# ETIOLOGY OF DENTAL CARIES

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**Abstract:** Dental caries is a multifactorial, biofilm-mediated, diet-modifiable disease characterized by the demineralization of dental hard tissues. Its etiology involves a complex interaction between cariogenic microorganisms, fermentable carbohydrates, host susceptibility factors, and time. Mutans streptococci, Lactobacillus species, and other acidogenic and aciduric bacteria play a central role by metabolizing dietary sugars into organic acids, leading to a sustained decrease in plaque pH. Host-related factors—including tooth morphology, enamel composition, saliva flow and buffering capacity, and overall oral hygiene—significantly influence caries risk. Environmental and behavioral factors such as frequent sugar intake, poor dietary habits, inadequate fluoride exposure, and socioeconomic conditions also contribute to disease development. Understanding the etiology of dental caries is essential for implementing targeted preventive and therapeutic strategies, including nutritional counseling, plaque control, fluoride therapy, and minimally invasive treatment approaches.

**Keywords:** Dental caries, Etiology, Cariogenic bacteria, Mutans streptococci, Fermentable carbohydrates, Demineralization, Saliva, Fluoride, Biofilm, Risk factors

**Introduction:** Dental caries remains one of the most widespread chronic diseases globally, representing a major public-health challenge. According to the latest reports by World Health Organization (WHO), roughly 2.5 billion people worldwide suffer from caries in permanent teeth, while hundreds of millions of children have

caries in their primary (deciduous) dentition. This staggering burden underscores that caries is not confined to childhood but persists across the entire lifespan — from deciduous teeth in early childhood to permanent dentition, and even into older age.

Epidemiological data illustrate that despite advances in dental care, the global incidence and prevalence of dental caries have remained stubbornly high over the past decades. For example, a recent systematic analysis showed that between 1990 and 2019, the number of caries cases in permanent teeth in children aged 5–14 increased from ~382 million to ~440 million — a 15.3 % rise in absolute numbers. Meanwhile, across all age groups, untreated caries in permanent dentition affects approximately 2.3 billion people worldwide. In older adults, meta-analytic evidence estimates a global caries prevalence of about 60.7 %.

The etiology of dental caries is complex and multifactorial, implicating interactions between microbial colonization, dietary behaviors (particularly fermentable carbohydrate intake), host susceptibility (e.g., enamel composition, saliva characteristics, tooth morphology), and behavioral and socioeconomic determinants. Disruptions in the delicate balance between demineralization and remineralization — driven by acidogenic bacterial metabolism of dietary sugars — lead to progressive breakdown of dental hard tissues. Given this complexity, the burden of caries reflects not only biological predisposition but also environmental, social, and behavioral contexts.

Moreover, because caries is preventable and progression can be modified through interventions such as fluoride exposure, oral hygiene practices, dietary counseling, and timely dental care, its persistent high prevalence points toward significant gaps in preventive dental health strategies worldwide. This gap is especially pronounced in low- and middle-income regions, where access to preventive services may be limited. Given the global epidemiologic burden, the multifaceted etiology, and the modifiable nature of many risk factors, a thorough, evidence-based understanding

of dental caries etiology is critical. Such understanding is foundational for designing effective preventive and therapeutic interventions tailored to different populations — from children with primary dentition to older adults — and for reducing the enormous personal, social, and economic costs associated with untreated caries.

In this review, we explore in detail the microbial, dietary, host, and environmental components contributing to dental caries. We also consider how changing demographic, dietary, and behavioral trends may influence future caries prevalence — highlighting the need for robust, proactive public health responses.

**Literature analysis: Recent large-scale meta-analytic evidence indicates substantial global burden of caries among older adults: a systematic review covering studies from 1991 to November 2024 (31 studies, total N = 26,703) estimated a pooled prevalence of 60.7% (95% CI: 54.6%–66.4%) for dental caries in the elderly. Region- and age-specific literature reveals striking heterogeneity. For instance, a meta-analysis on permanent-teeth caries in children from Arab countries reported a pooled prevalence of 72.6% (95% CI: 65.3%–78.9%) and a mean Decayed-Missing-Filled Teeth (DMFT) score of ~1.675.**

Epidemiological cross-sectional data from large school-based surveys further illustrate caries prevalence in younger populations. For example, a 2021 cross-sectional study among 21,403 school-aged children (mean age 12.8 ± 2.5 years) reported an overall caries prevalence of 40.5% (95% CI: 39.8–41.1%), with mean DMFT = 1.31 ± 2.11 and mean dmft (primary teeth) = 0.39 ± 1.24.

Beyond prevalence, recent bibliometric analyses have highlighted research trends and gaps in the field: one such bibliometric study examined 1,630 articles on “dental caries” (across etiology, detection, prevention, management) to identify prolific authors, institutions, and geographic contributions — shedding light on uneven global research distribution. Review literature focusing on socio-economically disadvantaged populations underscores the interplay between socioeconomic context

and heightened caries risk, often accompanied by higher disease severity and limited access to preventive care or restorative treatment.

Overall, the literature demonstrates that dental caries persists across all age groups, though prevalence, severity (e.g., DMFT), and risk factors vary substantially by region, age, socioeconomic status, and local public-health infrastructure. The observed heterogeneity suggests that etiology cannot be generalized globally; instead, local context (diet, hygiene practices, fluoride exposure, access to dental care) significantly modulates risk.

**Methodology of This Review:**

To build a robust, evidence-based understanding of caries etiology, the following methodology was adopted:

1. **Search Strategy & Source Selection**

We conducted systematic searches in major bibliographic databases using combinations of controlled vocabulary and free-text keywords: “dental caries,” “prevalence,” “DMFT,” “etiology,” “risk factors,” “systematic review,” “meta-analysis,” “cross-sectional study,” “longitudinal study.” Additional manual searches (reference-list screening, citation chaining) and gray-literature searches (national oral health surveys, WHO reports) supplemented database searches. Inclusion criteria: original research or review articles (epidemiological studies, meta-analyses, systematic reviews, longitudinal or cross-sectional), published in peer-reviewed journals, presenting quantitative data on caries prevalence, risk factors, or mechanistic investigations. Exclusion criteria: studies without adequate description of diagnostic criteria or those focusing solely on restorative outcomes without etiologic insights.

2. **Quality Assessment**

For meta-analyses and systematic reviews, methodological quality was appraised using established tools. For cross-sectional studies, we assessed sample representativeness (sampling method: random or stratified vs. convenience), sample size, diagnostic method (clinical vs. inclusion of radiographic examination), and adjustment for confounding variables. Where possible, we evaluated heterogeneity and potential publication biasas performed in the underlying studies.

3. **Data Extraction & Synthesis**

From each selected study we extracted: authors, year, country/region, sample size, age ranges, diagnostic criteria, caries prevalence (%), mean DMFT/dmft or comparable indices, measure of variance (95% CI or SD), and identified risk or protective factors. Quantitative data (prevalence, index scores) were tabulated and where appropriate pooled in narrative-synthesis form, highlighting ranges, central tendencies (mean/median), and variation across populations. Qualitative data (identified risk factors, socioeconomic determinants, protective behaviors) were categorized thematically (microbial factors; diet & nutrition; host-related factors saliva, enamel, tooth morphology; environmental & behavioral factors; public-health infrastructure / access).

4. **Critical Appraisal of Methodological Limitations**

We explicitly noted limitations in the existing literature: many cross-sectional studies use convenience sampling (which may bias prevalence estimates), diagnostic criteria often rely solely on clinical examination without adjunct radiography (thus underestimating lesion prevalence), and substantial heterogeneity between studies (different age groups, diagnostic thresholds, socioeconomic contexts) complicates direct comparisons. This aligns with prior global reviews indicating methodological variation hampers cross-study comparisons. Folder adult caries prevalence studies, we considered factors such as tooth retention (older cohorts retaining more teeth may artificially inflate caries prevalence) and access to dental care, which could influence

both prevalence and reporting bias. These issues are revealed in meta-analytic heterogeneity and effect-modifying analyses in recent works.

5. **Temporal and Predictive Analysis**

By examining temporal trends from longitudinal and repeated cross-sectional studies (where available) and meta-analytic time-trend analyses, we identify evolving patterns in caries epidemiology. Based on current trends — rising caries prevalence among older adults globally, combined with growing tooth retention in aging populations — we predict that unless preventive measures improve, the global burden of dental caries will further increase. This will likely exacerbate demand for restorative dental services and public-health interventions, especially in middle- and low-income countries undergoing demographic transition and dietary shifts.

***Results:*** *The present review, synthesizing global epidemiological and meta-analytic evidence, yields a detailed picture of the current burden, distribution, and likely future trajectory of Dental Caries. Key findings are organized below along major dimensions: global burden and trends; age- and region-specific prevalence; untreated caries and disability burden; and implications for future projections.*

**Global Burden and Trends**

According to the most recent comprehensive data from World Health Organization (WHO) and the Global Burden of Disease Study 2019 (GBD 2019), the global prevalence of caries in permanent teeth (for individuals > 5 years) is estimated at ≈ **29%**, corresponding to over **2.02 billion cases in 2019**.

Over the 1990–2019 period, the number of global cases of untreated caries in permanent teeth increased by approximately **46%**, while age-standardized incidence rates showed a slight upward trend (estimated annual percentage change, EAPC ≈ +0.01). Nevertheless, the age-standardized prevalence and years-lived-with-disability

(YLD) rates demonstrated modest declines (EAPC ≈ −0.13), likely reflecting improvements in detection, treatment, or reporting over time.

These findings indicate that while per-person risk (standardized) may be marginally decreasing, absolute numbers of affected individuals continue to rise — driven largely by global population growth and aging.

**Age and Regional Variability**

A recent meta-analysis focusing on older adults (age unspecified, global data from 1991–2024) estimated a pooled prevalence of dental caries at **60.7%** (95% CI: 54.6%–66.4%) for this age group. Within that meta-analysis, considerable variability was observed: reported prevalence ranged from as low as ~10.4% in some studies up to ~96.7% in others. The meta-regression associated higher caries prevalence with more recent study year (i.e., increasing over time), while larger sample sizes and higher study quality were correlated with slightly lower prevalence — suggesting some bias in small or lower-quality studies. Data for younger populations remain concerning: for example, global early-childhood caries (ECC) continues to show persistent or rising rates according to the most recent work from the Global Burden of Disease Study 2021.

Overall, these patterns highlight that the burden of dental caries is uneven: older adults globally carry very high disease prevalence, and children in many regions remain at persistent risk — often with wide disparity linked to regional, socioeconomic, and access-to-care factors.

**Untreated Caries and Disability Burden**

GBD 2021 data indicate that oral diseases affected approximately **3.69 billion people globally**, with untreated dental caries (permanent teeth) being the most common oral condition. The age-standardized prevalence of untreated caries in permanent teeth in 2021 was estimated as **27,500 per 100,000 population** (i.e., 27.5%), making it the leading contributor among oral conditions worldwide. The

enormous scale of untreated disease underscores serious gaps in access to preventive and restorative dental care globally — especially in low- and middle-income countries. These data confirm that dental caries remains not just a theoretical risk but an active, unmet health burden for large segments of the world population.

**Predictive Implications: Future Trajectory**

From the observed data and trend analyses, several predictions emerge:

1. **Absolute burden will continue to rise** — Given global population growth and demographic shifts (aging populations, particularly in developing nations), even if per-person caries risk stabilizes or declines modestly, the total number of individuals with caries is likely to increase over the next two decades.
2. **Growing load in older age cohorts** — As more older adults retain natural teeth into advanced age (due to better dental care, prosthetics avoidance), the high prevalence (~60%) in this group suggests a rising demand for complex restorative, preventive, and maintenance dental services.
3. **Persistent inequities across regions** — Without targeted improvements in access to dental care, fluoride exposure, dietary counseling, and oral hygiene — especially in low- and middle-income regions — the disparities in untreated caries prevalence are likely to widen, exacerbating oral-health-related inequality.
4. **Increased disability and healthcare burden** — Given the prevalence and chronicity of caries, the overall years-lived-with-disability (YLD) attributable to untreated caries may continue growing, imposing heavy economic and social costs globally.

**Summary of Key Quantitative Findings**

| Metric / Population | Estimated Value (Global / Pooled) |
|---|---|
| Prevalence of caries in permanent teeth (age >5) — 2019 | ≈ 29% |
| Number of affected individuals (permanent teeth) — 2019 | ≈ 2.02 billion |
| Growth in number of cases 1990–2019 | +46% |
| Prevalence among older adults (meta-analysis 1991–2024) | 60.7% (95% CI 54.6%–66.4%) |
| Age-standardized prevalence of untreated caries (2021) | 27,500 per 100,000 (≈ 27.5%) |

**Interpretation: The data synthesized here confirm that dental caries remains a leading global oral-health burden, affecting billions worldwide across all age groups. The increase in absolute case numbers — despite slight declines in standardized prevalence — underscores that demographic and systemic factors (population growth, aging, unequal access to care) play a major role. The high pooled prevalence among older adults is particularly worrisome, indicating that an expanding segment of the global population may require complex, long-term dental treatment. Meanwhile, persistence (or growth) of caries in children suggests that early-life prevention is still insufficient in many regions. Taken together, these results bolster the view that dental caries is less a relic of the past and more a contemporary, growing challenge — requiring renewed public-health focus, resource allocation, and preventive strategy implementation worldwide.**

***DISCUSSION:*** *The results of this review reinforce the conclusion that Dental Caries remains a dominant global oral-health challenge, pervasive across ages,*

*geographies, and socioeconomic strata. Despite decades of preventive efforts globally, the sheer scale of disease — now affecting billions — suggests that etiological determinants remain insufficiently controlled in substantial portions of the world.*

**Interpretation of Global Trends & Burden**

According to data from the Global Burden of Disease Study (GBD 2021), about 3.69 billion people worldwide were affected by oral conditions in 2021 — with untreated caries of permanent teeth being the most common. The age-standardized prevalence of untreated caries in permanent dentition was estimated at 27,500 per 100,000 population in 2021. While age-standardized rates (prevalence and YLD) for caries have shown modest declines over the 1990–2019 period (EAPC ≈ –0.13% for both ASPR and ASYR), the **absolute number** of cases surged: in 2019 alone, there were ~3.09 billion incident cases of untreated caries in permanent teeth, and ~2.03 billion prevalent cases. This divergence between standardized rates and absolute case loads underscores a key point: demographic shifts — population growth and ageing — are driving the rising total burden even if per-person risk is relatively stable or slightly decreasing.

This pattern suggests that interventions have had **some effect** at reducing risk per individual (reflected in declining standardized rates), but are **insufficient** to offset population-level drivers. In particular, the large increases in case numbers in low- and middle-income regions point to structural and systemic challenges (access to preventive care, effective public-health programs, socioeconomic inequalities) that hinder meaningful reductions in disease burden.

**Heterogeneity across Regions and Populations**

Our review also highlights wide heterogeneity in caries burden across demographic and geographic contexts. For example, a recent meta-analysis of older

adults worldwide estimated a pooled caries prevalence of 60.7% — though individual studies ranged from as low as 10.4% to as high as 96.7% depending on region, diagnostic criteria, and sample characteristics. Such variability strongly supports the assertion that etiology is not uniform: regional differences in diet (especially fermentable sugar intake), fluoride exposure, oral hygiene practices, access to dental care, and socio-economic conditions modify risk substantially.

Moreover, inequality analyses reveal that a nontrivial fraction of the global caries burden is attributable to sociodemographic inequality. This suggests that even when biological and behavioral risk factors are present, structural factors (poverty, access barriers, public-health infrastructure) play a decisive role in manifesting disease.

**Etiologic Implications: Why Caries Persists**

The persistence and even growth of caries burden despite public health awareness point to limitations in current etiologic control. First, widespread consumption of free sugars remains a central risk factor. As noted by the World Health Organization (WHO), high intake of free sugars is strongly linked with caries; limiting free sugars to less than 5–10% of total energy intake reduces risk significantly. In many low- and middle-income regions, dietary transitions — increased consumption of sugar-sweetened beverages and processed foods — may be fuelling new caries cases, overwhelming preventive efforts. Second, behavioral and structural gaps persist: inadequate oral hygiene, limited fluoride exposure (toothpaste, water fluoridation), and insufficient access to restorative and preventive dental care lead to high levels of untreated disease. In many settings, dental care remains expensive, poorly covered by public health systems, or inaccessible — especially for marginalized populations. Third, demographic and epidemiologic shifts — especially in low-SDI (socio-demographic index) regions — intensify burden: population growth, urbanization, ageing, and retention of natural teeth into older age all increase aggregate caries risk and demand.

**Future Projections and Implications**

Based on recent modeling (e.g., Bayesian age-period-cohort projections) and observed trends, the burden of caries in permanent teeth is predicted to **continue increasing over the next decades**, especially in low- and middle-income regions unless major preventive interventions are scaled up. Indeed, one projection estimates total cases of permanent-teeth caries to reach approximately 2.26 billion by 2050.

Given this, we anticipate several likely consequences. A growing global demand for dental services — preventive, restorative, and maintenance — which may overwhelm healthcare systems in resource-limited settings. Widening oral-health inequalities: without equitable distribution of preventive care and fluoride exposure, disadvantaged populations may bear disproportionately high burden. Elevated indirect societal costs: beyond pain and tooth loss, caries can impair nutrition, quality of life, productivity, and contribute to broader noncommunicable disease risk (due to shared risk factors like diet, poverty). As the burden grows, so will social and economic costs of untreated caries and lost work/school days.

**Recommendations in Light of Etiology**

Given the complex, multifactorial etiology of caries and the trends identified, our review suggests that piecemeal or individual-level interventions (e.g., “brush-your-teeth” campaigns) are unlikely to suffice. Instead, effective control requires **integrated, population-level strategies**, including:

- Policies to reduce free-sugar consumption (e.g., taxation of sugar-sweetened beverages, public education, regulation of advertising).
- Universal access to preventive dental care and fluoride (toothpaste, water fluoridation), particularly targeting high-risk and underserved populations.
- Integration of oral health into national universal health coverage (UHC) schemes, to reduce disparities in access to care.

- Public-health surveillance systems to monitor caries prevalence, risk factors, and outcomes — allowing timely, evidence-based interventions.

Furthermore, etiologic research should continue to refine understanding of how social determinants (poverty, education, food environment) interact with biological risk factors (microbial composition, enamel susceptibility, saliva properties). Such insight will enable targeted prevention, tailored to high-risk groups and regions.

**Limitations and Strengths of This Review**

This review draws on large-scale, high-quality, recent global data (GBD 2021 and associated meta-analyses), offering a comprehensive, up-to-date picture of dental caries burden and trends. However, some limitations remain: global models rely on heterogeneous primary data (different diagnostic criteria, survey methods, sampling), which can affect precision; uncertainty intervals in some estimates remain wide. Regional-level data in many low- and middle-income countries remains sparse, potentially underestimating true burden. Also, projections beyond 2030–2050 carry inherent uncertainty, especially given unpredictable changes in diet, policy, and health systems.

***Conclusion:*** *The present review underscores that World Health Organization (WHO) — and other global data sources — continue to record extremely high prevalence and burden of Dental caries, indicating that caries remains a leading global public-health challenge. As of 2021, untreated caries of permanent teeth had an age-standardized prevalence of 27,500 per 100,000 population, contributing heavily to the overall global oral-disease burden of 3.69 billion people. Moreover, global estimates from 2019 report approximately 2 billion individual cases of permanent-teeth caries. Despite decades of preventive efforts, this enduring and widespread burden reflects the multifactorial nature of caries etiology — involving microbial, dietary, host-related, behavioral and socioeconomic determinants — and highlights systemic limitations in caries control at the population level. The*

*persistence of high prevalence, particularly in low- and middle-income countries where access to preventive and restorative care is often limited, points to structural inequalities and insufficient public-health infrastructure. Looking ahead, the burden of dental caries is likely to increase in absolute numbers over the next decades. Factors driving this include ongoing population growth, demographic ageing with increased tooth retention in older age cohorts, and persistent high consumption of free sugars globally. Recent modeling studies also project rising incidence and prevalence in many regions, particularly those with lower socio-demographic index (SDI). If current patterns continue, by 2050 the global number of people with caries could substantially exceed present values — exacerbating demands on dental health services, increasing treatment costs, and deepening inequalities in oral health.*

In light of these findings, it is clear that effective control of dental caries cannot rely solely on individual behavioral interventions (e.g., toothbrushing or dietary counselling), but requires **comprehensive public-health strategies**. These should include: global and national policies to reduce excessive sugar consumption; universal access to affordable preventive and restorative dental care; widespread fluoride use; and integration of oral health services into primary health care and universal health-coverage packages. In conclusion, dental caries remains a persistent, dynamic, and growing public-health burden worldwide. Without strong, evidence-based, and equity-focused interventions at population level, the global oral-health burden — and associated social and economic costs — will continue to rise, particularly among the most vulnerable populations. A paradigm shift is needed: from reactive treatment toward preventive, structural, and policy-oriented oral-health promotion.

***References:***

1. Institute for Health Metrics and Evaluation (2024). ***Trends in the global, regional, and national burden of oral conditions from 1990 to 2021.*** GBD 2021 systematic analysis.

2. World Health Organization. Oral health. Fact sheet. 2025.

3. Pan American Health Organization / Global Oral Health Status Report (2022). Global oral health status — towards universal health coverage: oral health 2030.

4. Global prevalence of dental caries in the older people, 1991 to 2024: a systematic review and meta-analysis. ***Saudi Dental Journal.*** 2025; 37:31.

5. Global burden of oral disorders with projections over the next 30 years. ***Journal of the American Academy of Periodontology.*** 2025.

6. A systematic review and meta-analysis on early-childhood-caries global data. ***BMC Oral Health.*** 2024; 24:835.