Wang *et al. BMC Oral Health* (2025) 25:434
https://doi.org/10.1186/s12903-025-05796-8

BMC Oral Health

RESEARCH

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Epidemiological trends and age-period-cohort effects on periodontal diseases incidence across the BRICS from 1992 to 2021

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Abstract

Background Periodontal diseases are prevalent oral conditions, particularly burdensome in developing countries. This study examines global and BRICS countries' changing trends in periodontal diseases incidence from 1992 to 2021, focusing on associations with age, period, and cohort effects.

Materials and methods A cross-sectional burden of disease study was conducted. Data on the total population and periodontal diseases cases, all-age incidence rate, age-standardized incidence rate, and relative change in periodontal diseases incidence from 1992 to 2021 within BRICS were obtained from the Global Burden of Disease study (GBD) 2021. Furthermore, the Age-Period-Cohort (APC) model with an intrinsic estimator (IE) algorithm was employed to assess the effects of net drift, local drift, age, period, and cohort on the incidence rates of periodontal diseases over specific time periods.

Results Globally, the new cases of periodontal diseases in 2021 were reported at 8961 thousand (95% uncertainty intervals: 7907, 10101), reflecting a 71.21% increase compared to 1992. In 2021, the age-standardized incidence rate of periodontal diseases across the BRICS countries ranged from 600.50 (95% uncertainty intervals: 481.27, 763.54) per 100,000 population in South Africa to 1268.96 (95% uncertainty intervals: 1119.16, 1409.94) per 100,000 population in India. The age distribution of periodontal diseases cases was relatively stable globally and among BRICS countries from 1992 to 2021. Countries exhibited similar age-effect patterns, with increasing risk with increasing age, and varying period and cohort effects, indicative of differential control measures and temporal incidence trends.

Conclusions Brazil, India, and China experienced an increasing trend in the age-standardized incidence rates of periodontal diseases from 1992 to 2021, in contrast to the declining trends observed in the Russian Federation and South Africa. Furthermore, the APC analysis indicates the intricate dynamics of age, period, and cohort influences on periodontal diseases incidence. Distinct national trajectories, shaped by varying socioeconomic, cultural, and historical frameworks, highlight that public health initiatives must be meticulously customized to mitigate and control the periodontal diseases burden across diverse settings.

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Keywords Periodontal diseases, BRICS, Incidence, Age-period-cohort, Trend

Background

Periodontal diseases, is a chronic inflammatory condition that affects the tissues surrounding and supporting the teeth. It encompasses gingivitis, characterized by inflammation and bleeding gums, and periodontitis, which involves the accumulation of dental plaque, bacterial dysbiosis, tissue destruction, and ultimately tooth loss [1, 2, 3]. The prevalence of periodontitis reaches a staggering 62%, with over 23.6% of individuals experiencing severe forms, significantly contributing to the global burden of chronic non-communicable diseases [4]. According to estimations, the global burden of periodontitis in 2019, including the costs of direct treatment and productivity losses associated with tooth loss, amounted to $186 billion and $142 billion, respectively [5]. Moreover, periodontal diseases is closely associated with various systemic disorders, including diabetes [6], cardiovascular disease [7], Alzheimer's disease, and colorectal cancer [8]. Therefore, gaining a comprehensive understanding of the incidence of periodontal diseases is crucial in formulating preventive policies to enhance both oral and overall systemic health.

The BRICS countries, comprising Brazil, the Russian Federation, India, China, and South Africa, representing nearly half of the global population, are all classified as developing countries and have made rapid progress in economic advancement. As a powerful political and economic alliance, the BRICS countries play a significant role in global affairs [9]. However, alongside their achievements, the BRICS countries face a common challenge in the form of the rapid increase in periodontal diseases. This condition is recognized as one of the foremost oral health issues contributing to the global burden of chronic diseases, with a particularly high prevalence in developing countries [10]. Moreover, the BRICS countries share similar healthcare development history, challenges, and healthcare aspirations [11]. Therefore, conducting in-depth research within the BRICS countries can provide valuable insights into the incidence of periodontal diseases in these member countries and other developing countries. This research can serve as a beneficial reference for promoting relevant study findings in similar countries.

The previous studies leveraging the Global Burden of Disease (GBD) 2019 framework have documented the high burden of periodontal diseases, revealing significant regional heterogeneity that underscores the disparities in healthcare access and service provision among countries, particularly in developing regions [12, 13, 14]. Although a foundation for understanding the burden of periodontal diseases was provided, these descriptive epidemiological studies often fall short in disentangling the intricate period and cohort-specific trends of the disease, limiting the ability to accurately elucidate the significant impacts of specific factors on disease burden and to comprehensively grasp the disease's temporal evolution. The Age-Period-Cohort (APC) model presents a valuable approach to fill this gap, offering a robust analytical framework that can disentangle the complex interactions among age, time, and cohort effects in relation to periodontal diseases incidence [15]. Moreover, the recent updates to the GBD 2021 database provide an excellent opportunity to investigate the trends and regional variations of periodontal diseases in BRICS countries, facilitating a nuanced understanding of how epidemiological dynamics evolve over time. Data extracted from GBD 2021 can serve as critical evidence for developing targeted health policies and interventions aimed at improving health outcomes associated with periodontal diseases.

This study utilized the latest GBD 2021 database to comprehensively evaluate the incidence trend of periodontal diseases from 1992 to 2021. Employing the APC model, it conducted a detailed analysis of the effects of age, period, and cohort on the incidence rate of periodontal diseases, with a specific focus on the burdened region of the BRICS countries. The research seeks to inform health strategies and highlight the importance of addressing periodontal diseases within the broader context of oral health in developing countries. The insights gained from this study will be essential for policymakers, healthcare providers, and researchers dedicated to enhancing the health and well-being in these influential nations.

Materials and methods

Data sources

A cross-sectional analysis of periodontal diseases burden was conducted in this study, and the retrospective data can be available through the Global Health Data Exchange GBD Results Tool (https://ghdx.healthdata.org/gbd-2021). The GBD 2021 conducted a comprehensive analysis of disease and injury burden, utilizing 100,983 data sources to estimate years lived with disability (YLDs), years of life lost (YLLs), disability-adjusted life years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries. It considered the impact of the COVID-19 pandemic on disease burden trends. Data were derived from multiple sources, including vital registration systems, verbal autopsy, population censuses, household surveys, disease registries, health service utilization data, and others [1]. Compared to GBD 2019, GBD

2021 incorporated more data sources (100,983), introduced new analysis indicators, considered the impact of COVID-19, and utilized diverse data sources, resulting in a more comprehensive and accurate understanding of global disease burden [1, 16]. The inherent characteristics of the GBD database have been thoroughly considered concerning model selection, parameter estimation, and data input quality. By replicating the sample 1000 times, the 95% uncertainty intervals (UIs) were successfully obtained. The upper and lower bounds of these intervals are determined by the 2.5th and 97.5th percentiles of the uncertainty distribution [1].

In the GBD 2021, periodontal diseases were defined as Community Index of Periodontal Treatment Needs (CPITN) Class IV, attachment loss (AL) > 6 mm, or gingival pocket depth (PD) > 5 mm [1]. It classified based on the International Classification of Diseases, 9th edition (ICD-9 codes: 523.0–523.9), and 10th edition (ICD-10 codes: K05.0 -K05.6) [1]. We gathered the incidence numbers, all-age incidence rate, age-standardized incidence rate, and their calculated relative percentage changes in periodontal diseases on a global scale and within BRICS countries, spanning age groups from 15 to 94 years and the time period from 1992 to 2021. The age groups under 15 and over 95 years old were excluded from this study due to the absence or rarity of periodontal diseases in those age ranges. Moreover, the age distribution of periodontal diseases burden, categorizing cases into five age strata (15–39, 40–59, 60–79, and 80–94 years), and the proportion of cases in each stratum were examined and calculated. As this study analyzed pre-aggregated, modeled estimates from the GBD 2021 database, no additional inclusion/exclusion criteria were applied. The GBD collaborators applies standardized data inclusion protocols, detailed in their methodology reports, to ensure cross-country comparability and validity [1, 17, 18].

Statistical analysis

Age–Period–Cohort analysis

In this study, we employed the APC model, incorporating age, period, and cohort as independent variables. The dependent variable was the incidence of the observed event or phenomenon in the population, assuming a probability distribution. This model enabled us to analyze disease trends beyond traditional epidemiological approaches [19]. Our findings contribute to a comprehensive understanding of periodontal diseases patterns and identify influential factors. We utilized the incidence estimates of periodontal diseases from the GBD 2021 database, along with population data for global and BRICS, as inputs for the APC model. The research results under the APC model reveal key indicators such as net drift, local drift, longitudinal age curve, period relative risk, and cohort relative risk. Net drift unveils a logarithmic linear trend between different time periods and cohorts within the overall population, capturing the general temporal pattern in the data. On the other hand, local drift elaborates on the logarithmic linear trend between different time periods and cohorts within specific age groups, providing a more detailed insight into how these trends manifest across different demographic groups. The longitudinal age curve plays a pivotal role in depicting the expected age-specific incidence rates, considering period effects and comprehensively showcasing the impact of age on the incidence rate of periodontal diseases. Furthermore, period relative risk quantifies the relative risk of the population across different time periods while adjusting for age and cohort effects. This metric is crucial for understanding the temporal changes in population risk, independent of age and cohort effects. Cohort relative risk offers insights into the relative risks within different cohorts, adjusting for age and period effects. By separating cohort-specific risks from the effects of age and period, this metric helps reveal potential differences in the risk profiles of different birth cohorts regarding investigated health outcomes. The APC model was analyzed using the intrinsic estimator (IE) method. For detailed methodological information, please refer to the previous literature [20].

Data arrangement

In APC model, the requirement for equal intervals between age and period was enforced. Consequently, we partitioned the population aged 15–94 into 16 age groups (15–19, 20–24,..., 90–94) with a consistent age interval of 5 years. Additionally, the period data from 1992 to 2021 were partitioned into consecutive 5-year intervals (1992–1996, 1997–2001,..., 2017–2021). Given that the birth cohort is determined by the subject's age and the event's date, i.e., cohort = period - age [21], the corresponding birth cohorts range from 1898 to 1906 (median 1902) to 1998–2006 (median 2002).

Results

Globally and in BRICS countries trends in periodontal diseases incidence, 1992–2021

Table 1 presents the population, total number of incidences, all-age incidence rates, age-standardized incidence rate, and the net drift of incidence rates. In 2021, the new cases of periodontal diseases were 8961 thousand (95% UI: 7907, 10101), representing a 71.21% increase compared to 1992. The global age-standardized incidence rate for periodontal diseases increased by 1.28% from 1055.90 (95% UI: 850.05, 1215.66) per 100,000 population in 1992 to 1069.44 (95% UI: 942.71, 1204.58) per 100,000 population in the year 2021 (Table 1).

All BRICS countries exhibited varying degrees of increase in the number of new cases from 1992 to

Table 1 Trends in periodontal diseases incidence across BRICS, 1992–2021

	Global		Brazil		Russian Federation		India		China		South Africa	
	1992	2021	1992	2021	1992	2021	1992	2021	1992	2021	1992	2021
Population												
Number, n x 1,000,000*	5497 (5379, 5624)	7891 (7667, 8131)	153 (142, 165)	220 (188, 251)	152 (138, 166)	145 (125, 164)	885 (819, 951)	1414 (1240, 1602)	1206 (1111, 1302)	1423 (1319, 1530)	39 (35, 42)	57 (50, 64)
Percentage of global, %	100.0	100.0	2.8	2.8	2.8	1.8	16.1	17.9	21.9	18.0	0.7	0.7
Incidence												
Number, n x 1,000*	5234 (4132, 6068)	8961 (7907, 10101)	136 (105, 161)	291 (252, 323)	190 (155, 219)	199 (169, 233)	940 (723, 1107)	1853 (1617, 2071)	1017 (786, 1221)	1830 (1575, 2073)	23 (17, 29)	33 (26, 43)
Percentage of global, %	100.0	10 0.0	2.6	3.2	3.6	2.2	18.0	20.7	19.4	20.4	0.4	0.4
Percent change of incidence 1992–2021, %	71.21		113.97		4.74		97.13		79.94		43.48	
All-age incidence rate												
Rate per 100,000*	952.11 (751.66, 1103.89)	1135.59 (1001.97, 1279.95)	887.47 (686.54, 1049.79)	1320.36 (1142.18, 1466.07)	1253.81 (1022.31, 1444.48)	1374.29 (1168.28, 1607.42)	1062.31 (817.16, 1250.84)	1309.86 (1142.92, 1464.24)	843.14 (651.56, 1012.10)	1285.90 (1106.87, 1457.01)	592.78 (436.86, 748.82)	581.51 (456.47, 749.92)
Percent change of rate 1992–2021, %	19.17		48.78		9.61		23.30		52.51		-1.90	
Age-standardized Incidence rate												
Rate per 100,000*	1055.90 (850.05, 1215.66)	1069.44 (942.71, 1204.58)	1060.75 (855.60, 1231.05)	1164.41 (998.65, 1300.77)	1091.48 (884.24, 1266.80)	1049.06 (869.80, 1255.05)	1263.45 (1005.20, 1453.91)	1268.96 (1119.16, 1409.94)	922.01 (723.63, 1093.46)	967.03 (830.95, 1100.24)	796.95 (588.97, 996.43)	600.50 (481.27, 763.54)
Percent change of rate 1992–2021, %	1.28		9.77		-3.89		0.44		4.88		-24.65	
APC model estimates												
Net drift of incidence rate, % per year#	0.02 (-0.03, 0.08)		0.14 (-0.22, 0.50)		-0.12 (-0.16, -0.08)		-0.05 (-0.23, 0.13)		0.39 (0.13, 0.65)		-0.92 (-0.97, -0.86)	

Notes: All-age incidence rate: crude incidence rate

Age-standardized incidence rate is computed by direct standardization with global standard population in the GBD 2021

Net drifts are estimates derived from the age-period-cohort model and denotes overall annual percentage change in incidence rate, which captures the contribution of the effects from calendar time and successive birth cohorts

* Parentheses for all GBD health estimate indicate 95% uncertainty intervals due to the inherent characteristics of model selection, parameter estimation, and the quality and availability of data inputs for GBD 2021

\# Parentheses for net drift indicate 95% confidence intervals

APC: age-period-cohort, UI: uncertainty interval, CI: confidential interval

2021, ranged from 4.74% in the Russian Federation to a remarkable 113.97% in Brazil. In 2021, India exhibited the highest age-standardized incidence rate of periodontal diseases, with 1268.96 (95% UI: 1119.16, 1409.94) per 100,000 population. Conversely, South Africa demonstrated the lowest age-standardized incidence rate, with 600.50(95% UI: 481.27, 763.54) per 100,000 population. Between 1992 and 2021, an upward trend in age-standardized incidence rate attributable to periodontal diseases was observed in Brazil, India, and China, whereas the Russian Federation and South Africa displayed declining trends. According to the APC model estimation, the annual net drift in periodontal diseases incidence varied among the BRICS countries, ranging from -0.92% (95% confidential interval [22]: -0.97, -0.86) in South Africa to 0.39% (95% CI: 0.13, 0.65) in China (Table 1).

Time trends in periodontal diseases incidence rate across different age groups

According to Fig. 1A, we examined the annual percentage changes in periodontal diseases incidence rates across different age groups. Globally, the majority of age groups exhibited local drift values close to 0, indicating no significant changes in periodontal diseases incidence rates within these age groups. These consistent trends were independently observed and verified in Brazil, India, and Russian Federation. In China, there was an increase in periodontal diseases incidence rates among the younger age group (15–54 years), while the rates remained relatively unchanged among middle-aged and elderly individuals. Encouragingly, in South Africa, nearly all age groups, except for the 80–94 age group, experienced a decline in periodontal diseases incidence rates.

Figure 1B shows the long-term trend of the age distribution of periodontal diseases. Over the period from 1992 to 2021. Overall, the majority of global periodontal diseases cases are recorded among individuals aged 15–59 years, and comparable distributions are observed in Brazil, China, and India. However, nearly all cases of periodontal diseases occur in middle-aged and elderly populations (40–79 years) in Russian Federation and South Africa. Concurrently, the age distribution of periodontal diseases cases is relatively stable globally and in BRICS countries from 1992 to 2021, but there was an emerging transition of incidences from the young population 15–39 years) to the middle-aged and old population (40–79 years) in China.

Age, period, and cohort effects on periodontal diseases incidence rate

Figure 2 presents the estimates of Age-Period-Cohort effects derived from the APC model, including both global data and data specific to the BRICS countries. Globally, the incidence rate of periodontal diseases experiences a rapid increase in the age group of 15–39 years, followed by a stable rise with advancing age. This pattern is consistently observed in Brazil, China, Russian Federation, and South Africa. However, in India, the incidence rate of periodontal diseases experiences a rapid increase only in the age group of 15–29 years, followed by a stable rise thereafter (Fig. 2A).

Figure 2B illustrates the period effects. Globally, over the past three decades, the incidence risk has remained relatively stable with little variation. India and Russian Federation exhibit similar trends in this regard. South Africa displayed a distinct pattern, with decreased period risks prior to the reference period (2002–2006), followed by a subsequent increase. The incidence rate ratios of periodontal diseases in Brazil are observed to exhibit a fluctuating pattern, marked by an initial rise, subsequent decline, and a renewed upward trend. Furthermore, China follows a more complex nonlinear trajectory, demonstrating three phases of decline interspersed with two phases of increase over the study period.

Figure 2C shows that the cohort effects on past incidence risk have remained relatively stable globally, in Brazil, India, and the Russian Federation. However, in China, there has been a gradual increase in incidence risk after the reference cohort (1948–1956). In contrast, South Africa has shown a gradual decline in incidence risk after the reference cohort (Fig. 2C).

Discussion

This study highlights significant changes in the burden of periodontal diseases from 1992 to 2021, with a particular focus on BRICS countries. The findings reveal a varying degree of increase in periodontal diseases incidence across BRICS nations. Notably, incidence rates rise substantially with age and tend to stabilize after 40 years. Moreover, significant heterogeneity was observed in period and cohort effects, underscoring considerable epidemiological disparities among BRICS countries. These findings emphasize the need to prioritize targeted interventions within the BRICS framework to mitigate the burden of periodontal diseases across different age, period, and cohort effects.

From 1992 to 2021, the global cases of periodontal diseases increased by 71.21%, likely driven by population growth. Four out of five BRICS members exhibited an increase in all-age incidence rate, whereas South Africa showed a declining trend. After adjusting for age distribution changes, the variation in age-standardized incidence rate for periodontal diseases from 1992 to 2021 suggests that, beyond demographic shifts, other underlying factors have also contributed to changes in the disease burden. The local drift of periodontal diseases in most BRICS countries (Brazil, Russian Federation and

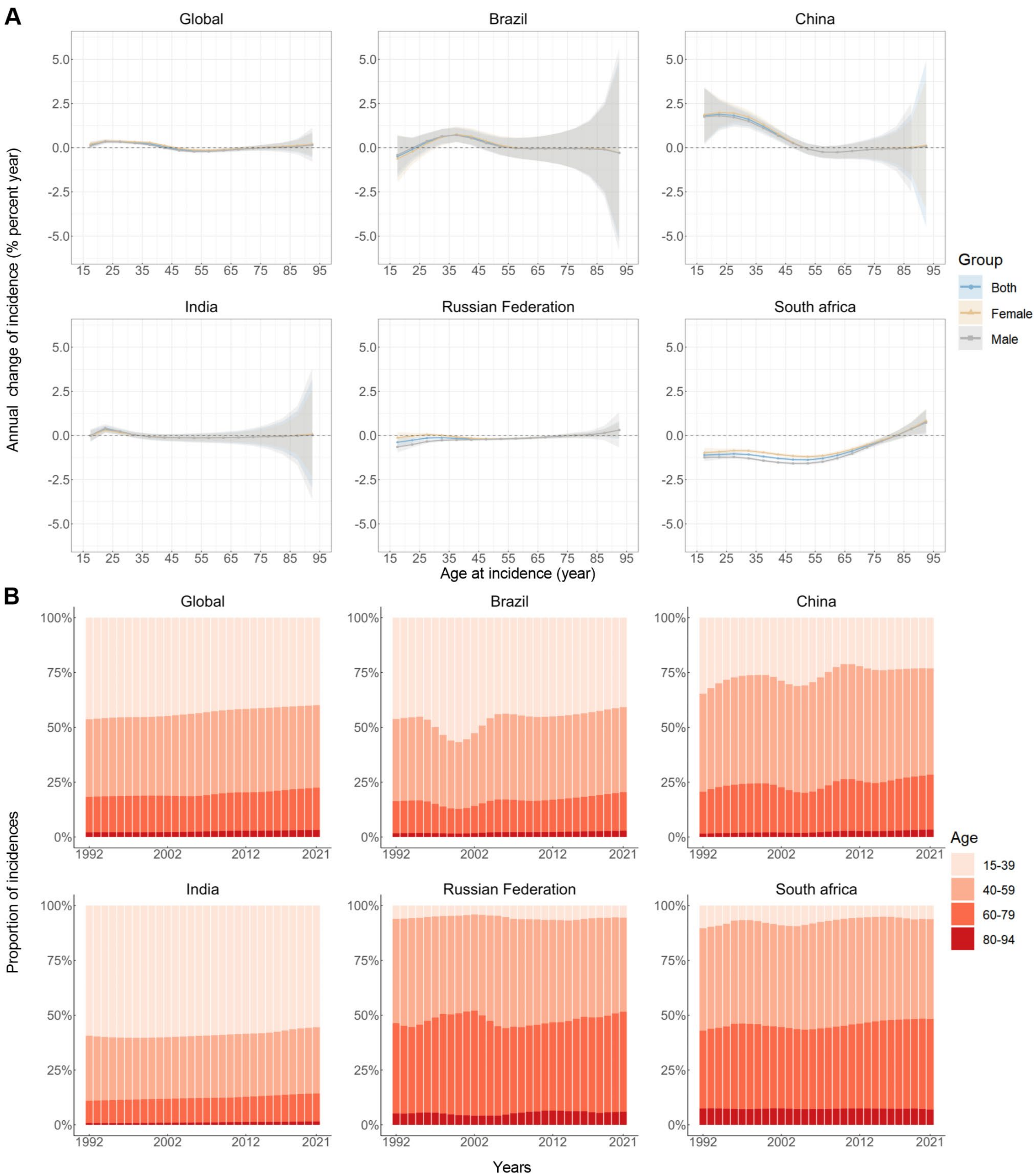

Fig. 1 Local drifts of incidence rate and age distribution of incidences in global and BRICS, 1992–2021. (**A**) Local drifts of periodontal diseases incidence rate (estimates from age-period-cohort models) for age groups (15–19 to 90–94 years), 1992–2021. The dots and shaded areas indicate the annual percentage change of incidence rate (% per year) and the corresponding 95% CIs. (**B**) Temporal change in the relative proportion of periodontal diseases incidences across age groups, 1992–2021

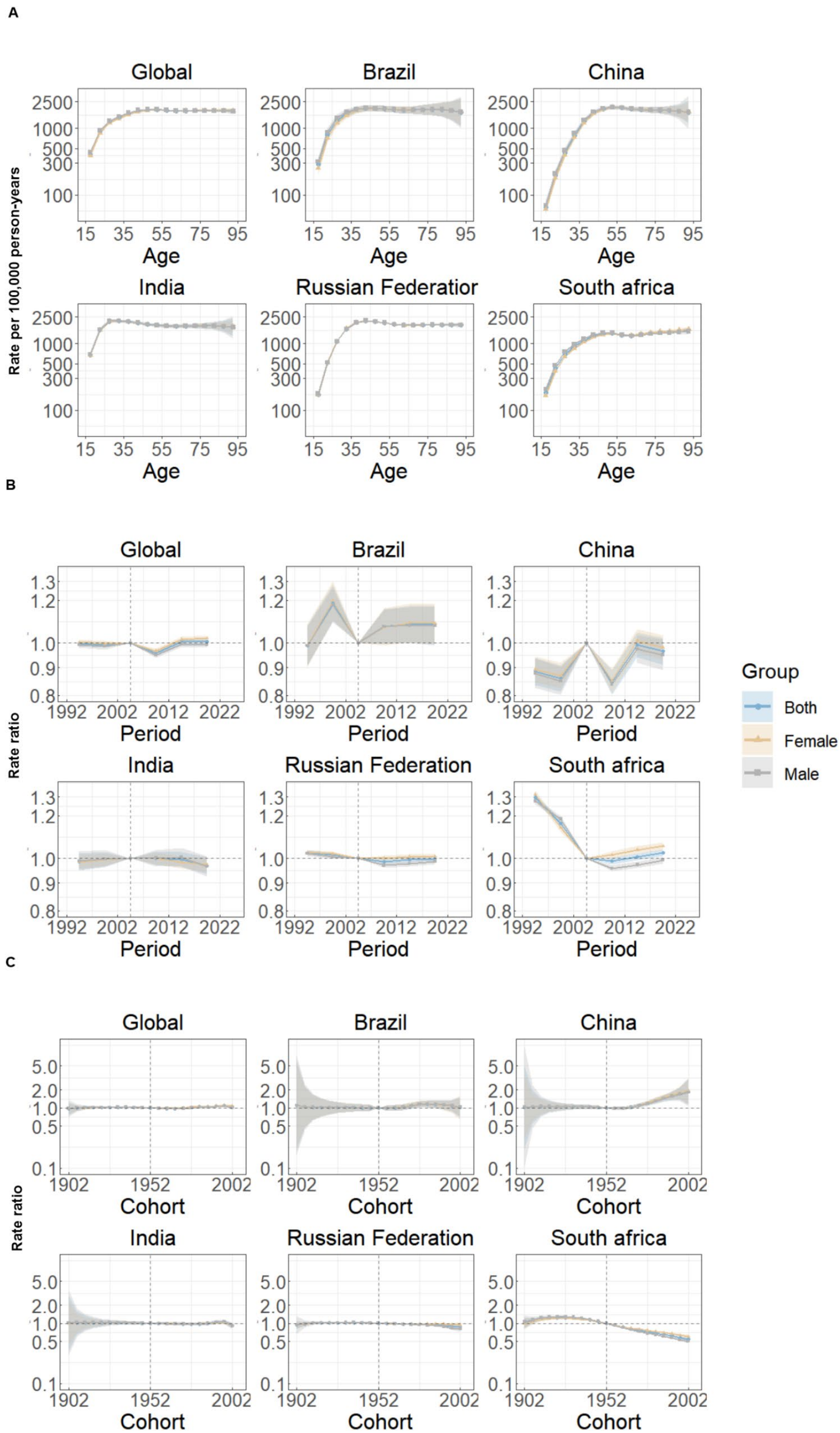

Fig. 2 (See legend on next page.)

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Fig. 2 Age, period and cohort effects on periodontal diseases incidence in global and BRICS. (**A**) Age effects are shown by the fitted longitudinal age curves of incidence rate (per 100,000 person-years) adjusted for period deviations. (**B**) Period effects are shown by the relative risk of incidence rate (incidence rate ratio) and computed as the ratio of age-specific rates from 1992–1996 to 2017–2021, with the referent cohort set at 2002–2006. (**C**) Cohort effects are shown by the relative risk of incidence rate and computed as the ratio of age-specific rates from the 1902 cohort to the 2002 cohort, with the referent cohort set at 1952. The dots and shaded areas denote incidence rates or rate ratios and their corresponding 95% CIs

India) was almost zero in all age groups. The observed positive local drift values among young and middle-aged individuals (15–54 years) in China highlight potential health concerns. This phenomenon may be associated with the high levels of occupational, familial, and social stress experienced by this population, which may promote the onset and progression of periodontal diseases [23]. Furthermore, Over the past three decades, the age distribution of periodontal diseases cases has remained relatively stable globally, as well as in Brazil, the Russian Federation, India, and South Africa. Interestingly, the cases of periodontal diseases in China were rapidly shifting from affecting younger individuals to impacting the elderly population, likely reflecting the aging population and the increasing exposure of older individuals to risk factors traditionally associated with younger populations [24, 25, 26].

The incidence of periodontal diseases in the BRICS countries shows significant variation. National policymakers can assess country - specific attributes related to this issue to inform decision - making, while also considering their country's position relative to others. However, the potential risk factors for periodontal diseases often attract attention, highlighting the need for further investigation into age, period, and cohort effects. Given these considerations, this study focuses on using the APC framework to analyze the incidence patterns of periodontal diseases globally and in the BRICS countries. Our results consistently show similar age effects globally and within the BRICS countries, indicating that the risk of periodontal diseases increases with age and stabilizes at a high incidence after the age of 40. The cumulative effect of bacterial plaque and tartar becomes more pronounced with age, and the immune system weakens, making it more difficult for the body to fight off infections, including those in the periodontal tissues [24, 25].

India and the Russian Federation have consistently exhibited similarly stable trends in terms of the period and cohort effects of periodontal diseases, with both countries showing a lack of significant improvement in reducing disease risk despite various healthcare advancements. In India, substantial efforts have been made through the establishment of numerous dental schools and the implementation of the National Oral Health Program (NOHP), which aims to improve oral health awareness and services [27]. Similarly, the Russian Federation has developed a three-tier dental professional structure and initiated optimized dental care activities to address the growing oral health needs [28]. However, despite these advancements, both countries continue to face significant challenges stemming from prevalent unhealthy lifestyles and dietary habits that continue to undermine efforts to reduce periodontal diseases risks. Alcohol consumption and smoking rates, historically higher among Russians, compound risk factors associated with periodontal pathologies [29, 30]. The use of traditional tobacco products, including betel quid, which is prevalent in many regions of India, is significantly associated with periodontal diseases and disproportionately affects younger generations [31]. Moreover, urban centers see advanced dental infrastructure, but smaller cities and rural areas remain critically underserved. For these developing countries, it remains evident in their insufficient dental workforce-to-population ratios and inequities affecting oral preventative care programs [32, 33]. Ongoing developments in dental workforce policies and improving the reach of oral health education are crucial as part of the government's strategy to address noncommunicable diseases. Future efforts should integrate preventive dental healthcare into broader public health endeavors, emphasizing the complex interplay between healthcare infrastructure and socio-economic factors affecting oral health.

Brazil has shown an interesting fluctuating trend in periodontal diseases incidence rates, which could be contextualized within the country's unique socio-economic conditions and evolving healthcare policies. The implementation of the Brazilian Unified Health System has increased access to health services and preventive measures, greatly enhancing oral health awareness, but it may also lead to more cases of periodontitis being diagnosed [34, 35, 36]. A high prevalence of edentulism was reported in Brazil [37], indicating that as more individuals maintain their teeth into older age, they may inadvertently be exposed to long-term periodontal health problems. Additionally, Brazil's growing consumption of processed, sugar-filled foods over the last several decades, combined with suboptimal oral hygiene among certain demographics, creates an environment that fosters periodontal diseases [38]. Research has also indicated that Brazil has high smoking rates, although policies have recently initiated effective control measures in some segments, which may yield measurable impacts in future trends [39, 40, 41]. South Africa exhibits notable fluctuations in periodontal diseases incidence risk that reflect the historical and socio-political complexities in healthcare access. The significant decline in risk before the reference period (2002–2006) can be attributed to enhanced public health policies and campaigns advocating for oral hygiene, particularly in the democratization period [42]. Changes in socio-economic factors, including increased funding for healthcare services and health education among various population segments, contributed positively during this phase [43, 44, 45]. However, the subsequent increase in risk could indicate disparities in accessing care; disparities that remain entrenched in the country due to historical inequities in resource allocation [45]. Cultural factors, such as dietary practices involving sugar consumption, combined with socio-economic stress, might be contributing factors to this rising incidence [46]. The declining cohort effect points to a necessity for continual education and accessible dental care, particularly focusing on the lower socioeconomic groups that remain vulnerable. In addressing the multifactorial causes, cross-sector engagement remains essential for sustainable improvement in oral health [47].

In contrast to the long-term stability observed in Brazil, China exhibits a distinct cohort effect, characterized by a gradual increase in disease risk among successive younger birth cohorts, highlights the significant influence of lifestyle and industrialization. Chinese dietary patterns underwent drastic shifts over the last decades, transitioning from traditional low-sugar consumption to Westernized, sugar-rich foods, which elevate risks of oral health issues [48, 49]. The trajectory of period effects in China is notably more complex with nonlinear patterns, reflecting the nation's substantial social and economic transformations. Undoubtedly, the rapid growth of the Chinese economy has increased public awareness of oral hygiene and health promotion [50]. Recently, the Chinese Communist Party Central Committee and the State Council of the People's Republic of China issued the "Healthy China 2030" plan, which aims to improve the population's health and includes specific goals for oral health [51]. The General Office of the State Council also released the "Medium-to-Long Term Plan of China for the Prevention and Treatment of Chronic Diseases (2017–2025)", emphasizing the importance of reducing salt, oil, and sugar intake, and focusing on oral health, weight management, and bone health [52]. These ongoing reforms in China's healthcare system, aiming for universal health coverage, have improved overall healthcare access, but challenges remain in integrating oral health into these reforms comprehensively [53]. Considering the vast land and dense population of China, future efforts should still focus on implementing extensive public health campaigns and education programs, which are crucial for raising public awareness of periodontal health and effective prevention strategies.

Compared to the most recent GBD 2019 reports [12, 13, 14], this study has analyzed the global and BRICS countries' periodontal diseases burden by integrating age, period, and cohort effects. Our contribution lies in quantifying the age distribution of incidence and its localized drift from 1992 to 2021, while the application of the APC model elucidates the complex interactions among specific age groups, period, and cohort effects on the disease burden, thereby enhancing our understanding of the epidemiological patterns of periodontal diseases. Indeed, it is crucial to acknowledge some limitations. First, the GBD 2021 dataset was sourced from diverse inputs, including surveys, registries, and administrative records, with significant variations observed in data quality and completeness. This heterogeneity introduces potential biases and uncertainties into epidemiological estimates. Second, the GBD framework relies heavily on modeled estimates for regions with scarce empirical data. The assumptions underpinning these models may lack universal applicability, particularly given the influence of cultural, genetic, and environmental factors on periodontal diseases burden among BRICS. Nevertheless, the GBD 2021 remains committed to addressing potential biases in modeling data: (1) a systematic review of the literature was conducted for GBD 2021 which resulted in the addition of four new sources with data for periodontal diseases; (2) revised crosswalk models to include age pattern for alternate definitions of AL) > 5 mm, AL > 4 mm, and CPITN Class 3. Third, this ecological analysis utilizes aggregated population-level data and does not capture individual behavioral factors, such as oral hygiene practices. To mitigate these limitations, multiple hypotheses grounded in current evidence have been proposed to explain causal relationships driving temporal trends in periodontal diseases incidence. Although causal inference is limited, the APC framework remains robust for identifying macro-level trends, which can guide future research targeting individual risk factors.

Conclusions

This study provides an in-depth analysis of the periodontal diseases burden within the BRICS members. From 1992 to 2021, Brazil, India, and China experienced an increasing trend in the age-standardized incidence rates of periodontal diseases, in contrast to the declining trends observed in the Russian Federation and South Africa. Furthermore, five countries displayed similar age-effect patterns characterized by initial increases followed by subsequent stabilization with advancing age, along with distinct period and cohort effects. The findings highlight the critical need for tailored interventions spanning age, period, and cohort dimensions to effectively address the distinct challenges posed by periodontal diseases in these nations undergoing rapid development.

Acknowledgements
Thanks to the IHME and the Global Burden of Disease study collaborations.

Author contributions
Xiaochan Wang: project administration (equal), conceptualization (lead), writing-original draft (lead), formal analysis (lead), and writing-review and editing (equal). Yuting Xu: supervision (equal), data curation (equal) and software (equal), conceptualization (supporting), formal analysis (supporting), and writing-review and editing (equal). Xiangming Ma: methodology (lead), formal analysis (supporting), and writing-review and editing (equal). Ruixing Nan: conceptualization (supporting), data curation (equal) and writing-review and editing (equal). Peiyu Cheng: project administration (equal) and writing-review and editing (equal). Yuhang Wu: resource (equal), con-ceptualization (supporting), investigation (equal) and writing-review and editing (equal). All au-thors gave their final approval and agree to be accountable for all aspects of the work.

Funding
This work was supported by Department of Science and Technology of Hunan Province (grant number: 2022ZK4262) and Special Science and Technology Major Project of Hunan Province (grant number: Z2023146).

Data availability
The datasets generated during and/or analyzed during the current study are available in the GBD Data Tool repository (http://ghdx.healthdata.org/gbd-results-tool). This public link to the database of GBD study is open, and the use of data does not require additional consent from IHME.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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Received: 9 December 2024 / Accepted: 13 March 2025
Published online: 26 March 2025

References

1. GBD 2021 Diseases and Injuries Collaborators. Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the global burden of disease study 2021. Lancet (London England). 2024;403(10440):2133–61.
2. Peres MA, Macpherson LMD, Weyant RJ, Daly B, Venturelli R, Mathur MR, Listl S, Celeste RK, Guarnizo-Herreño CC, Kearns C, et al. Oral diseases: a global public health challenge. Lancet. 2019;394(10194):249–60.
3. Ghaffari M, Rakhshanderou S, Ramezankhani A, Noroozi M, Armoon B. Oral health education and promotion programmes: Meta-Analysis of 17-Year intervention. Int J Dental Hygiene. 2018;16(1):59–67.
4. Trindade D, Carvalho R, Machado V, Chambrone L, Mendes JJ, Botelho J. Prevalence of periodontitis in dentate people between 2011 and 2020: A systematic review and meta-analysis of epidemiological studies. J Clin Periodontol. 2023;50(5):604–26.
5. Pattamatta M, Chapple I, Listl S. The value-for money of preventing and managing periodontitis: Opportunities and challenges. *Periodontology 2000*. 2024.
6. Wei X, Zhang X, Chen R, Li Y, Yang Y, Deng K, Cai Z, Lai H, Shi J. Impact of periodontitis on type 2 diabetes: a bioinformatic analysis. BMC Oral Health. 2024;24(1):635.
7. Yang X, Luo M, Jiang Y. The regulatory effect of zinc on the association between periodontitis and atherosclerotic cardiovascular disease: a cross-sectional study based on the National health and nutrition examination survey. BMC Oral Health. 2024;24(1):703.
8. Zhu J, Li M, Li J, Wu J. Sialic acid metabolism of oral bacteria and its potential role in colorectal cancer and Alzheimer's disease. Carbohydr Res. 2024;541:109172.
9. Radulescu IG, Panait M, Voica C. BRICS countries challenge to the world economy new trends. Procedia Econ Finance. 2014;8:605–13.
10. Petersen PE, Baehni PC. Periodontal health and global public health. Periodontol 2000. 2012;60(1):7–14.
11. Liu Z, Wang Z, Xu M, Ma J, Sun Y, Huang Y. The priority areas and possible pathways for health Cooperation in BRICS countries. Global Health Res Policy. 2023;8(1):36.
12. Chen MX, Zhong YJ, Dong QQ, Wong HM, Wen YF. Global, regional, and National burden of severe periodontitis, 1990–2019: an analysis of the global burden of disease study 2019. J Clin Periodontol. 2021;48(9):1165–88.
13. Zhang X, Wang X, Wu J, Wang M, Hu B, Qu H, Zhang J, Li Q. The global burden of periodontal diseases in 204 countries and territories from 1990 to 2019. Oral Dis. 2024;30(2):754–68.
14. Wu L, Zhang SQ, Zhao L, Ren ZH, Hu CY. Global, regional, and National burden of periodontitis from 1990 to 2019: results from the global burden of disease study 2019. J Periodontol. 2022;93(10):1445–54.
15. Sun R, Xu X, Dong Y, Li J, Guan W, Huang Y, Li S, Wang Y, Li J. Global and regional trends in prevalence of untreated caries in permanent teeth: Age-period-cohort analysis from 1990 to 2019 and projections until 2049. J Dent. 2024;147:105122.
16. GBD 2019 Diseases and Injuries Collaborators. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the global burden of disease study 2019. Lancet (London England). 2020;396(10258):1204–22.
17. GBD 2021 Risk Factors Collaborators. Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990–2021: a systematic analysis for the global burden of disease study 2021. Lancet (London England). 2024;403(10440):2162–203.
18. GBD 2021 Causes of Death Collaborators. Global burden of 288 causes of death and life expectancy decomposition in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the global burden of disease study 2021. Lancet (London England). 2024;403(10440):2100–32.
19. Bell A. Age period cohort analysis: a review of what we should and shouldn't do. Ann Hum Biol. 2020;47(2):208–17.
20. Yang Y, Schulhofer-Wohl S, Fu WJJ, Land KC. The intrinsic estimator for age-period-cohort analysis: what it is and how to use it. Am J Sociol. 2008;113(6):1697–736.
21. Fienberg SE, Hodges JS, Luo LY, Ko C-W, Yang Y, Land KC. Journal of the American Statistical Association, 109, 865: Comment by Fienberg, Hodges, and Luo and Replies. *Journal of the American Statistical Association*. 2015;110(509):457–457.
22. Santos NRDJC, Coletiva S. The Brazilian Unified Health System (SUS), State Public Policy: Its institutionalized and future development and the search for solutions. 2013;18(1):273–280.
23. Hu Z, Tang L, Zhan Y. Depression, stress-related disorders and risk for dental caries and periodontitis: A bidirectional and multivariable Mendelian randomization study. J Affect Disord. 2024;361:285–90.
24. Marsh PD. Dental plaque as a biofilm and a microbial community - implications for health and disease. BMC Oral Health. 2006;6(Suppl 1):S14.
25. Preshaw PM, Henne K, Taylor JJ, Valentine RA, Conrads G. Age-related changes in immune function (immune senescence) in caries and periodontal diseases: a systematic review. J Clin Periodontol. 2017;44(Suppl 18):S153–77.
26. Fang EF, Xie C, Schenkel JA, Wu C, Long Q, Cui H, Aman Y, Frank J, Liao J, Zou H et al. A research agenda for ageing in China in the 21st century (2nd edition): Focusing on basic and translational research, long-term care, policy and social networks. *Ageing research reviews*. 2020;64:101174.

27. Jiang CM, Chu CH, Duangthip D, Ettinger RL, Hugo FN, Kettratad-Pruksapong M, Liu J, Marchini L, McKenna G, Ono T, et al. Global perspectives of oral health policies and oral healthcare schemes for older adult populations. Front Oral Health. 2021;2:703526.
28. Urukov NY, Rukodayny OV, Urukov YN, Sharapova OV, Gerasimova LI, Smirnova TL, Barsukova EV, Zhuravleva NV. Aspects of managerial and organizational decisions in Building dental services in Russia (literature review). Health Risk Anal. 2023;4:172–9.
29. Cockerham WC. Health lifestyles in Russia. Soc Sci Med. 2000;51(9):1313–24.
30. Marschner F, Lechte C, Kanzow P, Hraský V, Pfister W. Systematic review and meta-analysis on prevalence and risk factors for gingival recession. J Dent 2025:105645.
31. Sivaprasad S, Bhuvanewari E, Usha R, Anitha P. Health Implications of Tobacco and Betel Quid Chewing–an Etiological Survey in The Chittoor District of Andhra Pradesh, India. 2014.
32. Ali E. Urbanisation in India: causes, growth, trends, patterns. Consequences & Remedial Measures; 2020.
33. Nurutdinova A. The Content Modification within the Framework of the Massive Open Online Courses (Case Study: International and Russian Practices). In: *Massive Open Online Courses - Current Practice and Future Trends.* edn. Edited by Goundar S. Rijeka: IntechOpen; 2023.
34. Ortega F, Pele A. Brazil's unified health system: 35 years and future challenges. Lancet Reg Health Americas. 2023;28:100631.
35. Pimentel FG, Buchweitz C, Onocko Campos RT, Hallal PC, Massuda A, Kieling C. Realising the future: health challenges and achievements in Brazil. SSM - Mental Health. 2023;4:100250.
36. Martins FC, Santos B, Crosato EM, Teixeira MCL, Gabriel M, Araújo ME, Goes PSA, Carrer FCA. Orthodontics in the oral health care network of the unified health system (SUS). Brazilian Oral Res. 2024;38:e011.
37. Rihs LB, da Silva DD, de Sousa Mda L. Dental caries and tooth loss in adults in a Brazilian southeastern state. J Appl Oral Science: Revista FOB. 2009;17(5):392–6.
38. Alves-Costa S, Leite FRM, Ladeira LLC, Lima-Soares F, de Andrade Paes AM, de Souza BF, Nascimento GG, Ribeiro CCC. Behavioral and metabolic risk factors associated with periodontitis in Brazil, 1990–2019: a multidimensional analysis for the global burden of disease study 2019. Clin Oral Investig. 2023;27(12):7909–17.
39. Machado JAD, Fantin JV, Campos JC, Traebert E, Oliveira C, Traebert J. Prevalence of current smoking and associated factors in older adults in Brazil. Revista Da Associacao Med Brasileira (1992). 2024;70(9):e20240372.
40. Malta DC, Gomes CS, Andrade FMD, Prates EJS, Alves FTA, Oliveira PPV, Freitas PC, Pereira CA, Caixeta RB. Tobacco use, cessation, secondhand smoke and exposure to media about tobacco in Brazil: results of the National health survey 2013 and 2019. Revista Brasileira De epidemiologia = Brazilian J Epidemiol. 2021;24(suppl 2):e210006.
41. Figueiredo VC, Turci SRB, Camacho LAB. Tobacco control in Brazil: the achievements and challenges of a successful policy. In: *Cad Saude Publica.* vol. 33Suppl 3; 2017: e00104917.
42. Mukhari-Baloyi NA, Bhayat A, Madiba TK, Nkambule NRJSADJ. A review of the South African National oral health policy. 2021;76(9):551–7.
43. Gumede V, Bila S, Biyase M, Chauke S, Arogundade S. Socio-economic Transformation in South Africa. In: *South African Economy: Trails and Possibilities.* edn. Edited by Gumede V, Bila S, Biyase M, Chauke S, Arogundade S. Cham: Springer Nature Switzerland; 2024: 51–88.
44. Bhayat A, Madiba T, Nkambule N. A review of the South African National oral health policy. SADJ: J South Afr Dent Association = tydskrif Van Die Suid-Afrikaanse Tandheelkundige Vereniging. 2021;76:551–7.
45. Whyle EB, Olivier J. A socio-political history of South Africa's National health insurance. Int J Equity Health. 2023;22(1):247.
46. Seloka M, Matshipi M, Mphekgwana M, Monyeki K. The association between the consumption of Sugar-Sweetened beverages and metabolic syndrome components in young rural adults in South Africa. Appl Sci. 2022;12:3015.
47. Wood N. Reimagining dental care funding in South Africa: A call for equitable healthcare. South Afr Dent J. 2024;79(05):235–7.
48. Liu Y, Cheng J, Wan L, Chen W. Total and added sugar intakes are increasing among children and adolescents in China: findings from CHNS 1997–2011. Nutrients 2022;14(16).
49. Haiyan G, Peng W, Tam T. Chinese social value change and its relevant factors: an age-period-cohort effect analysis. J Chin Sociol. 2024;11(1):7.
50. Zhang T, Zhang Q, Peng Y, Zheng K, Yang L, Xiao Q, Liu H, Tang W, Liu Y. Retrospective summary analysis on the results of oral health epidemiological investigations in China. J Oral Biol Craniofac Res. 2022;12(6):809–17.
51. National Health Commission of the People's Republic of China. Notice on Issuing the Healthy Oral Action Plan (2019–2025). 2019.
52. The General Office of State Council of the People's. Republic of China issued the Medium-to-Long Term Plan of China for the Prevention and Treatment of Chronic Diseases (2017–2025).
53. Zeng XJ, Zhou XD, Chen WX. Development and improvement of Chinese oral public health system. Zhonghua Kou Qiang Yi Xue Za zhi = Zhonghua Kouqiang Yixue Zazhi = Chin J Stomatology. 2020;55(6):361–6.

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