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SOCIAL DETERMINANTS AND GENETIC FACTORS IN ORAL HEALTH: TOWARD A PRECISION DENTISTRY APPROACH

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ABSTRACT
Oral health is increasingly recognized as a multidimensional concept influenced by biological, behavioral, environmental, and social determinants. In recent decades, growing evidence has highlighted the contribution of genetic susceptibility and inflammatory pathways to the development and progression of oral diseases. This narrative review aims to summarize current knowledge regarding the influence of social determinants and inflammatory genetic factors on oral health outcomes. Socioeconomic status, educational attainment, and access to dental services significantly affect oral disease burden and contribute to persistent health inequalities. Concurrently, genetic polymorphisms involving immune mediators such as interleukin-1 and interleukin-6 may alter host responses to microbial challenges, thereby influencing the susceptibility and severity of periodontal diseases. Rare inherited inflammatory disorders, including Behçet disease, PAPA syndrome, and Papillon–Lefèvre syndrome, further illustrate the role of genetic dysregulation in oral pathology. Advances in genomics have created opportunities for precision dentistry through individualized prevention, risk stratification, and targeted therapeutic approaches. Nevertheless, the successful implementation of personalized oral healthcare requires the integration of genomic discoveries with established public health strategies aimed at addressing the broader social determinants of health. Combining population-based interventions with emerging precision medicine approaches may contribute to reducing oral health disparities and improving long-term outcomes.

KEYWORDS: oral health; social determinants; periodontitis; genetics; precision dentistry; personalized medicine.

INTRODUCTION
Oral health is increasingly recognized as a complex and multidimensional component of general health and well-being. The FDI World Dental Federation defines oral health as multifaceted and inclusive of the ability to speak, smile, smell, taste, touch, chew, swallow, and convey positive emotions without pain, discomfort, or disease affecting the craniofacial complex. This broader perspective emphasizes that oral health extends beyond the absence of oral pathology and is intrinsically linked to quality of life, social participation, and overall health status.[1]

The determinants of oral health are diverse and encompass biological, behavioral, psychological, social, and environmental factors. These determinants influence the development, progression, and consequences of oral diseases throughout the life course. Social conditions, including education, income, occupation, and access to healthcare services, significantly affect health-related

behaviors, utilization of preventive services, and treatment-seeking patterns, thereby contributing to disparities in oral health outcomes among populations.[2,3]

In parallel with social influences, advances in molecular biology have highlighted the importance of genetic factors in determining individual susceptibility to oral diseases. Genetic variations may influence tooth development, enamel composition, salivary characteristics, immune responses, and inflammatory pathways, ultimately modifying the risk and severity of oral conditions such as dental caries, periodontitis, and oral cancer.[4,5]

The interaction between genetic predisposition and environmental exposures represents a key concept in contemporary oral medicine. While population-level interventions remain essential for reducing disease burden, an improved understanding of host genetic variability may facilitate the development of personalized preventive and therapeutic strategies.

The aim of this narrative review is to summarize current evidence regarding the influence of social determinants and inflammatory genetic factors on oral health outcomes and to discuss their implications for future preventive and personalized approaches in dentistry.

SOCIAL DETERMINANTS OF ORAL HEALTH

Socioeconomic inequalities have a profound impact on the distribution and burden of oral diseases across populations. Dental caries, the most prevalent oral condition worldwide, arises from a complex interaction of biological, behavioral, and social determinants. Numerous studies have demonstrated that individuals from disadvantaged socioeconomic backgrounds experience a greater prevalence and severity of dental caries. Indicators such as lower educational attainment, reduced income, and less favorable occupational status have consistently been associated with increased caries experience across different age groups.[6]

A similar pattern has been observed in periodontal diseases. Although the development of periodontitis is strongly influenced by microbial biofilms and host immune responses, socioeconomic factors also contribute significantly to disease susceptibility and progression. Individuals exposed to long-term socioeconomic disadvantage are more likely to develop periodontitis during adulthood, partly due to limited access to preventive care, higher prevalence of behavioral risk factors, and increased exposure to chronic stressors.[7]

The influence of social determinants extends beyond common oral diseases and includes serious conditions such as oral and head and neck cancers. Research has shown that lower income, reduced educational achievement, and social deprivation are associated with a higher risk of developing these malignancies.[8] These associations may be explained by disparities in healthcare access, delayed diagnosis, and increased exposure to established risk factors, including tobacco and alcohol consumption.

Other oral health conditions also exhibit clear socioeconomic gradients. Traumatic dental injuries represent a significant public health concern due to their high prevalence and potential consequences on aesthetics, psychosocial well-being, and quality of life. Similarly, temporomandibular disorders constitute one of the leading causes of non-dental orofacial pain and can substantially impair daily functioning and overall well-being. In both conditions, social and environmental factors may influence exposure to risk and access to appropriate treatment.[9,10]

Access to dental care remains a critical determinant of oral health outcomes. Individuals belonging to ethnic minority groups, immigrant populations, or lower socioeconomic categories generally utilize dental services less frequently than more advantaged groups. Income-related disparities are evident throughout the life course, with children from higher-income families receiving dental care more regularly and older adults with greater socioeconomic resources attending routine dental visits more often than those with limited financial means.[11,12] These findings highlight the important role of social determinants in shaping oral health inequalities and emphasize the need for targeted public health interventions aimed at reducing disparities in access to care and disease burden.

The evidence presented above demonstrates that oral diseases are not distributed randomly within populations. Instead, they are strongly influenced by broader social conditions that shape health behaviors, healthcare utilization, and exposure to risk factors. Table 1 summarizes the principal social determinants associated with oral health outcomes and the mechanisms through which they contribute to oral health inequalities.

Table 1: Social determinants influencing oral health outcomes.

Social determinant	Impact on oral health	Mechanisms involved	Representative oral conditions
Socioeconomic status	Increased disease burden in disadvantaged groups	Limited financial resources, reduced access to preventive services	Dental caries, periodontitis
Educational attainment	Lower oral health literacy and poorer preventive behaviors	Reduced awareness regarding oral hygiene practices and risk factors	Dental caries, periodontal disease
Access to dental	Delayed diagnosis and	Geographic, financial, and	Advanced caries, tooth loss,

care	treatment	organizational barriers	oral cancer
Ethnicity and migration status	Reduced utilization of dental services	Cultural differences, language barriers, discrimination	Untreated oral diseases
Health-related behaviors	Direct influence on disease development	Oral hygiene habits, tobacco use, dietary practices	Caries, periodontitis, oral cancer
Chronic psychosocial stress	Increased susceptibility to inflammatory diseases	Neuroendocrine and immune dysregulation	Periodontal disease, temporomandibular disorders

GENETIC AND INFLAMMATORY FACTORS IN ORAL HEALTH

Genetic predisposition has also been implicated in the pathogenesis of oral malignancies, where specific mutations can contribute to cancer susceptibility and progression.[13] Furthermore, hereditary factors play a significant role in determining tooth size, shape, eruption patterns, and occlusal relationships, all of which influence oral function and esthetics. Genetic regulation of salivary gland development and function may also affect saliva quantity and composition, thereby impacting the maintenance of oral homeostasis. In certain cases, genetic influences are evident from birth, contributing to craniofacial abnormalities such as cleft lip and cleft palate, conditions that arise through complex interactions between genetic susceptibility and environmental exposures.[14]

Beyond structural and developmental influences, genetic factors are also involved in the regulation of immune and inflammatory responses within the oral cavity.

Among the genetic factors investigated in periodontal disease, polymorphisms affecting inflammatory cytokines have received particular attention. Variations in the interleukin-6 (IL-6) gene have been associated with differences in host inflammatory responses. As IL-6 is a key mediator of immune regulation, certain genetic variants may promote a more pronounced inflammatory reaction following bacterial infection, thereby increasing the likelihood of periodontal tissue destruction and severe forms of periodontitis.[15]

The interaction between genetic predisposition and environmental exposures represents another important aspect of periodontal disease pathogenesis. One of the most extensively studied examples involves polymorphisms within the interleukin-1 (IL-1) gene cluster. Individuals carrying specific IL-1 variants associated with increased inflammatory activity appear to be more vulnerable to periodontal breakdown, particularly when additional risk factors are present. Tobacco smoking is considered a classic example of a gene–environment interaction, as it not only alters the oral microbiota but also enhances inflammatory responses in genetically susceptible individuals, contributing to accelerated periodontal attachment loss and alveolar bone destruction.[16]

Despite the substantial body of evidence regarding the contribution of genetic polymorphisms to common oral diseases such as dental caries and periodontitis, rare inherited inflammatory disorders provide additional insight into the complex relationship between genetic dysregulation and oral health. These conditions illustrate how alterations in immune signaling pathways may profoundly influence oral manifestations and disease severity.

The available evidence indicates that genetic factors contribute to oral diseases through multiple biological mechanisms, including altered immune responses, modifications of dental structures, and dysregulation of inflammatory pathways. Selected examples of genetic factors implicated in oral diseases are presented in Table 2.

Table 2: Genetic and inflammatory factors associated with oral diseases.

Genetic factor	Gene/polymorphism	Proposed mechanism	Associated oral condition
Interleukin-1 gene cluster	IL-1 polymorphisms	Enhanced production of pro-inflammatory cytokines	Chronic periodontitis
Interleukin-6	IL-6 variants	Altered host inflammatory response	Severe periodontal disease
Enamel-related genes	Multiple candidate genes	Modification of enamel composition and resistance to demineralization	Dental caries
HLA-B51	HLA-B51 allele	Immune dysregulation and abnormal inflammatory responses	Behçet disease
PSTPIP1 mutations	PSTPIP1 gene	Inflammasome dysfunction and excessive cytokine release	PAPA syndrome
CTSC mutations	Cathepsin C (CTSC) gene	Impaired immune function and defective neutrophil activity	Papillon–Lefèvre syndrome
Oncogenic mutations	Various susceptibility genes	Altered cell proliferation and apoptosis	Oral cancer

Behçet Disease

Behçet disease is a chronic multisystem inflammatory disorder characterized by recurrent episodes of inflammation affecting multiple organ systems, including the mucocutaneous, ocular, vascular, musculoskeletal, neurological, and gastrointestinal systems. Oral ulcerations are among the most frequent manifestations and often represent the earliest clinical sign of the disease. A distinguishing feature of Behçet disease is its relapsing-remitting course, with periods of exacerbation alternating with intervals of relative remission. Although the exact etiology remains incompletely understood, current evidence suggests that the disease results from a complex interaction between genetic susceptibility and environmental triggers. The HLA-B51 allele has been identified as one of the strongest genetic risk factors, while immune dysregulation and abnormal inflammatory responses are considered central mechanisms in disease pathogenesis.[17]

PAPA Syndrome

PAPA syndrome (Pyogenic Arthritis, Pyoderma Gangrenosum, and Acne syndrome) is a rare hereditary autoinflammatory disorder associated with mutations in the PSTPIP1 gene. These genetic alterations disrupt normal inflammatory regulation by affecting inflammasome activation, leading to excessive production of pro-inflammatory mediators. As a consequence, affected individuals experience recurrent episodes of sterile joint inflammation, severe skin lesions, and chronic inflammatory manifestations. The syndrome illustrates the critical role of genetic factors in controlling innate immune responses and highlights how disturbances in inflammatory signaling pathways can contribute to systemic disease.[18]

Papillon–Lefèvre Syndrome

Papillon–Lefèvre syndrome is a rare autosomal recessive disorder caused by mutations in the cathepsin C (CTSC) gene. The condition is classically characterized by palmoplantar hyperkeratosis and severe early-onset periodontal destruction. Oral manifestations are often among the most striking clinical features, with affected individuals developing intense gingival inflammation, rapid loss of periodontal attachment, and premature exfoliation of both primary and permanent dentitions. Because periodontal breakdown frequently represents the first major clinical sign, dentists often play a crucial role in the early recognition of the syndrome. Progressive tooth loss can significantly impair mastication, speech, and quality of life, emphasizing the importance of early diagnosis and multidisciplinary management. Papillon–Lefèvre syndrome represents a notable example of how genetic defects affecting immune and inflammatory pathways can profoundly influence periodontal health.[19]

The complex interactions between social determinants, environmental exposures, genetic susceptibility, and inflammatory pathways involved in the development of oral diseases are summarized in Figure 1.

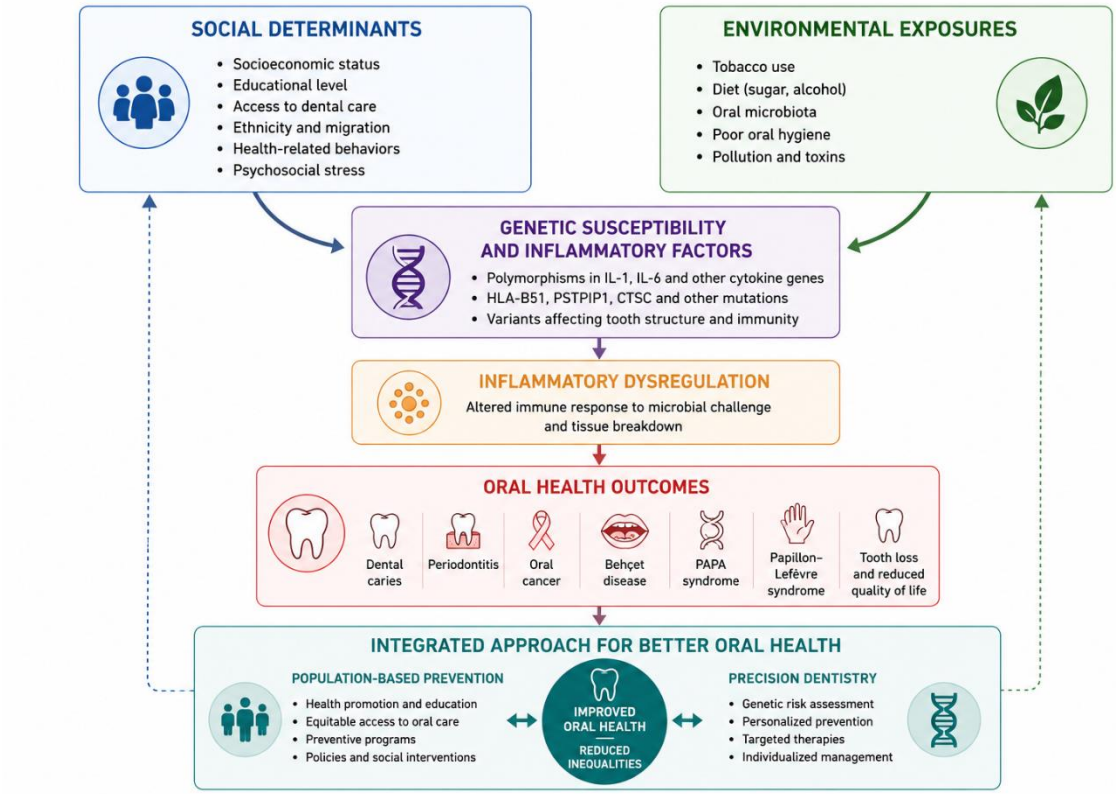

Figure 1. Proposed conceptual framework illustrating the interplay between social determinants, genetic susceptibility, inflammatory mechanisms, and oral health outcomes.

Legend: Schematic representation of the multifactorial determinants of oral health. Social determinants, including socioeconomic status, educational attainment, access to dental care, ethnicity, health-related behaviors, and psychosocial stress, interact with environmental exposures to influence oral health trajectories. Concurrently, host genetic susceptibility factors, such as polymorphisms in inflammatory cytokine genes and mutations associated with inherited inflammatory disorders, modulate immune responses and contribute to inflammatory dysregulation. These complex interactions may lead to the development and progression of various oral conditions, including dental caries, periodontitis, oral cancer, Behçet disease manifestations, PAPA syndrome, and Papillon–Lefèvre syndrome. The figure also highlights the complementary roles of population-based prevention strategies and precision dentistry approaches in promoting oral health and reducing health inequalities.

MANAGEMENT AND TREATMENT

The prevention and management of oral diseases require an integrated approach that addresses both population-level determinants and individual risk factors. Traditional preventive measures remain fundamental and include twice-daily toothbrushing with fluoride toothpaste, appropriate fluoride exposure, dietary counseling aimed at reducing free sugar intake, smoking cessation programs, and regular dental attendance. These interventions have consistently demonstrated effectiveness in reducing the prevalence of common oral diseases while contributing to lower healthcare expenditures.[20]

From a public health perspective, strategies designed to reduce oral health inequalities are equally important. Policies aimed at improving access to dental services, expanding preventive programs within underserved communities, and promoting oral health literacy may substantially reduce the burden of oral disease among vulnerable populations. Early-life interventions, particularly those targeting socially disadvantaged groups, have the potential to generate long-term benefits extending into adulthood.

Recent advances in genomics have introduced new opportunities for precision oral healthcare. Genetic testing may help identify individuals with increased susceptibility to conditions such as dental caries, aggressive forms of periodontitis, or hereditary syndromes with oral manifestations. Early identification of high-risk individuals may facilitate personalized preventive strategies, more frequent clinical monitoring, and timely therapeutic interventions.[21]

Furthermore, understanding genetic variations involved in inflammatory pathways may contribute to the development of targeted therapies capable of modulating host responses. In the field of oral oncology, the identification of genetic markers associated with increased cancer susceptibility may support earlier diagnosis and improve prognostic assessment.[22]

Nevertheless, several challenges currently limit the routine implementation of genomic dentistry in clinical practice. These include the high costs associated with genetic testing, limited accessibility in many healthcare systems, ethical considerations related to genetic information, and the need for further validation of predictive biomarkers in diverse populations. Consequently, although personalized approaches represent a promising direction for future dental care, their integration into routine practice should complement rather than replace established population-based preventive measures.[23]

As precision medicine continues to evolve, the combination of traditional preventive strategies with individualized risk assessment may contribute to improved treatment outcomes and more effective long-term oral health management.[24]

The transition toward precision dentistry has the potential to transform oral healthcare by integrating genetic information into preventive and therapeutic decision-making. Nevertheless, several barriers currently limit the widespread adoption of these approaches. Table 3 summarizes the principal applications, expected benefits, and existing challenges associated with personalized oral healthcare.

Table 3: Implications of precision dentistry for future oral healthcare.

Clinical application	Potential benefits	Current limitations
Genetic risk assessment	Early identification of susceptible individuals	Limited predictive value of isolated markers
Personalized prevention	Tailored preventive protocols and monitoring schedules	Insufficient evidence for routine implementation
Targeted therapies	Improved treatment outcomes through modulation of inflammatory pathways	High costs and limited availability
Oral cancer susceptibility testing	Earlier diagnosis and improved prognostic evaluation	Ethical considerations and need for validation
Integration of genomic data into dental practice	Enhanced precision in treatment planning	Lack of standardized guidelines and clinician training
Population-based precision health approaches	Reduction of disease burden through stratified interventions	Potential increase in healthcare inequalities if accessibility remains limited

DISCUSSION

The findings summarized in this review emphasize that oral diseases should not be regarded solely as the consequence of individual behaviors or biological susceptibility. Rather, they emerge from a complex interaction between social determinants, environmental exposures, and host-related genetic factors. While socially disadvantaged populations continue to experience a disproportionate burden of oral disease due to barriers in healthcare access and reduced preventive opportunities, genetically susceptible individuals may exhibit an exaggerated inflammatory response that further contributes to disease progression.[22]

Importantly, advances in oral genomics should not shift the focus away from population-based prevention. Although precision dentistry offers promising opportunities for individualized risk assessment and targeted interventions, its implementation must occur within an equitable healthcare framework. Failure to address social determinants may inadvertently widen existing health disparities by restricting access to emerging genomic technologies to more privileged populations.[25]

Future research should prioritize interdisciplinary approaches integrating epidemiological, genetic, and clinical data to better characterize the interactions between environmental influences and host susceptibility. Large multicenter studies and the development of validated predictive models may facilitate the translation of genomic discoveries into routine dental practice while preserving the principles of public health and equitable access to care.[26]

LIMITATIONS

The present article represents a narrative review of the available literature and therefore does not follow a systematic review methodology. The selection of studies was not based on predefined inclusion and exclusion criteria, which may introduce selection bias. In addition, the rapidly evolving nature of oral genomics and personalized medicine implies that newly emerging evidence may further refine current understanding of the genetic determinants involved in oral diseases. Future systematic reviews and meta-analyses are warranted to provide a more comprehensive evaluation of the interactions between social determinants, inflammatory pathways, and genetic susceptibility in oral health.

CONCLUSION

Oral health is determined by a complex interplay of social, environmental, and genetic factors that exert their influence throughout the life course. Social determinants, including socioeconomic status, educational attainment, and accessibility of dental care services, represent major drivers of oral health outcomes at the population level. Simultaneously, interindividual variability in genetic susceptibility and immune-inflammatory responses may significantly influence the onset, clinical expression, severity, and progression of oral diseases.

The conditions discussed in this review, including periodontitis, Behçet disease, PAPA syndrome, and Papillon–Lefèvre syndrome, exemplify the pivotal role of genetic and immunological mechanisms in oral health and disease. Their study contributes to a deeper understanding of the biological heterogeneity underlying oral pathologies and highlights the importance of interdisciplinary approaches in patient management.

As knowledge regarding genetic risk factors and disease-associated molecular pathways continues to expand, personalized approaches to prevention, risk assessment, and treatment are expected to assume an increasingly prominent role in dental practice. However, meaningful improvements in oral health outcomes will depend not only on advances in precision medicine but also on sustained efforts to address the broader social determinants responsible for persistent inequalities in oral healthcare access and disease burden.

Integrating population-based preventive strategies with emerging genomic technologies represents one of the major challenges and opportunities of contemporary dentistry. Achieving this balance may contribute not only to improved oral health outcomes but also to a more equitable distribution of the benefits associated with precision medicine.

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