Review Article

How Artificial Intelligence and Omics are Shaping Personalised Treatment in Dentistry

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Abstract

AI and omics technologies, including genomics, proteomics, metabolomics, and microbiomics, are driving forces in an era of personalized dentistry. AI rapidly analyses large-scale omics data, identifies patterns, predicts disease risks, and tailors treatment plans for individual patients. These tools support early diagnosis, precise interventions, and improved outcomes in oral healthcare. The article explores how AI integrates the application of omics in caries assessment, periodontal disease management, and oral cancer detection. It highlights the limitations and the future potential of new technologies in personalised care.

Keywords: Artificial intelligence, Omics, Personalised Dentistry,

Introduction

The dominant philosophy in dentistry remains rooted in traditional therapeutic approaches. However, a paradigm shift towards personalized clinical dentistry is on the horizon, driven by the integration of artificial intelligence and genomic technologies. This transformation promises to enhance diagnostics, treatment, precision, and overall patient care.

Omics encompasses genomics, transcriptomics, proteomics, and metabolomics technologies, which study biological molecules such as DNA and proteins. These technologies facilitate a deeper understanding of microbial populations and individual reactions to environmental factors at the molecular level.

Machine learning algorithms are adept at analysing and extracting meaningful patterns from complex omics data sets. It allows researchers to make predictions about diseases, states, drug responses, and biological mechanisms at a much deeper level than traditional methods. AI is a powerful tool for unlocking these insights hidden within omics data.

Omics as a catalyst to change

The suffix "Omics" contributes to these technologies.[(1)] They are

Genomics: decoding DNA and genetic disease

It is the study of the genome, or the genes, in the body. Genes are composed of DNA, which has a specific nucleic acid sequence. This sequence is determined by genomic technologies and used to study the variations of genes between individuals and mutations within their genomes. The human body is comprised of over 20,000 protein-coding genes, which form proteins necessary for normal body functions. If DNA is mutated, it can lead to severe disorders and diseases, such as cancer and cystic fibrosis.

Transcriptomics and gene expression

Transcriptomics studies the ribonucleic acid (RNA). Before DNA forms a protein, it undergoes transcription, and the DNA sequence of a specific gene is copied into a sequence of messenger RNA to synthesise a protein.[(1)]

Transfer RNA is also involved in protein synthesis, while ribosomal RNA and non-protein-coding RNA are involved in various cellular functions.

Similar to genomics, RNA sequences are evaluated through transcriptomics. Studying RNA tells gene activity, which determines gene expression. While almost all the cells in our body have the same genes, they have different gene expression patterns. Gene expression can be altered due to certain diseases.

Proteomics: proteins and their modifications

The study of proteins is called proteomics. Protein levels depend on the amount of mRNA made for that protein, which is also affected by other factors. After protein synthesis, it undergoes post-translational modifications (in turn PTMs) that alter the structure of the proteins, thereby changing their function. Proteomics is used to study proteins, including the amount of protein, how the protein is modified, and to estimate the rate at which proteins are produced and degraded.[(2)]

Metabolomics: profiling biochemical pathways

Metabolites are small molecules formed or used during metabolism when our body breaks down food, drugs, chemicals, or tissue in the cells, fluids, or organs. Metabolites include nucleotides, carbohydrates, amino acids, and fatty acids. Determining changes in metabolites helps diagnose certain diseases, predict disease progression, and elucidate the development of specific diseases.

Epigenomics: **gene regulation**

The epigenome is a combination of chemical compounds and proteins that attach to the DNA as a mark. Epigenetic marks can turn on or off the genes in particular cells, affecting gene expression. During cell division, the daughter cells may have the same epigenetic marks. Epigenetic marks get passed to a child from a parent. Cells in the body have different specific functions as they are a part of tissues and organs. As a result, only the genes necessary for that particular cell to function are expressed. The epigenome helps regulate the expression of this specific gene. Abnormal epigenetic marks can lead to the activation or inactivation of genes involved in various diseases, including cancer, autoimmune disorders, and neurological disorders.

Microbiomics- influencing the community

Bacteria, fungi, parasites, and viruses are the community of trillions of microorganisms in our body, forming a microbiome. The microbiome interacts with our body, and this interaction can:

- It is beneficial in helping you produce essential vitamins
- Harmful by increasing your risk of developing certain cancers
- Be neutral- neither harm nor benefit anyone

Investigating changes in the microbiome helps to understand diseases and the risk of developing them.

Interactomics: mapping the interactions

Different types of interactions can be studied, such as between

- protein-protein
- protein-metabolite
- RNA-protein
- DNA-protein
- RNA-RNA
- DNA-RNA

Studying these interactions is a key aspect of transcriptomics, which enhances our understanding of how the body functions and how diseases develop and progress, and aids in identifying potential drug targets for various diseases.

The Oral Microbiome

The mouth serves as an entry point to both the respiratory and digestive systems. It houses the highest concentration of bacteria after the gut, harboring over 700 species of bacteria. Numerous studies have linked oral microbiota to potential biomarkers of systemic diseases.

The hard and soft tissues in the oral cavity, along with the mucosa, provide a rich environment for bacteria to flourish.

Firmicutes, Proteobacteria, Bacteroidetes, Actinobacteria, and Fusobacteria thrive at 37 degrees centigrade and pH levels ranging from 6.5 to 7.5, making them ideal for the oral environment. *Streptococcus,*[(4)], along with *Prevotella, Veillonella, Neisseria, and Haemophilus,* are common inhabitants of the oral cavity.

The microbiome is a dynamic environment of trillions of bacteria, fungi, parasites, and viruses within our body. The core microbiome is the same, while the variable microbiome is unique. It changes daily, weekly, and monthly depending on our diet, medication, exercise, and other environmental exposures.[(3)]

Salivaomics: The New Era of Saliva in Dentistry

Saliva is a safe and non-invasive sample for studying oral and systemic diseases. It is gaining importance as a biofluid for the early diagnosis of several diseases. As a reflection of oral and systemic health, saliva is a valuable source of clinically relevant information. Studies have shown that saliva plays a role in detecting and diagnosing malignant tumors, human immunodeficiency virus (HIV), heart disease, and autoimmune diseases. Saliva is an important source of information.

Blood remains the primary diagnostic sample for diagnosing illnesses, but saliva is gradually gaining diagnostic relevance due to its non-invasive, simple, and rapid collection process. Saliva has fluids from major and minor salivary glands, gingival crevicular fluids, microorganisms, bronchial secretions, desquamated epithelial cells, and cellular components. It makes saliva a source of biomarkers. The disadvantage is the discrepancy between the serum and salivary markers.

Biomarkers are any substances, structures, or processes that can be measured in the body or its products and can influence or predict the incidence of outcomes or diseases.

Most disorders can be detected only when their symptoms appear. The biomarkers reflect health even before the symptoms appear. These biomarkers aid in the diagnosis of periodontal diseases, malignancies, and oral squamous cell carcinoma.

Porphyromonas gingivalis (*P. gingivalis*), *Tannerella forsythia* (*T. forsythia*), *Treponema denticola* (*T. denticola*), *Filifactor alocis* (*F. alocis*), and *Peptoanaerobacter stomatis*[4] are pathogens causing chronic periodontitis. The metabolic products of one bacterium interact with those of others, increasing the growth of P. gingivalis and contributing to the development of periodontitis. *F. alocis* is a key pathogenic bacterium in altering the oral microbiome in periodontitis, so it is a periodontal disease biomarker. Periodontitis diagnosis involves the use of X-rays, measuring gum pocket depth, assessing bleeding, and evaluating attachment loss around teeth. However, saliva contains molecules from the body and bacteria that reveal inflammation and tissue damage. These molecules, known as biomarkers, can aid in detecting, tracking, and treating gum disease.

Bacteria are not only biomarkers for periodontitis but also for oral cancer. *P. gingivalis* and *Fusobacterium nucleatum* have carcinogenic potential. An increased salivary concentration of *Capnocytophaga gingivalis*, *Prevotella melaninogenica,* and *Streptococcus mitis* occurs in oral cancer-affected patients.[4]

The Role of Omics in Dentistry

Omics technologies help us understand the molecular mechanisms behind oral conditions. For example:

- **Proteomics** detects specific protein biomarkers in saliva or gingival crevicular fluid, enabling the early diagnosis of inflammation and tissue damage.
- **Genomics** helps us identify genetic risk for periodontal disease or dental caries.
- **Metabolomics** reveals metabolic pathways associated with oral diseases, providing insights into the interactions between microbes and the host.

Despite these advancements, the volume and complexity of omics data pose significant challenges for their practical application in dentistry. Artificial Intelligence (AI) steps in, leveraging its transformative potential and gaining considerable attention.

AI Enhances Omics Integration

Dentists are the first to spot signs of gum disease. Gum diseases signal a systemic imbalance. By recognizing the unique salivary microbiome of patients with gum disease, dentists may one day be able to detect complications early, using saliva to test and tailor treatments.

Data Analysis and Pattern Recognition

Omics studies generate massive datasets of variables. AI algorithms, particularly machine learning (ML) models, are excellent at processing such data, identifying patterns, and correlating biomarkers with clinical outcomes. ML models can analyse salivary proteomic profiles and predict the onset of diseases.[3]

Predictive Modelling

AI can predict diseases, risks, and forecast treatment outcomes using omics data. In orthodontics, for example, genetic data with AI tools can help predict how a patient's teeth will respond to specific interventions, improving treatment planning and reducing complications.[5]

Personalized Treatment Plans

By combining patient-specific omics data with clinical records, AI can help design tailored treatment plans. For instance, AI can analyse a patient's genetic predisposition, microbiome composition, and proteomic markers to recommend individualised therapies for managing periodontal disease.[5]

Real-Time Decision Support

AI-powered tools integrated into dental software provide real-time insights based on omics data, enabling dentists to make data-driven decisions during chairside consultations and improve the quality and speed of care.

Applications in Dental Practice

Early Detection of Diseases

AI-driven omics data can detect subtle molecular changes that occur even before clinical symptoms appear, enabling the detection of peri-implantitis or early-stage oral infections.

Improving Implant Success Rates

Microbiomics and proteomics data, combined with AI models, help predict and mitigate the risks of implant failure. AI can analyse peri-implant tissue samples to identify markers of inflammation or microbial imbalance.

Non-Invasive Diagnostics

Saliva, a biofluid, is a rich source of omics data. AI-powered saliva-based diagnostic tools can non-invasively monitor oral health, detect systemic diseases, and even assess treatment progress.[6]

Education and Training

AI tools can help dental professionals interpret complex omics datasets, bridging the knowledge gap and facilitating the adoption of these technologies in clinical settings.

Future and challenges

Omics in personalized dental care marks a significant advancement in modern dentistry. By utilizing genetic information, dental professionals can offer precise, effective, and personalized treatment plans. However, using these techniques requires special training, continuous skill upgradation, and overcoming challenges related to accessibility, affordability, and resource availability. A seamless adoption necessitates collaborative efforts in education, research, and technology development.

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