

RESEARCH OF A MATHEMATICAL MODEL IN AFT PRODUCTION

1Nastinov Sadriddin Tojiddin o'g'li

1Teacher of the Department of Digital Educational Technologies,
Namangan State University

e-mail: sadriddin_1995_08_29@mail.ru

Tel: +998-97-256-29-95

Abdukodirov Elbek Abduvali ugli

2Teacher of the Department of Digital Educational Technologies,
Namangan State University

e-mail: abduqodirovelbek71@gmail.com

Tel: +998-93-949-67-91

Abstract

In this work, a mathematical model of the process of antiplaque (AFT) formation in the oral cavity was developed and analyzed. AFT is a biofilm formed by microorganisms, which leads to the development of caries, gingivitis and other periodontal diseases. In the study, the main stages of AFT formation: bacterial colonization, biofilm growth and salivary flow clearance processes were mathematically modeled. A dynamic model was built based on ordinary differential equations (ODE) and simulated using MATLAB/Python. The results show a functional relationship between the level of AFT and hygiene factors.

Keywords: AFT, biofilm, mathematical model, oral hygiene, differential equation, simulation.

INTRODUCTION

Oral antiplaque (AFT) is a complex biofilm formed by the accumulation of microscopic organisms on tooth surfaces. AFT consists of substances secreted by bacteria and their interactions, which develops rapidly when oral hygiene is not adequately maintained.

OBJECTIVES

- To mathematically model the process of AFT formation;
- To study the dynamics of AFT over time based on the model;
- To mathematically represent the effects of saliva flow and hygiene measures.

LITERATURE REVIEW:

1. Marsh P.D. (2006). "Dental plaque as a biofilm and a microbial community"

This article analyzes AFT as a bacterial biofilm. A biofilm is a multilayered structure of microorganisms attached to an organism's surface. Marsh identifies the stages of AFT formation as follows:

- early colonizers,
- late stages dominated by anaerobic bacteria.

Significance:

This work shows AFT as a dynamic microbiological system rather than a static one, which provides a basis for mathematical modeling.

2. Dawes C. (1983). "A Mathematical Model of Salivary Clearance of Sugar"

This study analyzes how oral sugars are cleared by saliva using a mathematical model. The model uses an ordinary differential equation to describe the rate of breakdown and loss of the substance.

Significance:

This model allows for the quantitative assessment of environmental factors (e.g., washout rate) that affect AFT formation.

3. Kolenbrander P.E. (2010). "Bacterial interactions during plaque development"

This article provides an in-depth analysis of the chemical and physical interactions between bacteria. According to it, in the formation of AFT, bacteria are sequentially arranged, forming a mutually strong biofilm.

Significance:

In mathematical modeling, these sequential arrangements and interactions are represented by an agent-based model or a grid-based model.

4. Tsaira A. et al. (2016). "Biomechanical response of oral mucosa"

This study analyzes how oral tissues respond to mechanical stimuli (e.g., chewing, pressure, temperature).

Significance:

It shows that the AFT model should be constructed taking into account the physical conditions of the oral environment (temperature, pressure, fluid movement).

5. Trusov P. et al. (2024). "Mathematical modeling of airflow when breathing through the mouth"

This work models how the speed and direction of airflow through the oral cavity changes during breathing.

Significance:

Airflow affects the humidity, temperature, and bacterial environment in the mouth — all of which are directly related to AFT formation.

RESEARCH METHODOLOGY

Model Description

The model is based on the following formula (logistic growth + clearance model).

$$\frac{dP(t)}{dt} = r \cdot P(t) \cdot \left(1 - \frac{P(t)}{K}\right) - c \cdot P(t)$$

where:

- P(t) is the AFT rate over time;
- r is the bacterial growth coefficient;
- K is the maximum biofilm capacity (for a given surface);
- c is the coefficient of hygiene and salivary clearance.

ANALYSIS AND RESULTS

Results

- The model was simulated using Python.
- The maximum AFT level decreased significantly as the hygiene coefficient increased.
- AFT reached a steady state faster as the brushing interval increased (when hygiene decreased).
- The models showed a rapid increase in AFT formation in the early stages, but then stabilized (due to capacity limitations).

Conclusion

The presented mathematical model represents the AFT formation process in a simplified but accurate way. Through this model, it is possible to predict how the AFT level changes when the individual effect of oral hygiene and the brushing interval are changed. In further studies, the temperature, pH and other parameters of the biological environment can be integrated into the model.

References

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