

Differences in mucin expression in the submandibular glands of rats during periodontitis induction

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ABSTRACT

Background: *Porphyromonas gingivalis* (Pg) produces lipopolysaccharide (LPS) which acts as a stimulator of inflammation in periodontal tissues. Periodontitis-induced apoptosis and vacuolation of the salivary gland, therefore, causes hyposalivation. Mucin secretion is produced by the submandibular gland under stimulation by the cholinergic and adrenergic receptors. Both forms of stimulation influence the volume of mucin secretion. Mucin saliva plays an important role in the early stages of Pg colonization in the oral cavity. On the other hand, it serves to protect against bacterial invasion. **Purpose:** The aim of this research was to identify differences in mucin expression in the submandibular gland during periodontitis induction. **Methods:** 32 male Wistar rats were assigned to either a sham periodontitis or a periodontitis group. The former group received a daily injection of a vehicle solution (n = 16), while members of the periodontitis induction group (n=16) were injected each day with 500 µL of Pg 108 into the mesial area of the upper molar. Mucin in the submandibular gland was analyzed at the 7th, 14th, 21th and 28th days after injection by means of periodic acid schiff (PAS) staining. **Results:** 28 days after injection mild gingivitis was developed in the periodontitis experiment group. Junctional epithelium (JE) thickness decreased gradually following the increase of PG injection periods (p<0.05). However, mucin expression increased prominently at 7th, 14th, and 21th days after injection and decreased on day 28th after PG injection. Mucin was expressed in the duct cells of the submandibular gland. **Conclusion:** The result of this study suggests that there are different levels of mucin expression in the submandibular gland during periodontitis induction.

Keywords: mucin; submandibular gland; periodontitis; *Porphyromonas gingivalis* (Pg)

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INTRODUCTION

Periodontal disease has been renewed to cause inflammation in the gingiva, followed by connective tissue damage, alveolar bone resorption and systemic disease, including: atherosclerosis, rheumatoid arthritis, preterm-low birth weight, chronic kidney disease, diabetes and respiratory problems.¹⁻⁵ One of the bacteria causing periodontitis is *Porphyromonas gingivalis* (Pg), an anaerobic Gram negative oral bacteria that induces inflammation in periodontal tissue.^{2,3} Pg fimbria activates the innate and adaptive human immune system to induce monocytes and poorly activated epithelial cells to produce interleukin IL-6, IL-8, macrophage colony stimulating

factor (M-CSF) and tumor necrosis factor (TNF).^{6,7} This Pg virulence factor in periodontal areas will spread throughout the human body as one etiology of systemic disease. Saliva plays an important role in the early-entry stages of Pg bacteria in the oral cavity. Furthermore, it helps the attachment and initiation of Pg bacterial colonies on tooth surfaces and soft oral tissues. In the latest stages of infection, Pg bacteria begins to form biofilm binding to other bacteria through saliva mediation.⁸

Saliva performs multiple functions including: antibacterial, antimicrobial, antifungal, antiviral, immunity, clearance, wound healing and tissue repair⁹ due to its significant protein, carbohydrate and mineral content. Saliva components have been used widely as a biomarkers

of systemic disease.^{10,11} Mucin, as one component of saliva, is produced in large quantities in the submandibular gland. 20 types of mucin have been identified, five of them found in saliva, namely: MUC5B, MUC7, MUC1, MUC4, and MUC16.^{11,12} Mucin forms a slimy, viscoelastic film which coats all surfaces of the oral cavity. This layer acts as an important lubricant of opposing surfaces during mastication, swallowing and speech.⁹ The secreted salivary mucins, MUC5B and MUC7 modulate oral microorganisms.¹³ Mucin enables bacteria to adhere to oral surfaces.^{11,14} Other research shows that adolescents presenting a very high incidence of dental caries disease had increased levels of MUC1 and MUC5B, but decreased MUC7 protein levels.¹³

Saliva secretion is dynamic and susceptible to the effects of aging, systemic disease, medicine intake and radiotherapy treatment of the head and neck. Rat models have been used in cases of experimental periodontitis in order to analyze changes in saliva secretion. These have produced similar results to those observed in humans.¹⁵ However, changes in the mucin production of the salivary glands during the periodontitis process have not been well-documented in the literature on the subject. Previous studies have demonstrated that proinflammatory IL-1, IL-6, TNF- α , IFN- δ and *Pg* infection increase MUC1 genes in human oral epithelial cells. However, no effect was observed after *Pg* LPS treatment.¹⁶ On the other hand, incubation of acinar cells in the sublingual gland with LPS from *Pg* was shown to produce a decrease in salivary mucin synthesis.¹⁷ The purpose of this study was to determine differences in mucin expression in the submandibular gland during periodontitis induction. Mucin was used as a parameter considering its important role as one of the protective components of saliva. The results of this study will be used to develop mucin saliva as a biomarker of diagnostic and control tools in periodontitis therapy.

MATERIALS AND METHODS

The experimental protocol of this study was approved by the Research Ethics Committee, Faculty of Dentistry, Universitas Gadjah Mada (No.00377/KKEP/FGK-UGM/

EC/2015). 32 male, 8-week old Sprague Dawley rats with an average body weight of 150-200gms were involved. Housed in standard conditions with ad libitum access to food and water, the subjects were randomly divided into two main groups, those receiving periodontitis induction and others subjected to sham induction. Periodontitis induction was performed by means of a slightly modified Kusumawardhani procedure.¹⁸ Periodontitis induction groups received a daily 500 μ L injection of *Pg* 10⁸ in the mesial area of the upper first molar, while the sham periodontitis group received a daily injection of a placebo solution. The periodontitis and sham periodontitis groups were subsequently divided into subgroups according to the duration of the injection period, i.e., 7, 14, 21 and 28 days. Each group consisted of four models. During the injection period, the severity of experimentally induced periodontitis was monitored using a periodontal probe to ascertain the extent of pocket periodontal manifestation.¹⁹

The subjects were sacrificed one day after the last induction during their injection period by means of an overdose of intramuscular anesthesia. Their maxillary and submandibular glands were removed and separated from muscle and soft tissue for the histological process. The submandibular gland and maxillary area were immersed in 10% buffer formalin for 24 hours. Mandibles were incubated in 10% formic acid solution to promote decalcification and subsequently embedded in paraffin. They were then subjected to hematoxylin eosin (HE) staining, while the submandibular glands were processed for periodic acid shift (PAS) staining.^{20,21} All tissues were examined in three areas under a light microscope. Periodontal nuclei cell were stained blue by hematoxylin, whereas eosin stains cytoplasm and extracellular matrix varying degrees of pink. The thickness of JE was measured by counting the number of epithel layers from the cemento–enamel junction (CEJ) to the most coronal and apical sections of JE.²² The PAS positive gland staining produced a magenta-purple colour in the duct cell. The mucin level was measured based on the density of the mucin cell expression in the submandibular gland. Since there is no standard cellular density calculation for mucin expression cells, the standard based on the results of the research reported here was arranged and presented in Figure 1.

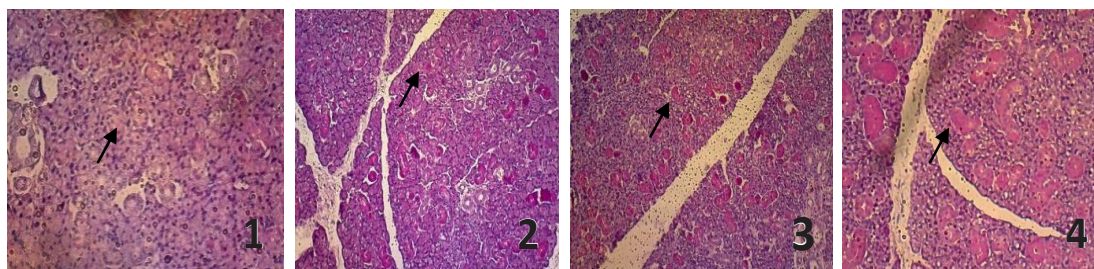


Figure 1. Mucin expression-cell density standard, 1=less than 25% of cells express mucin; 2 = 25%-50% of cells express mucin; 3 = 50%-75% cell expressed mucin; 4 = more than 75% of cells express mucin. Magenta color indicates the presence of mucin (black arrowhead).

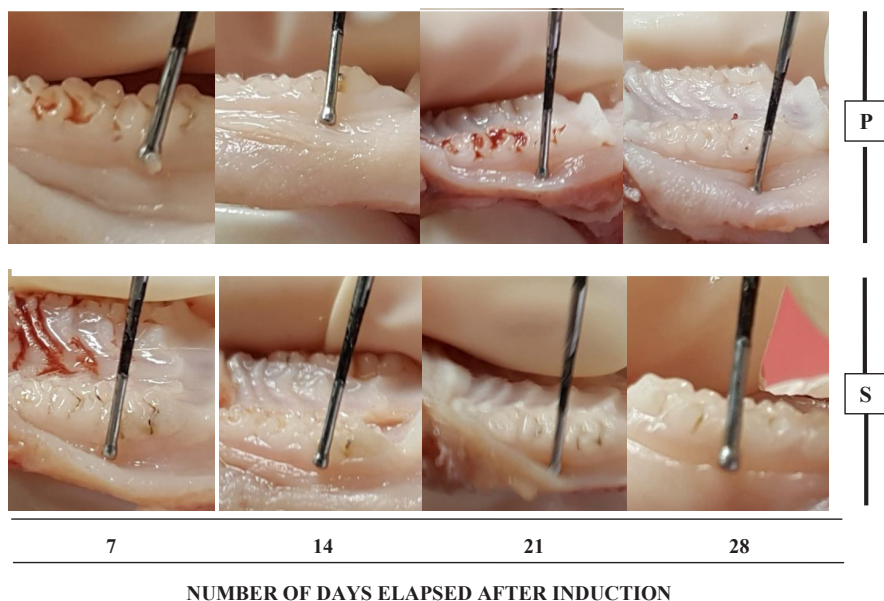


Figure 2. Periodontal pocket manifestation was examined in the molar region by means of a periodontal probe. Increasing probe depth occurred after 28 days of induction in contrast to days 21, 14, and 7. P: Periodontitis induction, S: sham induction.

While periodontitis was confirmed by examining the thickness of the mesio buccal JE of the upper molar,²³ a *Kruskal Wallis* test was used to analyze differences between the four groups followed by a Mann Whitney test. The statistical significance level was set at $p < 0.05$.

RESULTS

Gingival inflammation was detected in the periodontitis induction group due to the increased probing depth on

day 28 of treatment which had not occurred in the other groups (Figure 2). JE conversion to pocket epithelium is regarded as a hallmark in the development of gingivitis into periodontitis. Therefore, to confirm whether periodontitis induction was associated with inflammation in the periodontal tissues in this research, the thickness of the JE molar was examined by means of HE staining.²³ The results are contained in Figures 3 and 4.

As shown in Figures 3 and 4, the number of JE layers decreased in parallel with the number of days of

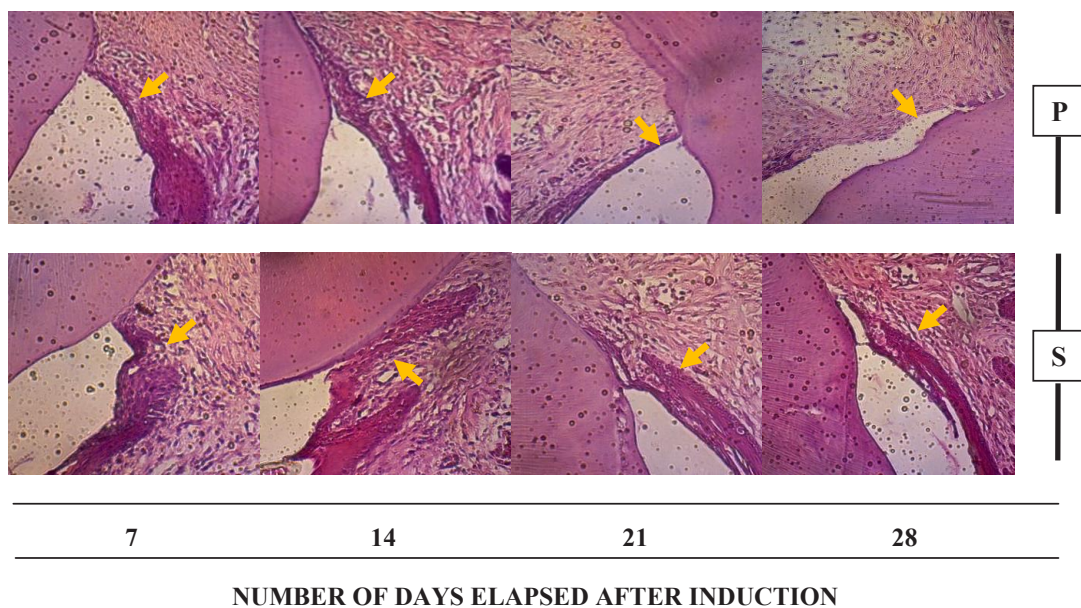


Figure 3. Changes in JE thickness after periodontitis induction (P). Data compared to sham (S) periodontitis induction on the same days (day 7, day 14, day 21 and day 28). The yellow arrowhead (↗) indicated JE. Picture was taken at 200x magnification.

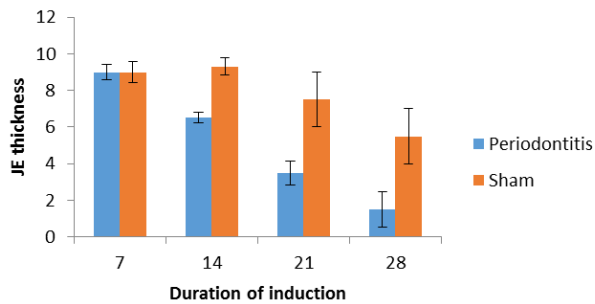


Figure 4. Thickness of JE molar teeth during periods of treatment.

periodontitis induction. Reduction in JE thickness began to occur on day 14 in the periodontitis induction groups. This JE thinning continued on days 21 and 28. The lowest thickness of JE was occurred in the periodontitis induction after 28 days. While the thickest was observed in the sham group on day 14.

Mucin saliva was detected by the presence of a magenta coloring in the cytoplasm of the duct cells. As seen in Figure 5, cell density which expressed mucin tended to increase up to days 21, but then decreased on day 28. The highest density was seen in rat periodontitis on day 21. The density of cells expressing mucin was analyzed statistically using a Kruskal Wallis test whose results indicated significant difference ($p=0.0001$). Subsequent statistical analysis was performed by means of a Mann Whitney test to investigate differences in cell expressing mucin density in the periodontitis and sham groups of the same duration. The results showed there to be significant difference between the periodontitis and sham periodontitis groups on day 7 ($p=0.008$), day 14 ($p=0.013$), day 21 ($p=0.008$) and day 28 ($p=0.004$).

DISCUSSION

According to the results of this study, injections of Pg decreased JE thickness. Depletion of the epithelial layer which facilitates the penetration of bacterial products into the deeper periodontal tissue was found on day 14. Previous studies have shown that a third LPS application induced the destruction of JE²² which was composed of an epithelium layer with no keratin in the cell surface.²⁴ This condition causes a decrease in the microscopic defensive system against injury. A previous study reported that proteinase from PG reduces epithelial cell adhesion to extracellular matrices, morphology changes and apoptosis.²⁴ High expression of TUNEL and M30CytoDeath as apoptosis markers results in the reduction of oral epithelial thickness.²⁵ This study found that JE thinning continued on days 21 and 28 and was confirmed by histology analysis that the method of injection of Pg induced periodontitis,

Salivary glands will respond to oral inflammation by increasing the molecular synthesis of acinar cells to

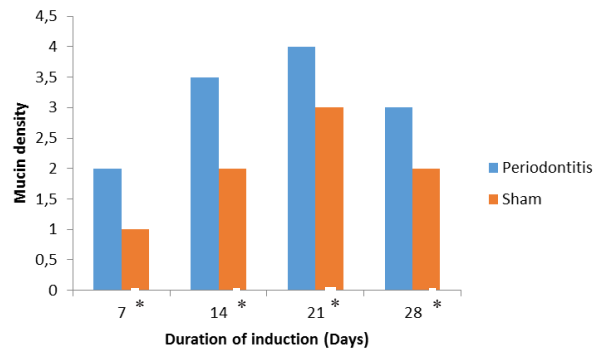


Figure 5. Mucin expression-cell density of submandibular gland on specific days of periodontitis induction. Data is presented as the median, * $p<0.05$; significantly different in both groups on the same day.

improve salivary protection function. Mucin is one source of molecular protection in saliva which is produced in large quantities in the submandibular gland. It has been established that LPS Pg influences mucin salivary secretion in the sublingual gland cells of rats.¹⁷ It can be seen from this study that PAS is strongly expressed in the duct cell, but very weakly in acinar cells. A previous study reported that mucin is expressed in the acinar duct and excretory duct cells.²⁶ The weakness of mucin expression in acinar cells is probably due to the continuing presence of mucin in the form of secretory granules which cannot be detected by means of PAS staining.²⁷

Saliva in patients suffering from chronic and aggressive periodontitis showed an increase in mucin and salivary amylase concentration.²⁸ As a part of secretory salivary protein, mucin is produced by the acinar cells under the control of the autonomic nervous system, while secretion of MUC5B is controlled by the parasympathetic nerve.²⁹ It has been reported that the submandibular gland produces mucin regulated by adrenergic and cholinergic signaling.³⁰ Changes in diseases and the environment regulate sympathetic nervous system responses. This pathway may be involved in systemic responses included modulation pain responses and inflammation.³¹ This study showed that mucin expression tends to increase with the duration of treatment involving injections. It has been firmly established that during the initial stages of bacterial infection, goblet and epithelial cells produce more mucin to prevent bacteria colonization. On the other hand, mucin facilitates bacteria adherence in the epithelia, showing that pathogenic bacteria compete with the protective function of mucin.^{12,27} An increased mucin expression between days 7 and 21 would produce a double function of mucin. An increase in mucin production in saliva has been reported in oral disease.^{13,28}

It has been established that the mucin submandibular gland is produced by the cholinergic and adrenergic system. LPS Pg induces inflammation through several mechanisms. LPS binds TLR receptor to induce secretion inflammatory cytokine, NOS and COX2. Evoked NOS

induces cholinergic system.³² The cholinergic system increases calcium concentration in the acinar cells of the submandibular glands. Furthermore, calcium evokes mucin secretion.³⁰ On the other hand, LPS Pg generates cytosolic phospholipase A₂ (cPLA₂) through up-regulation in the MAPK/ERK signaling pathway in the sublingual gland cell of rats resulting in cPLA₂ activated endothelin-1 mucin secretion.¹⁷ A decrease in mucin expression occurred on day 28 when periodontitis conditions were more severe than on day 21, possibly due to different signaling pathways being involved on each occasion. Further research is required to confirm which signaling pathways are involved in mucin secretion in the submandibular gland. It can be concluded from this study that mucin expression in the submandibular glands of rats differed during periodontitis induction. The expression of mucin increased gradually following the day of periodontitis induction with the highest level occurring on day 21 and decreasing on day 28.

ACKNOWLEDGEMENTS

This research was funded by Dana Masyarakat 2015 of the Faculty of Dentistry, Universitas Gadjah Mada.

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