract up to 100 $\mu$g/mL was not cytotoxic on human gingival fibroblast cells. By this finding, further researches are proposed to develop the Cricula triphenestrata cocoon extract as an alternative biomaterial for bone substitute.

References

