0304

Periodontal Biomarker and Diagnosis With Machine Learning and Causal Inference

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Objectives Periodontal disease arises from the complex multifaceted interplay of genetic, environmental, and particularly dysbiotic microbial activity. This imbalance in the oral microbiome triggers the disease, emphasizing the need for nuanced understanding and approaches in management. The capacity of Causal Inference to dissect the intricate cause-and-effect relationships among these varied factors offers a deeper understanding of disease. Machine Learning's ability to analyse extensive datasets unveils patterns crucial for predicting disease trajectories with heightened accuracy.

Our study aims to use Causal Inference and Machine Learning to link clinical parameters and microbial biomarkers in periodontal disease, developing a novel parameter to enhance diagnosis and enable personalised treatment strategies.
Methods In our study of 324 individuals, we explored the link between microbial markers (Lipopolysaccharides and Lipoteichoic acid) and clinical parameters of periodontal disease. Through Causal Inference, we established a connection between these biomarkers and disease categorizations, leading to the development of a novel biomarker. This was then evaluated in Machine Learning models (Random Forest, SVM, XGBoost, Lasso Regression) to refine disease progression prediction, aiming to improve diagnostic accuracy and personalize treatment approaches.
Results Our causal analysis identified a strong correlation between our newly synthesized biomarker and the progression of periodontal disease effectively capturing dysbiotic activity. Applying this biomarker across ML models—Random Forest, SVM, XGBoost, Lasso Regression—enhanced disease severity prediction accuracy. This uniform improvement across models highlights their diagnostic effectiveness, marking a step forward in periodontal diagnostics.
Conclusions This study marks the first application of a combined ML and CI approach to analyse periodontal biomarkers. By employing CI algorithms, we effectively integrated Endotoxin Activity (EA) and Lipoteichoic Acid (LTA) to demonstrate periodontal disease development. Furthermore, we compared multiple ML models for disease diagnosis. This innovative approach enhances our understanding of periodontal disease dynamics, offering the potential for more accurate diagnostics and personalised periodontal care.