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RESEARCH

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Global, regional, and National levels and trends in burden of dental caries and periodontal disease from 1990 to 2035: result from the global burden of disease study 2021

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Abstract

Background The global burden of dental caries (DC) and periodontal disease (PD) has evolved significantly from 1990 to 2021, influenced by demographic shifts and socioeconomic factors in oral health interventions. This study aims to analyze historical trends, project future trajectories to 2035, and identify inequalities to inform equitable oral health policy development.

Methods Utilizing data from the Global Burden of Disease Study (GBD), which integrates epidemiological records from systematic reviews, survey data preparation, disease registries, and case notifications, we conducted an observational analysis based on historical population-level data from 1990 to 2021.We analyzed the incidence, prevalence, and their corresponding age-standardized incidence rate (ASIR) and age-standardized prevalence rate (ASPR) for caries of deciduous teeth (CDT), caries of permanent teeth (CPT) and periodontal disease (PD). Bayesian age-period-cohort (BAPC) models with Integrated Nested Laplace Approximation (INLA) were employed to forecast trends through 2035, integrating second-order smoothing effects, overdispersion adjustments, and uncertainty quantification via 1,000 Monte Carlo simulations (95% UI) with future precision expressed as 95% confidence intervals (CI).

Results From 1990 to 2021, CDT prevalence declined regionally, while PD remained prevalent, particularly among middle-aged and elderly populations in high-burden regions like Sub-Saharan Africa and Southeast Asia. Significant gender disparities were noted, with females experiencing comparable deciduous DC in early childhood, whereas males showed dominant PD rates in middle/older ages. Low-income regions still face high burdens despite progress. Projections to 2035 suggest a CDT resurgence and aging-driven PD persistence.

Conclusions DC and PD persist as major public health issues, shaped by gender, age, and regional disparities. The projected resurgence of childhood DC and persistent PD prevalence by 2035 underscore the need for targeted

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interventions. Tailored public health initiatives are essential to mitigate long-term impacts and improve global oral health outcomes.

Keywords Global burden, Dental caries, Periodontal disease, Oral health disparities, Public health interventions

Introduction

The WHO's Global Oral Health Status Report (2022) estimates that nearly 3.5 billion people, or 50% of the global population, suffer from oral diseases, with dental caries (DC) and periodontal disease (PD) being among the most prevalent, contributing significantly to the global health burden [1]. DC, classified into caries of deciduous teeth (CDT) and caries of permanent teeth (CPT), remains the leading cause of tooth destruction from early childhood through old age [2, 3]. The high prevalence of CDT in children severely impacts their oral health and overall development, affecting their ability to learn and absorb nutrients [4–6]. While CPT is more commonly observed in adults, its burden remains significant, particularly as individuals age and, especially in the absence of proper oral health interventions [7, 8]. PD, a chronic inflammatory disease that progressively destroys the supporting structures of the teeth, primarily affects middle-aged and elderly populations, and is a major cause of tooth loss [9, 10]. In addition to its significant health impact, the economic burden of oral diseases is also considerable. In 2019, the global cost of oral diseases reached $710 billion, encompassing both treatment expenses and lost work productivity. Poor oral health not only undermines physical health but also adversely affects economic well-being by leading to missed school days, lower academic performance, reduced job opportunities, and diminished work productivity [11].

According to the World Health Organization, the global prevalence of CDT is as high as 43%, far exceeding the prevalence of CPT, making it a focal point of global oral health concerns [12]. While CPT is widely present in adult populations, CDT not only affects children's oral health but can also have long-lasting negative effects on their growth, development, nutrition, and learning capabilities [13, 14]. Due to the smaller size and thinner enamel of primary teeth, caries develops more rapidly, and untreated caries can lead to more severe complications, further affecting the normal development of teeth [15]. Therefore, this study will focus on the distinct characteristics and risks of CDT and CPT.

The Global Burden of Disease (GBD) study provides a comprehensive framework for evaluating the prevalence and health burden of various diseases worldwide, and is particularly valuable in analyzing trends and changes in oral diseases [16]. Based on extensive data from 1990 to 2021, the GBD study has revealed the global burden of CDT, CPT, and PD. It provides detailed analytical tools that allow for the identification of burden disparities across gender, age groups, and regions [17]. Previous GBD research by Wen et al. found that population growth is a key driver of the global increase in the number of DC. Similarly, studies by Wu et al. emphasize that the global burden of PD will continue to rise due to both population growth and aging [18, 19]. By systematically analyzing these trends, the GBD study offers robust data support for future public health interventions and provides a scientific basis for more precise oral health policies, optimized resource allocation, and strengthened preventive measures [20].

This study aims to analyze historical trends and project future trajectories of CDT, CPT, and PD through 2035, with the overarching purpose of informing targeted policy interventions by examining global trends, gender disparities, age-specific patterns, and regional variations in disease burden.

Material methods

Data sources

The GBD 2021 study systematically evaluated the global health burden by quantifying incidence, prevalence, mortality, and disability-adjusted life years (DALYs) for 369 diseases and injuries across 204 countries and territories between 1990 and 2021. To accurately measure the burden of DC and PD, GBD researchers integrated data from systematic literature reviews, national health surveys, longitudinal cohort studies, and clinical records into DisMod MR-2.1—a Bayesian meta-regression model tailored for disease burden research—while examining 204 countries and territories, which were further organized into 21 regional groupings and seven super-regional clusters to generate comparable burden estimates across different populations and time periods [21, 22]. Incidence is defined as the number of new cases of a disease or injury within a specific time period, while prevalence refers to the total number of cases (both new and existing) at a particular point in time. Various standardization methods were applied, and data adjustments were made using the DisMod MR-2.1 model and MR-BRT tool to ensure comparability and improve the accuracy of estimates across regions [21]. This study utilizes data from the 2021 GBD study to assess the incidence rate, prevalence rate, and their corresponding age-standardized incidence rate (ASIR) and age-standardized prevalence rate (ASPR) for three oral diseases (CDT, CPT, and PD). All GBD estimates are publicly available and adhere to the Guidelines on Accurate and Transparent Health Estimate Reporting [23].

The case definition for DC is "teeth with unmistakable coronal cavity at dentin level, root cavity in cementum that feel soft or leathery to probing, temporary or permanent restorations, or missing teeth extracted due to a caries lesion". Excluded definitions include crowns with isolated cosmetic defects, stained enamel pits, or fissures without visible cavitation or softening, fluorosis, and abrasion lesions. We elected to model deciduous caries and permanent caries as separate entities and then add the estimates together for an overall estimation of the global burden of DC. This is the modelling approach which has been taken in each iteration since GBD 2010 This definition corresponds to an ICD-9 code of 521.0 and an ICD-10 code of K02.3–K02.9 [24].

The GBD definition of disability associated with symptomatic severe PD is "bad breath, a bad taste in the mouth, and gums that bleed a little from time to time, but which does not interfere with daily activities". The ICD-10 codes for PD are K05.0–K05.6, and the ICD-9 codes are 523.0–523.9 [24].

Statistical analysis

We used the incidence rate, prevalence rate, ASIR and ASPR from the GBD database to evaluate the impact and patterns of DC and PD across different genders, age groups, and regions. The BAPC analysis employed the Integrated Nested Laplace Approximation (INLA) method [25]. To ensure data smoothness, the BAPC model assumes that the second-order differences of all effects follow independent normal distributions with a mean of zero. In the model, prior distributions for age and period effects were appropriately specified to capture variations in prevalence rates [26]. Specifically, the study estimated the number and rate of disease cases for future periods and incorporated an independent random effect to adjust for overdispersion [25]. In this investigation, projections of DC and PD-related ASPR for 2022–2035 were generated. Summary estimates for all variance parameters (including the mean, standard deviation, 5% quantile, median, and 95% quantile) are presented in Additional file(Additional file 23–28).

Uncertainty analysis

All estimates were provided with 95% uncertainty intervals (UI), calculated through 1,000 Monte Carlo simulations to quantify the uncertainty of the estimates [27]. For the future predictions, 95% confidence intervals (CI) were used to express the precision of the data [28].

Statistical tools

In this study, the R software package (version 4.3.3) was used for data processing, statistical analysis, and drawing the figures.

Result

Global trends (2021): PD highest worldwide; DC concentrated in poor area

According to the 2021 age-standardized data, PD have the lowest global ASIR, with 1,069.44 per 100,000 people (95% UI: 942.71–1,204.58), significantly lower than CPT at 29,777.03 per 100,000 (95% UI: 26,310.27–33,490.91) and CDT at 17,781.15 per 100,000 (95% UI: 13,952.40–23,035.44). The highest rates of PD are observed in the Caribbean at 1,138.31 per 100,000 (95% UI: 943.48–1,335.36) and Central Latin America at 1,196.97 per 100,000 (95% UI: 1,033.36–1,365.93), while high-income regions like Western Europe have lower rates, at 841.70 per 100,000 (95% UI: 694.51–1,008.33).

CPT, the most prevalent condition globally, peaks in South Asia at 31,398.81 per 100,000 (95% UI: 27,644.28–35,248.05) and Tropical Latin America at 36,541.09 per 100,000 (95% UI: 31,903.79–41,303.27), but remains high even in High-income North America at 30,898.22 per 100,000 (95% UI: 26,814.08–34,828.49).

Although less common than CPT, CDT is more prevalent in Southeast Asia at 20,366.78 per 100,000 (95% UI: 15,172.99–29,250.65) and Southern Sub-Saharan Africa at 18,238.40 per 100,000 (95% UI: 13,484.31–23,381.99). In South Asia, the ASIR is 17,488.24 per 100,000 (95% UI: 13,708.08–22,367.38), which is in line with the global average (Fig. 1, Additional file 1–4, 29,30).

Gender differences (2021): gender-similar in DC; male-dominant PD with aging

In females aged 2–4 years, CDT has an incidence rate of 63,091 cases per 100,000 people (95% UI: 45,274–81,082) and a prevalence rate of 51,043 cases per 100,000 people (95% UI: 39,599–61,503). For males in the same age group, the incidence rate is 62,606 cases per 100,000 people (95% UI: 44,751–80,195), and the prevalence rate is 52,060 cases per 100,000 people (95% UI: 40,473–62,402). These numbers indicate that CDT rates in early childhood are comparable between sexes, with females showing marginally higher incidence rate and slightly lower prevalence rate than males (Fig. 2A-B, Additional file 5–6).

For CPT, females and males exhibit comparable incidence rates in adolescence. The incidence rate in females aged 15–19 is 46,126 cases per 100,000 people (95% UI: 36,363–56,627), closely matching males (46,311; 36,297–56,805). By age 20–24, female incidence rate rises to 54,162 (95% UI: 43,928–63,506), while males show a similar increase to 54,484 (44,523–63,599). Both sexes demonstrate progressive risk escalation in early adulthood, with no clear evidence of earlier onset in females. (Fig. 2C-D, Additional file 7–8).

In the case of PD, females exhibit a progressive increase in prevalence rate from 4,249 cases per 100,000 people

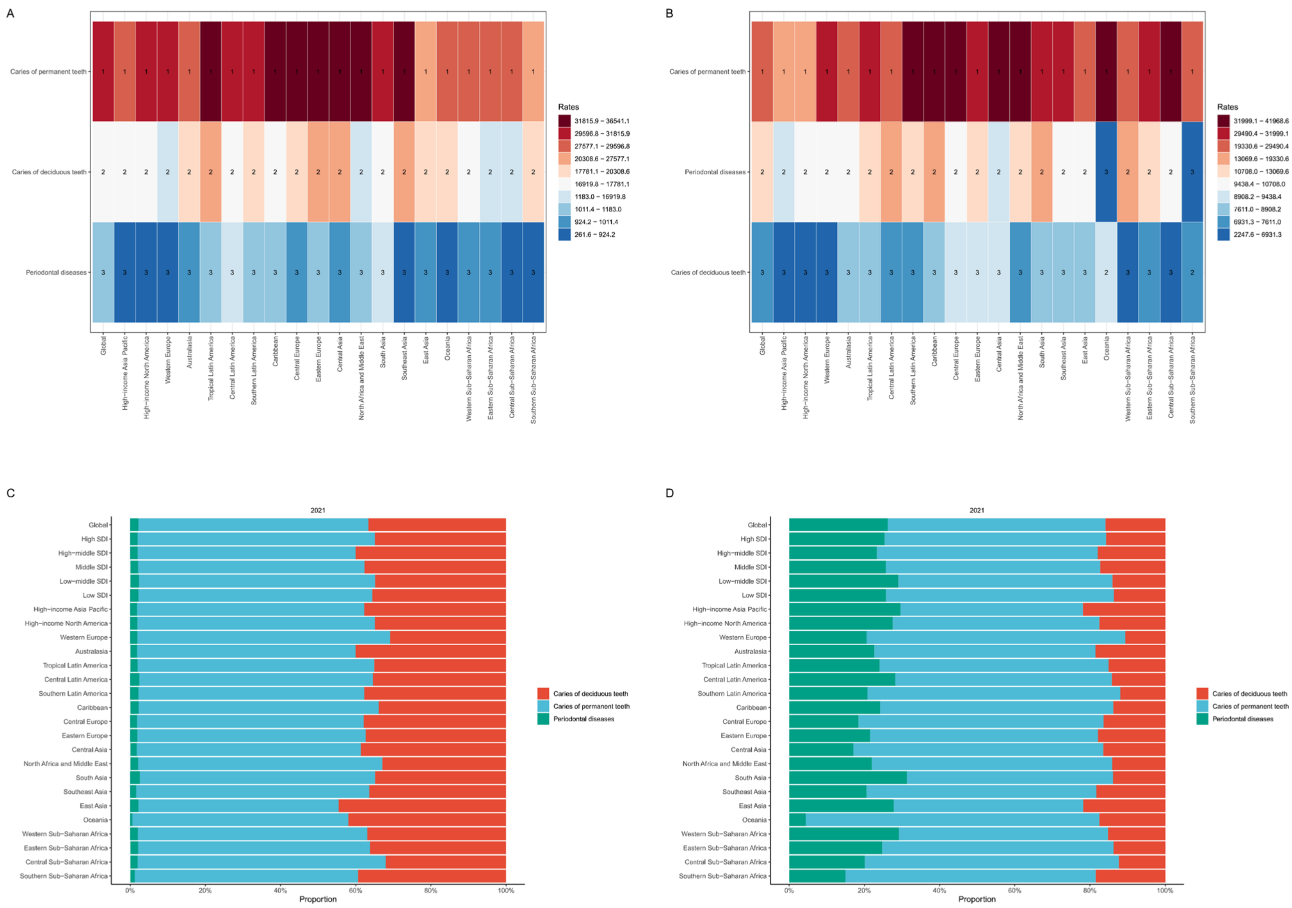

Fig. 1 Heatmap present ASIR (**A**) and ASPR (**B**) for CDT, CPT and PD by location in 2021. The colors in the figure represent rankings from high (red) to low (blue). The composition ratio of ASIR (**C**) and ASPR (**D**) of CDT, CPT, and PD by region in 2021

(95% UI: 2,836–6,115) at ages 20–24 to 13,577 cases per 100,000 (95% UI: 9,564–18,310) by ages 30–34. In contrast, males demonstrate consistently higher prevalence rate across all age groups, peaking at 30,512 cases per 100,000 (95% UI: 24,523–36,129) in the 50–54 age group. Incidence rate for males aged 50–54 are 1,883 per 100,000 (95% UI: 1,225–2,471). These findings indicate that males face a higher burden of PD compared to females, particularly in middle and older age groups. (Fig. 2E-F, Additional file 9–10).

Age differences (1990–2021): childhood-adolescent DC Spike in high-income regions; mid-adulthood PD drops in vulnerable populations

In the 2021 data, CDT incidence rate in the 2–4 age group increased in high-income regions such as North America (High-income North America), from 50,953 cases per 100,000 people (95% UI: 26,664–81,244) in 1990 to 62,195 cases per 100,000 people (95% UI: 38,499–89,426) in 2021, an increase of 11,242 cases. In Australasia, the 5–9 age group saw a sharp rise in incidence rate from 31,838 cases per 100,000 people (95% UI: 23,353–40,203) in 1990 to 74,543 cases per 100,000 people (95% UI: 50,997–101,639) in 2021, an increase of 42,705 cases. For the 10–14 age group in Australasia, incidence rate increased from 98,577 cases per 100,000 people (95% UI: 85,042–114,212) in 1990 to 116,847 cases per 100,000 people (95% UI: 59,428–162,169) in 2021, while prevalence rate surged from 6,692 cases per 100,000 people (95% UI: 5,736–7,662) to 14,081 cases per 100,000 people (95% UI: 10,649–17,713) (Fig. 3A-B, Additional file 11–12).

For CPT, in the 15–19 age group, East Asia saw a substantial increase in incidence rate, rising from 21,716 cases per 100,000 people (95% UI: 19,544–23,888) in 1990 to 41,774 cases per 100,000 people (95% UI: 37,597–45,952) in 2021.In the 20–24 age group, Southeast Asia experienced a slight increase in incidence rate, from 55,750 cases per 100,000 people (95% UI: 44,116–65,876) in 1990 to 57,159 cases per 100,000 people (95% UI: 46,406–66,440) in 2021. In the 45–49 age group, East Asia showed an increase in incidence rate, rising from 16,838 cases per 100,000 people (95% UI: 12,922–21,749) in 1990 to 20,150 cases per 100,000 people (95%

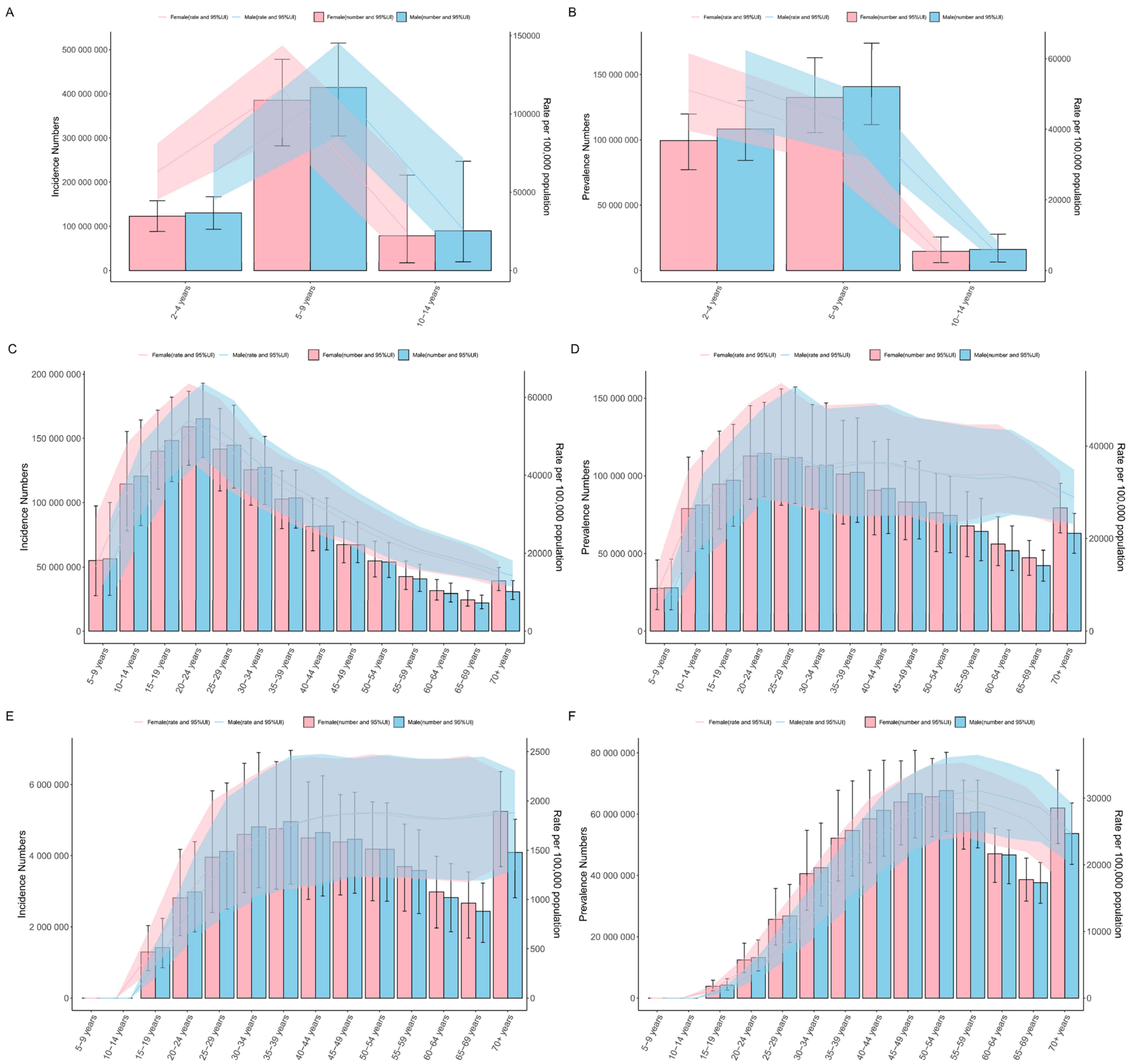

Fig. 2 This figure illustrates the incidence and prevalence of oral diseases, including CDT (**A**, **B**), CPT (**C**, **D**) and PD (**E**, **F**), are shown for males (blue) and females (pink) across different age groups. The x-axis represents different age groups, the left y-axis shows the absolute number of cases, and the right y-axis displays the standardized rate. The bar charts and their error bars indicate the number of cases and corresponding uncertainty intervals, while the shaded areas represent the 95% UI of the rates

UI: 15,290–26,495) in 2021. (Fig. 3C-D, Additional file 13–14).

Additionally, the most notable changes in the incidence rate of PD were observed in the following age groups and regions. In the 25–29 age group, Central Sub-Saharan Africa saw a significant decrease in incidence rate, from 2,208.82 cases per 100,000 people (95% UI: 1,152.97–3,256.40) in 1990 to 935.18 cases per 100,000 people (95% UI: 417.99–1,901.74) in 2021. In Oceania, the 30–34 age group experienced a sharp decline, with the incidence rate falling from 1,073.71 cases per 100,000 people (95% UI: 531.81–1,847.56) in 1990 to 217.43 cases per 100,000 people (95% UI: 100.78–447.87) in 2021.For the 50–54 age group, Oceania again showed a large reduction, with the incidence rate dropping from 2,032.57 cases per 100,000 people (95% UI: 1,169.61–2,891.48) in 1990 to 526.18 cases per 100,000 people (95% UI: 212.51–1,102.17) in 2021. (Fig. 3E-F, Additional file 15–16).

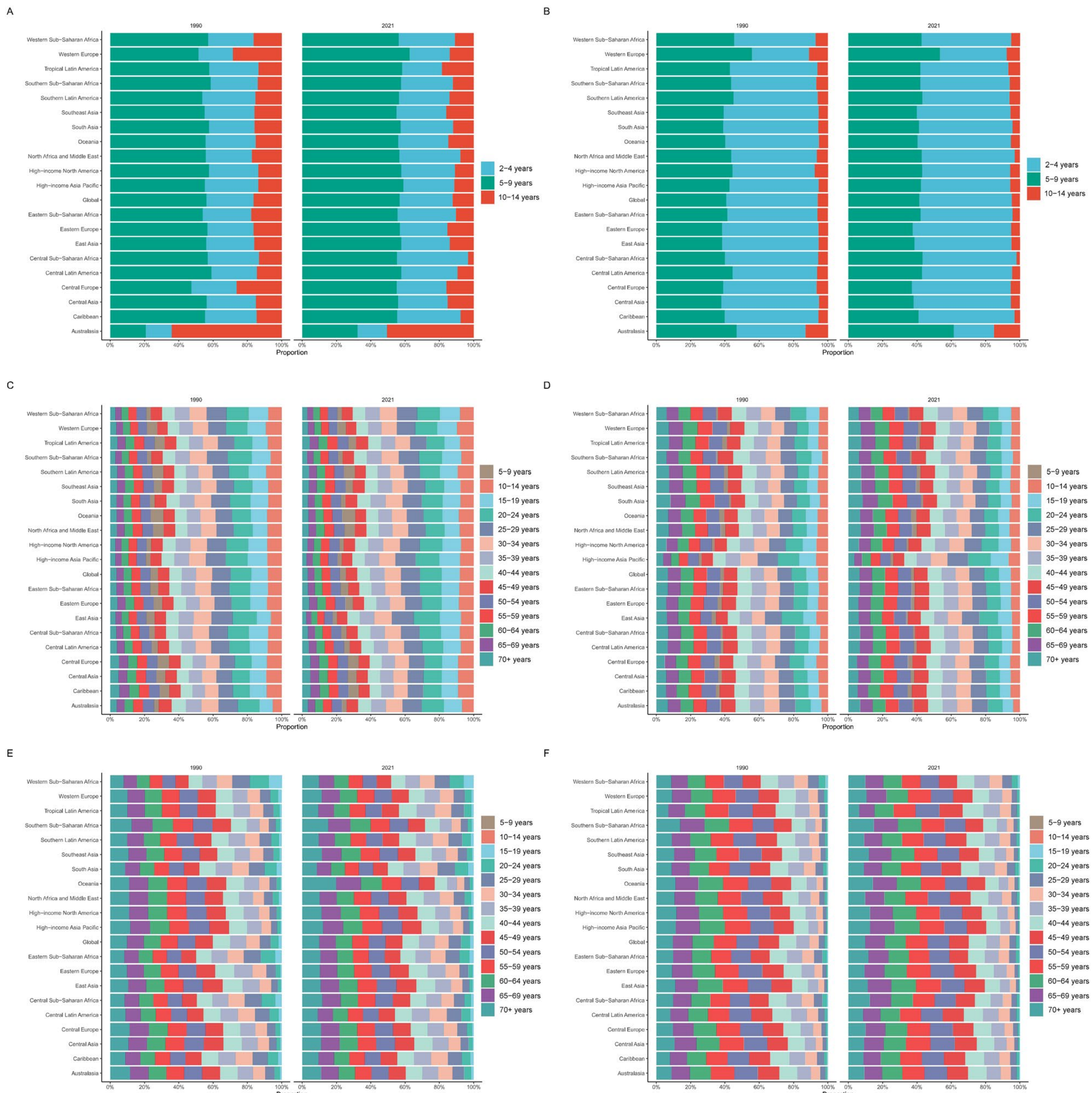

Fig. 3 This figure compares incidence and prevalence across different age groups for CDT (**A**, **B**),CPT (**C**, **D**) and PD (**E**, **F**) in 1990 and 2021

Regional differences (1990–2021): DC rises in affluent regions; PD drops in poor areas

From 1990 to 2021, the ASIR of CDT in Sub-Saharan Africa decreased by 12.02% (UI: -22.38% – 5.67%), while ASPR also declined by 6.20% (UI: -15.54% – 6.63%). During the same period, Southeast Asia saw a slight increase in the ASIR of CDT by 0.57% (UI: -2.31– 3.61%) and a ASPR change of -2.70% (UI: -4.55% – -0.86%). North America experienced a 10.88% rise in the ASIR of CDT (UI: -0.92–31.61%) and a 20.08% increase in ASPR (UI: 8.43–35.79%) from 1990 to 2021. Western Europe reported a reduction in the ASIR of CDT by 6.62% (UI: -16.65% – 1.63%) and a ASPR change of -17.31% (UI: -24.20% – -10.47%) during the same timeframe. (Fig. 4A-B, Additional file 17–18).

Regarding CPT, East Asia saw a significant increase in ASIR by 31.20% (UI: 22.31– 44.87%) from 1990 to 2021, whereas South Asia experienced a modest rise of 1.68% (UI: -0.75 – 4.07%). In North America, the ASIR of CPT decreased by 2.98% (UI: -6.03% – 0.18%) over the 1990–2021 period, while Northern Europe had a slight increase of 0.53% (UI: -3.08 – 4.70%) and Western Europe rose by

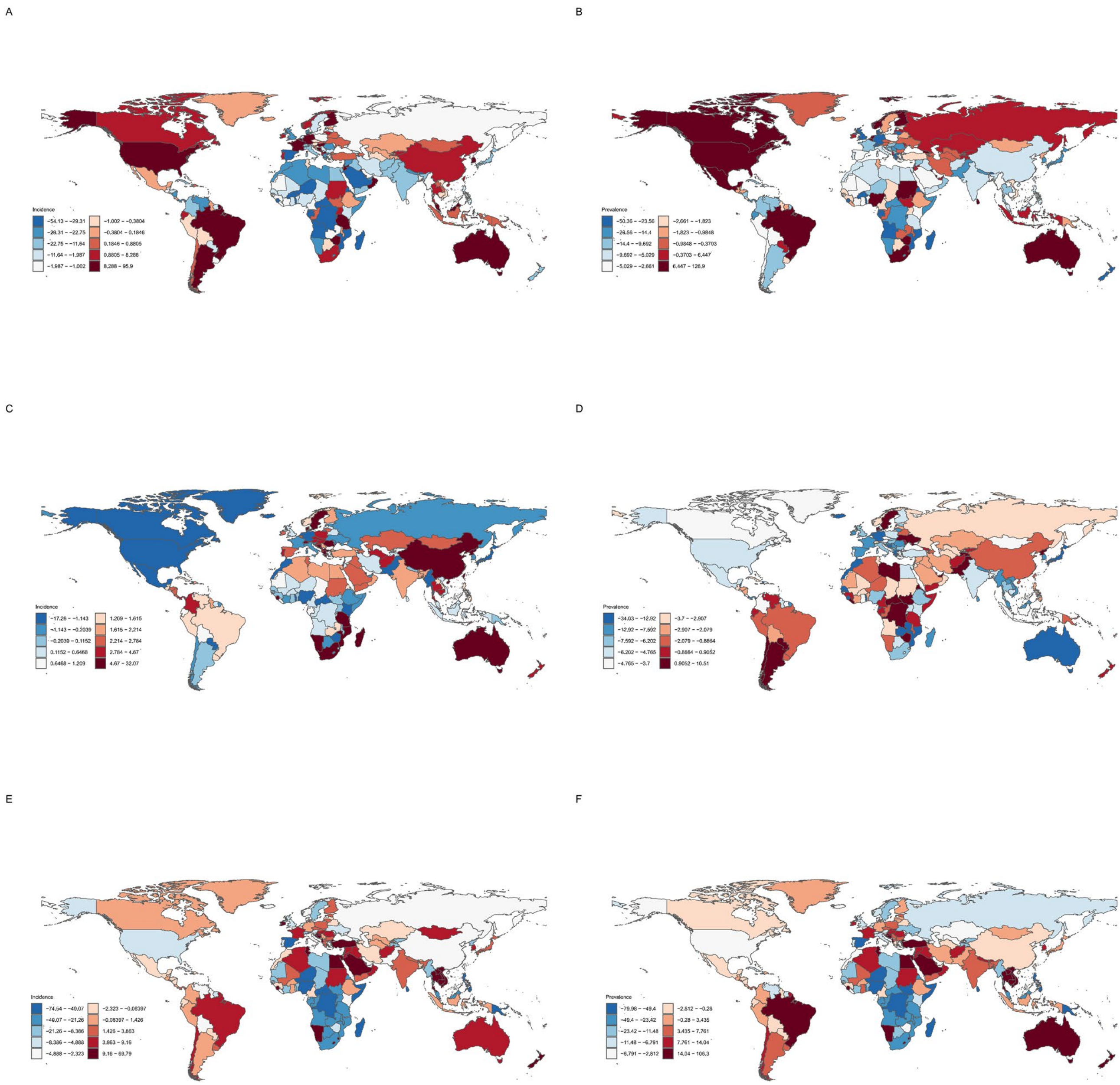

Fig. 4 World percent change map of age-standardized for both from 1990–2021 in incidence and prevalence rate for CDT (**A**, **B**), CPT (**C**, **D**) and PD (**E**, **F**): The percentage is the raw data multiplied by 100

0.53% (UI: -3.08 – 4.70%). In terms of ASPR, East Asia saw a decrease of 0.94% (UI: -8.73% – 7.67%), South Asia decreased by -5.74% (UI: -7.48% – -3.46%), North America decreased by -5.13% (UI: -8.54% – -1.35%), Northern Europe rose by 2.83% (UI: -0.47 – 6.60%), and Western Europe decreased by -8.91% (UI: -13.53%– -4.07%) in CPT ASPR from 1990 to 2021. (Fig. 4C-D, Additional file 19–20).

Concerning PD, Sub-Saharan Africa experienced a significant decline in ASIR by -29.26% (UI: -40.45% – -13.51%) from 1990 to 2021, with Western Sub-Saharan Africa showing an even greater decrease of -34.78% (UI: -42.87% – -23.80%). In Southeast Asia, the ASIR of PD changed by -8.46% (UI: -17.34% – 4.52%) during this period, while North America saw a -5.88% change (UI: -18.45% – 11.71%). Western Europe reported a decrease in PD ASIR by -9.50% (UI: -27.51% – 15.06%) from 1990 to 2021. (Fig. 4E-F, Additional file 21–22).

BAPC prediction (2021–2035): resurgence in childhood CDT; improvement in adolescent CPT; deterioration of PD in middle-aged/elderly populations

From 1990 to 2020, the overall ASPR of CDT gradually declined from 28,108.90 cases per 100,000 (95%

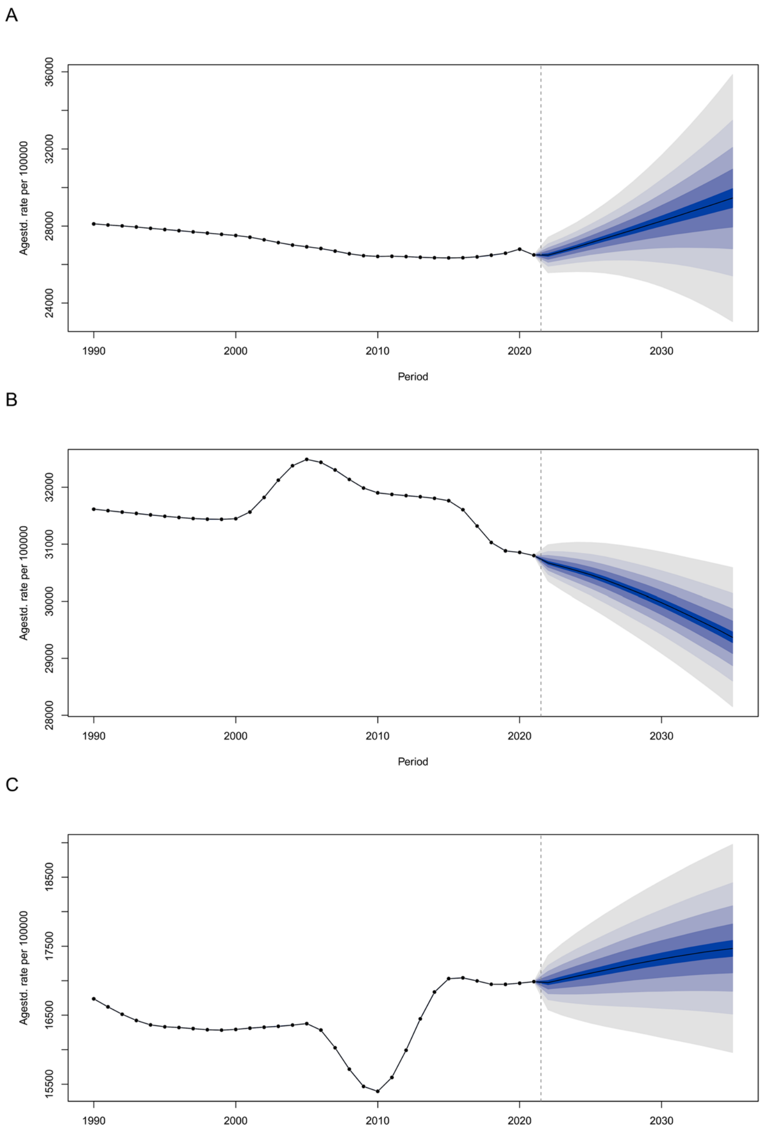

Fig. 5 The global temporal trends of ASPR of CDT (**A**), CPT (**B**) and PD (**C**) between 1990 and 2021, along with their projected trends up to 2035. The black dots represent the observed values, and the predictive mean value is shown as a solid line. The blue region shows the upper and lower limits of the 95% UI. The vertical dashed line indicates where the prediction starts

UI: 28,106.42–28,111.39) to 26,796.70 cases per 100,000 (95% UI: 26,794.43–26,798.98), with projections indicating a rise to 29,447.78 cases per 100,000 (95% CI: 21,840.17–37,055.39) by 2035. Among children under 5 years of age, prevalence rate decreased from 35,008.79 cases per 100,000 (95% UI: 35,002.69–35,014.90) in 1990 to 33,917.97 cases per 100,000 (95% UI: 33,912.01–33,923.93) in 2020, and is projected to increase to 43,626.47 cases per 100,000 (95% CI: 34,236.60–53,016.34) by 2035.Additionally, for children aged 5–9 years, prevalence rate declined from 41,641.48 cases per 100,000 (95% UI: 41,635.10–41,647.86) in 1990 to 39,735.10 cases per 100,000 (95% UI: 39,729.09–39,741.10) in 2020, with an anticipated rise to 43,626.47 cases per 100,000 (95% CI: 34,236.60–53,016.34) by 2035. Among those aged 10–14 years, prevalence rate decreased from 6,080.48 cases per 100,000 (95% UI: 6,072.15–6,088.80) in 1990 to 4,910.58 cases per 100,000 (95% UI: 4,901.78–4,919.38) in 2020, and is expected to reach 5,590.75 cases per 100,000 (95% CI: 4,889.02–6,292.47) by 2035. (Fig. 5A, Additional file 23–24, 31).

The prevalence rate of CPT changed differently across age groups from 2022 to 2035. For the 5–9 age group, cases fell sharply from 9,496.63 per 100,000 (95% UI: 9,489.29–9,503.97) in 1990 to 8,060.55 (95% UI: 8,052.92–8,068.18) in 2021, and will likely drop further to 7,163.20 (95% CI: 5,540.37–8,786.02) by 2035. For the 10–14 age group, cases also decreased from

26,313.72 (95% UI: 26,307.46–26,319.97) to 23,989.37 per 100,000 (95% UI: 23,983.38–23,995.36) between 1990 and 2021, and are expected to reach 21,217.69 (95% CI: 18,304.92–24,130.45) by 2035.In the 15–19 age group, cases had a small decrease from 30,747.88 (95% UI: 30,741.53–30,754.23) to 30,718.23 per 100,000 (95% UI: 30,712.19–30,724.27) from 1990 to 2021, but predictions show a bigger drop to 27,141.72 (95% CI: 25,177.03–29,106.40) by 2035. For the 20–24 age group, cases went down from 39,396.96 (95% UI: 39,390.27–39,403.65) to 38,039.96 per 100,000 (95% UI: 38,033.73–38,046.20) during this period, and may decrease to 35,517.78 (95% CI: 33,768.35–37,267.20) by 2035. In the 25–29 age group, cases slightly declined from 38,100.12 (95% UI: 38,093.23–38,107.01) to 37,842.43 per 100,000 (95% UI: 37,836.17–37,848.69), with a predicted fall to 35,327.53 (95% CI: 32,604.31–37,050.76) by 2035.However, the 65–69 age group was different. Their cases rose from 34,168.14 (95% UI: 34,157.09–34,179.19) in 1990 to 32,432.73 per 100,000 (95% UI: 32,424.86–32,440.59) in 2021, and are expected to keep rising to 32,336.81 (95% CI: 30,707.38–33,905.99) by 2035. (Fig. 5B, Additional file 25–26, 32).

For PD, the overall ASPR decreased slightly from 28,250.67 (95% UI: 28,242.56–28,258.77) in 1990 to 27,605.47 (95% UI: 27,598.21–27,612.73) in 2021, with projections indicating a decrease to 28,607.75 (95% CI: 28,516.43–28,699.07) by 2035.The 50–54 age group exhibited a decline from 30,745.90 per 100,000 (95% UI: 30,736.34–30,755.46) in 1990 to 29,595.13 (95% UI: 29,588.50–29,601.75) in 2021, projected to reach 32,136.12 (95% CI: 31,336.74–32,935.51) by 2035. Other age groups also demonstrated notable trends. For individuals aged 15–19 years, the prevalence rate increased from 1,127.70 (95% UI: 1,114.99–1,140.40) in 1990 to 1,305.39 (95% UI: 1,293.10–1,317.69) in 2021, with a projected prevalence rate of 1,167.90 (95% CI: 819.15–1,516.65) by 2035.Among individuals aged 20–24 years, prevalence rate increased from 3,725.77 (95% UI: 3,716.24–3,735.30) to 4,309.55 (95% UI: 4,300.42–4,318.69), with a predicted prevalence rate of 3,992.01 (95% CI: 3,215.78–4,768.25) by 2035.In the 30–34 age group, prevalence rate increased from 12,864.32 (95% UI: 12,857.21–12,871.43) to 13,751.46 (95% UI: 13,744.79–13,758.13), with an expected increase to 14,164.95 (95% CI: 12,619.11–15,710.78) by 2035.Additionally, the 65–69 age group saw a slight increase from 27,409.16 (95% UI: 27,398.93–27,419.39) in 1990 to 27,651.64 (95% UI: 27,644.03–27,659.24) in 2021, with a projected prevalence rate of 27,142.08 (95% CI: 24,210.45–30,073.71) by 2035. (Fig. 5C, Additional file 27–28, 33).

Discussion

Comprehensive comparison of Temporal trends and future predictions

The temporal trends of CDT, CPT, and PD exhibit distinct epidemiological patterns. Between 1990 and 2021, the global ASPR of CDT declined from 28,108.90 to 26,796.70 cases per 100,000 people. However, the BAPC model projects a resurgence to 29,447.78 cases per 100,000 by 2035. This suggests that despite short-term public health successes, persistent inequalities in oral hygiene infrastructure—particularly in low-income regions—may drive a future rebound of CDT [29]. For CPT, while the global prevalence rate has decreased over the past three decades, its ASIR among adolescents and young adults (15–24 years) has risen sharply in specific regions. In East Asia, the incidence rate of CPT in the 15–19 age group surged between 1990 and 2021. Although economic development and dietary shifts may contribute to a projected slight decline in global CPT prevalence rate by 2035, the persistent rise in adolescent cases underscores the urgent need for targeted interventions in high-risk regions [11, 30–32]. Meanwhile, PD demonstrates a divergent trajectory. Despite a modest decline in overall prevalence rate from 1990 to 2021, projections indicate a potential deterioration by 2035. This trend is particularly pronounced among middle-aged and elderly populations (e.g., in Oceania, the 50–54 age group saw incidence rate drop by 74% from 1990 to 2021, yet global prevalence rate remains high due to aging demographics). These patterns highlight the lifespan-specific nature of oral diseases: CDT and CPT predominantly affect children and adolescents, whereas PD disproportionately burdens older adults, necessitating age-tiered prevention—fluoride varnish programs in preschools and geriatric PD screening by non-dental health professionals in primary care systems [33].

Comparison of gender differences and public health implications

Gender differences in oral health reveal nuanced disparities with public health implications. For CDT in early childhood, females show a marginally higher ASIR of 63,091 per 100,000 compared to males at 62,606 per 100,000 but slightly lower prevalence rate than males. This indicates comparable early-life exposure between sexes rather than a clear female disadvantage [34]. Regarding CPT, both sexes exhibit nearly identical incidence rates in adolescence, with females and males showing similar rates in the 15–19 and 20–24 age groups. This finding contrasts with some regional studies, which show more pronounced gender differences [35, 36]. The reason for this discrepancy may be that, in these age groups, the global perspective of GBD studies, which involves a vast amount of data, masks inherent gender differences in risk, leading to similar rates of incidence across genders. Conversely, PD demonstrates a pronounced male-dominant burden with aging. While females show a progressive increase in prevalence rate from the 20–24 age group to the 30–34 age group, males exhibit substantially higher rates across all ages, peaking in the 50–54 age group. Male incidence rate in this group highlights an age-dependent escalation of risk. This aligns with projections that PD prevalence rate in males aged 50–54 will rise by 2035, emphasizing a critical need for targeted interventions [37]. These findings focus on two policy directions: early-life CDT prevention programs that require sex-neutral approaches and age-specific PD management for males, especially those over 50 years. The predicted rise of childhood CDT in high-income regions and ongoing PD burden in older males need strategies that combine screening, education, and socioeconomic interventions to address disparities, particularly through gender-neutral school fluoride initiatives and task-shifting PD care to nurses in low-resource settings [38, 39].

In-depth comparison of age differences

Sustained public health efforts have led to a gradual decline in the prevalence rate of CDT among children under 5 years old, with a notable reduction observed from 1990 to 2020. However, projections indicate a concerning reversal, with the prevalence rate expected to surge by 2035. This resurgence is particularly pronounced in high-income regions, such as North America and Australasia. Among children aged 2–4, the incidence rate increased significantly from 1990 to 2021, and a similar trend was observed in the 5–9 age group. These trends highlight the growing need for targeted interventions to address emerging risk factors in affluent populations, particularly as emerging cross-cohort microbiome evidence reveals a causal association between early dental plaque colonization by cariogenic taxa (notably Streptococcus mutans and Scardovia wiggsiae) and subsequent severe CDT progression, underscoring the imperative of integrating microbial biomarker profiling into preschool preventive screening programs [12, 40].

While CPT remains more prevalent than CDT globally, its overall prevalence has slightly decreased from 1990 to 2021, with projections indicating this decline will continue through 2035. However, a concerning trend emerges in East Asia, where the incidence rate of CPT among adolescents aged 15–19 more than doubled during the same period. This stark divergence highlights a dual burden: declining rates in high-income regions, contrasted with persistently high rates in low-income areas. These differences may be driven by dietary shifts and limited access to preventive care in the latter regions, calling for subsidized fluoride toothpaste distribution in East Asian schools and AI-powered teledentistry for elderly PD patients in Sub-Saharan Africa [39, 41].

PD, which demonstrated the highest global incidence rate among the three conditions in 2021, presents a paradoxical trend. While its overall prevalence rate has decreased slightly, projections suggest a resurgence by 2035. The middle-aged and elderly populations face disproportionate risks, with males aged 50–54 experiencing the highest prevalence rate. Past research has indicated that periodontitis was highly prevalent in regions like Central Sub - Saharan Africa and Oceania [19, 42]. However, alarmingly, these regions have recently reported dramatic declines in PD incidence rate, which might be attributed to underreporting rather than genuine progress, given persistent healthcare disparities.

Integrated comparison of regional differences in oral health

Regional disparities in oral disease prevalence and incidence rate are shaped by complex interactions between socioeconomic factors, healthcare infrastructure, and cultural practices. Data from 1990 to 2021 confirm that low-income regions, such as Sub-Saharan Africa and Southeast Asia, continue to face high burdens of CDT, driven by limited access to oral healthcare and nutritional challenges [43]. For instance, Sub-Saharan Africa experienced a 12.02% reduction in CDT incidence rate and a 6.20% decline in prevalence rate, while Southeast Asia saw a marginal 0.57% increase in CDT incidence rate alongside a 2.70% decrease in prevalence rate. These trends highlight persistent inequities in preventive care despite localized improvements [44].

In contrast, middle-income regions like East Asia reported a 31.20% surge in CPT incidence rate, likely tied to rapid dietary shifts and delayed public health responses. High-income regions, however, demonstrated divergent trajectories: North America saw a 10.88% rise in CDT incidence rate and 20.08% increase in prevalence rate, whereas Western Europe reduced CDT incidence rate by 6.62% and prevalence by 17.31%. Concurrently, CPT rates in North America and Northern Europe remained stable or declined modestly, underscoring the effectiveness of sustained preventive policies [3, 18].

PD exhibited the most striking regional contrasts. Sub-Saharan Africa achieved significant progress, with PD incidence rate declining by 29.26% and Western Sub-Saharan Africa by 34.78%, likely due to targeted hygiene interventions. Conversely, high-income regions like North America and Western Europe reported minimal reductions in PD incidence rate. This stagnation aligns with projections of worsening PD burdens among aging populations, suggesting that lifestyle factors and sequelae of restorative treatments may offset gains from advanced healthcare systems, demanding policy integration of oral health into Sustainable Development Goals 3 [45].

The current research has several caveats on data interpretation and methodological constraints that should be acknowledged. First, our analysis relied entirely on pre-existing datasets rather than original data collection, which introduces the possibility of inaccuracies due to inconsistent measurement standards and reporting formats across different geographic areas [46]. Second, while statistical modeling provided a useful framework for examining disease patterns, these computational tools inherently involve simplifications. As a result, the models likely excluded important social and biological factors that jointly influence disease outcomes, which could limit the comprehensiveness of the findings. Third, our descriptions of trends primarily relied on point estimates of data changes, without accounting for the overlapping UIs or CIs. This approach prioritizes clarity in reporting but may obscure potential uncertainties in interpreting true increases or declines [47]. Incorporating these factors in future studies could substantially improve the interpretation of epidemiological trends.

Conclusion

In line with our aim to guide targeted oral health policy, the analysis of GBD 2021 incidence, prevalence, and their age-standardized data highlights notable trends of DC and PD from 1990 to 2021, with projections through 2035 based on BAPC analysis. CDT declined in some high-income regions yet is projected to resurge by 2035, while CPT remains widespread in older populations, particularly in East Asia. PD persists among middle-aged and elderly males, with Sub-Saharan Africa facing substantial burdens. Low-income regions continue to shoulder disproportionate oral health inequalities. These findings underscore the need for age- and region-specific interventions to mitigate long-term effects and strengthen global oral health equity.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12903-025-06108-w.

Supplementary Material 1
Supplementary Material 2
Supplementary Material 3
Supplementary Material 4
Supplementary Material 5
Supplementary Material 6
Supplementary Material 7
Supplementary Material 8
Supplementary Material 9
Supplementary Material 10
Supplementary Material 11
Supplementary Material 12
Supplementary Material 13
Supplementary Material 14
Supplementary Material 15
Supplementary Material 16
Supplementary Material 17
Supplementary Material 18
Supplementary Material 19
Supplementary Material 20
Supplementary Material 21
Supplementary Material 22
Supplementary Material 23
Supplementary Material 24
Supplementary Material 25
Supplementary Material 26
Supplementary Material 27
Supplementary Material 28
Supplementary Material 29
Supplementary Material 30
Supplementary Material 31
Supplementary Material 32
Supplementary Material 33
Supplementary Material 34

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Author contributions

Jiangqiuchen Wu: Formal analysis, Data curation, Writing draft.Jiangqiuchen Wu, Jinhao Chen: Writing-Original draft preparation, Results interpretation. Jiangqiuchen Wu, Leilei Zhou: Data inspection and modification, Writing RevisionLeilei Zhou, Cunming Lv: Supervision, Reviewing and Editing.

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Data availability

Data is provided within the manuscript or supplementary files.The datasets generated during and/or analyzed during the current study are available from the Global Health Data Exchange query tool (http://ghdx.healthdata.org/gbd-results-tool).

Declarations

Ethics approval and consent to participate

Our study utilized publicly accessible GBD data, thus eliminating the need for informed consent or ethical review. Since it exclusively used publicly accessible data that did not contain any confidential or personally identifiable patient information. Given the nature of the data, informed consent was not required, and no ethical review or patient consent was needed, ensuring both transparency and ethical integrity in using secondary, non-identifiable health data for our research.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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