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Incidence trends and projections of lip and oral cavity cancer in China 1990-2021: an age-period-cohort and decomposition analysis

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Abstract

Objective To investigate the historical trends, underlying causes, and future projections of lip and oral cavity cancer (LOCC) incidence in China.

Methods Annual cases and age-standardized incidence rates (ASIR) for LOCC in China from 1990 to 2021 were extracted from the Global Burden of Disease (GBD) 2021 study. Age-Period-Cohort (APC) models were employed to assess the effects of age, period, and cohort. Bayesian APC models were applied to project future incidence trends, and decomposition analysis was conducted to identify factors influencing incidence.

Result From 1990 to 2021, the cases and ASIR of LOCC increased substantially in male and slightly in female. The ASIR and number of cases in male were higher than that in female during the study period. The APC model showed that the net drift of ASIR in males and females during the study period was 2.34% (95% confidence interval [CI]: 2.10% to 2.59%) and 0.26% (95% CI: 0.13 to 0.39), respectively. LOCC incidence increased the fastest among males and females aged 25–29 years. The incidence of LOCC in male and female increased with age, reaching its peak in the age group of 90–94 years (73.35/100,000 and 11.14/ 100,000, respectively). The period effect showed an increasing trend, while the birth cohort effect showed a decreasing trend. Predictions show that the incidence and cases of LOCC will continue to rise. Population growth, ageing and epidemiological factors in both male and female contributed to the rise of LOCC cases, except for a decrease in the period 1997–2013 due to changing epidemiological factors in female.

Conclusion The increasing trend of LOCC in China is closely related to age, period and cohort. Future projections emphasize the need for targeted prevention focusing on high-risk groups and modifiable factors.

Keywords Age-period-cohort, Lip and oral cavity cancer, Age-standardized incidence rates

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Introduction

Lip and oral cavity cancer (LOCC) including those of the lip, tongue, and mouth, rank as the 16th most common cancer globally are the most prevalent form of head and neck cancer globally, with around 350,000 new cases and over 177,000 deaths reported in 2018 [1]. The most common form of this cancer in the majority of cases is squamous cell carcinoma [2]. The age-standardized incidence rate (ASIR) of LOCC is highest in the Southeast Asia region, followed by Europe and the Eastern Mediterranean region [3]. Despite advancements in early diagnosis and treatment techniques, the 5-year survival rate for oral cancer remains low, ranging between 40 and 50% [4].

LOCC is a common malignancy in many developing countries, with a high disease burden in China [5]. The National Central Cancer Registry of China releases the Cancer Registry Report, which provides a summary of cancer registration data across the country. The latest report published in 2023 estimates that in 2018, there were about 21,047 new cases and 10,389 deaths from oral and oropharyngeal cancer, accounting for 1.35% and 1.14% of all new cancer cases and deaths, respectively [6]. Mouth was the most common subsite of the oral cavity and pharyngeal cancer, representing 28.26% of total cases, followed by the tongue (21.93%), salivary glands (15.30%), and hypopharynx (12.60%) [6].

Various factors, such as tobacco and alcohol use, betel nut consumption, dietary habits, human papillomavirus (HPV) infection, and genetic predisposition, have been associated with the development of LOCC [7, 8]. In the foreseeable future, the incidence of LOCC will be on the rise, and the elderly population is a high-risk group with a higher incidence [5]. The socio-economic changes over the past decades have resulted in significant shifts in the China demographic structure and an accelerated population aging process. In 2019, there were 254 million people aged 60 or older in China. By 2040, this number is projected to rise to 402 million, accounting for approximately 28% of the population [9]. These changes have significant implications for health in China, including an increasing risk and burden of non-communicable diseases and a growing demand on health and social care systems [9]. To the best of our knowledge, no studies have comprehensively evaluated the impact of prolonged population growth and aging on LOCC in China. The lack of such comprehensive research hinders the Chinese government's ability to formulate and adapt its healthcare policies to address the growing healthcare needs of the ageing population.

The main aim of this study was to examine the patterns and trends in LOCC incidence in China using the age-period-cohort (APC) model. The model helps identify the influence of birth cohort and diagnosis period on the long-term trends in LOCC incidence. In addition to analyzing historical data, we also conducted a forecast analysis of LOCC incidence trends in China from 2022 to 2036. Finally, the core of this study is to quantitatively decompose the contribution of epidemiological and demographic factors to the increase in new cases of LOCC. Our research findings contribute to identify potential patterns and trends in the incidence of oral cancer to gain valuable insights, ultimately informing the development of effective prevention and early detection strategies to mitigate the impact of LOCC on the population.

Methods

Data collection

The GBD 2021, released in 2024, provides detailed estimates of exposure levels, relative health risks, and the disease burden attributable to 88 risk factors across 204 countries and territories, as well as 811 subnational locations, spanning the years from 1990 to 2021 [10]. A summary of the GBD data collection, modeling/analysis, and dissemination processes is provided in the supplementary appendix (Appendix S1). Incidence data and corresponding population data of LOCC (C00-C08) from 1990 to 2021 was sourced from the GBD 2021 database. The data includes age group, sex, and year. Through this website to access the 2021 GBD database (https://vizhub.healthdata.org/gbd-results/).

Statistical analysis

The trend test used the Joint Regression Program 4.9.0.0 software developed by the National Cancer Institute to calculate the annual average percentage change (AAPC) and its 95% confidence interval (CI), when the AAPC was statistically significant according to a two-sided p value < 0.05, and as stable otherwise [11].

The influence of age, period, and birth cohort on trends in the incidence of LOCC was assessed using an age-period-cohort model [12]. Based on Poisson distribution, the age-period-cohort model estimates the effects of age effects, period effects and cohort effects on the incidence of an event when adjusting age, period and birth cohort at the same time [13]. We divided the number of cancer cases and population data into seventeen 5-year age groups (ranging from 15–19 years to 95 + years) and six 5-year calendar periods (1992–1996 to 2017–2021) and one 2-year calendar period (1990–1991). The age effect, period effect and cohort effect of APC model were described by longitudinal age curve, period rate ratio and cohort RR. The net drift value represented the annual change in the disease rate over the entire study period, while the local drift value described the annual change in the disease rate for each specific age group [13]. APC model fitting and Wald test were achieved by using web tools (https://analysistools.cancer.gov/apc/). All tests were 2-sided and a significance level of 0.05.

In this study, Bayesian APC model was used to predict the incidence and number of LOCC in 2022–2036. The Bayesian APC model can predict the incidence and number of diseases. One key advantage of using the Bayesian APC model is its flexibility in handling small sample sizes, non-linear trends, and missing data, which are common in public health datasets. The model employs Markov Chain Monte Carlo (MCMC) methods for parameter estimation, but this approach can sometimes lead to convergence issues due to the complexity of the models. To mitigate this problem, we incorporated Integrated Nested Laplace Approximation (INLA), a more efficient and stable method for Bayesian inference, which helps avoid the convergence problems often associated with MCMC methods [14]. The aim of our research using this method is to make more reliable predictions about future trends in LOCC incidence rate and new cases.

We applied the approach of Cheng and his colleagues to decompose changes in LOCC populations into three group-level factors: population growth, population aging, and epidemiological changes, in order to assess the contribution of each factor to the overall change [15]. Further details on decomposition are provided in Supplementary Appendix S2.

Results

Trends in the incidence of LOCC, 1990 to 2021

From 1990 to 2021, the male cases of LOCC in China increased 341.20% (95% uncertainty interval [UI]: 303.50–376.45) from 9.44×10^3 (95% UI: 7.72–11.38) to 41.65×10^3 (95% UI: 31.15–54.22) (Fig. 1, Table 1). The female cases of LOCC in China increased 180.33% (95% UI: 167.21–191.31) from 5.25×10^3 (95% UI: 4.27–6.33) to 14.71×10^3 (95% UI: 11.41–18.44) (Fig. 1, Table 1). The male's ASIR of LOCC in China increased 81.05% (95% UI: 65.96–94.87) from 2.28 (95% UI: 1.88–2.73) per 100,000 to 4.13 (95% UI: 3.12–5.32) per 100,000 (Fig. 1, Table 1). The female's ASIR of LOCC in China increased 15.25% (95% UI: 9.18–20.98) from 1.20 (95% UI: 0.98–1.43) per 100,000 to 1.38 (95% UI: 1.07–1.73) per 100,000 (Fig. 1, Table 1). From 1990 to 2021, the ASIR of LOCC in both male and female was on the rise with AAPC of 2.39 (95% CI: 2.13–2.65) and 0.30 (95% CI: 0.08–0.53), respectively (Table 1). ASIR increased faster in male than in female (Table 1).

APC modeling in the incidence of LOCC, 1990 to 2021

The APC model showed a significant upward net drift from 1990 to 2021 in LOCC incidence in both male and

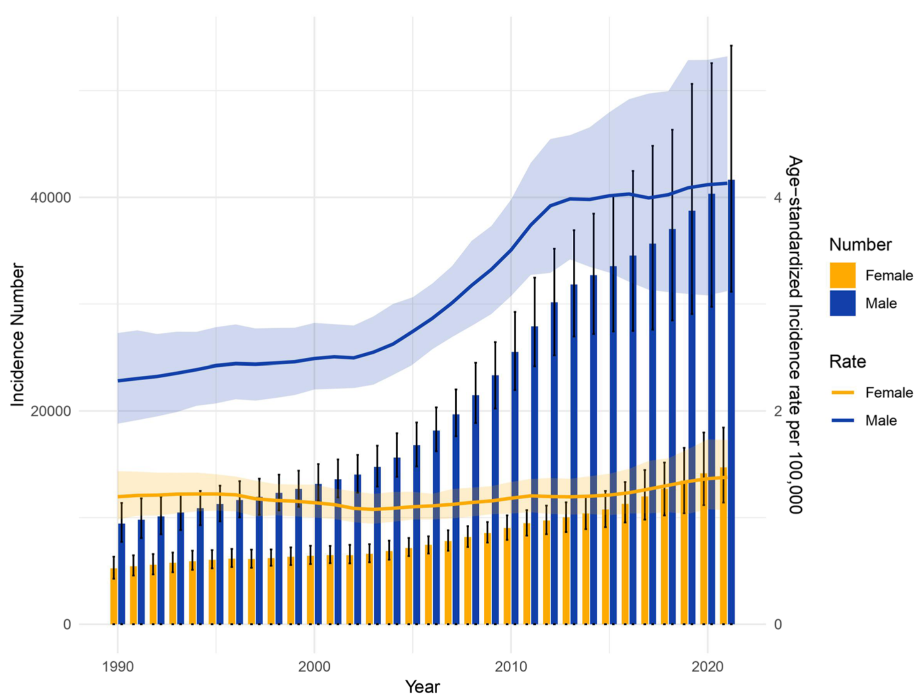

Fig. 1 Absolute cases and ASIR in China from 1990 to 2021

Table 1 Absolute cases and age-standardized incidence rate (ASIR) in China of LOCC in 1990 and 2021, and their average annual percentage changes (AAPCs) from 1990 to 2021

	1990		2021		Changes		
Gender	Number no.*10^3 (95%UI)	ASR per 100,000 (95%UI)	Number no.*10^3 (95%UI)	ASR per 100,000 (95%UI)	Change in absolute number (%, 95%UI)	Change in absolute rate (%, 95%UI)	1990–2021 EAPC of ASR (95%CI)
Male	9.44 (7.72–11.38)	2.28 (1.88–2.73)	41.65 (31.15–54.22)	4.13 (3.12–5.32)	341.20 (303.50-376.45)	81.05 (65.96-94.87)	2.39 (2.13–2.65)
Female	5.25 (4.27–6.33)	1.20 (0.98–1.43)	14.71 (11.41–18.44)	1.38 (1.07–1.73)	180.33 (167.21-191.31)	15.25 (9.18–20.98)	0.30 (0.08–0.53)

* represents the multiplication sign in mathematics

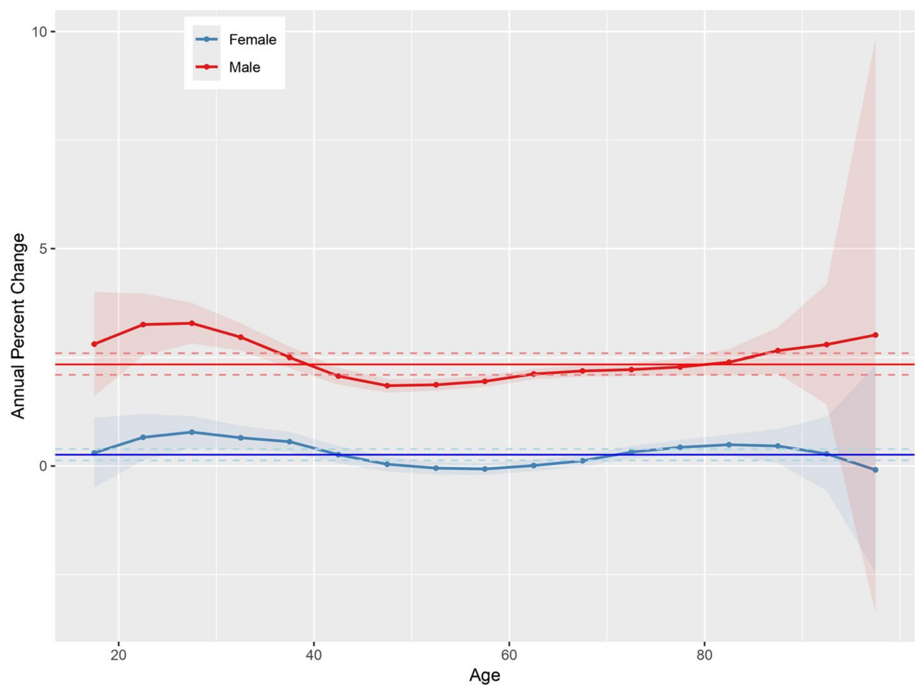

Fig. 2 Local drifts with net drift values for esophageal cancer incidence in China from 1990 to 2021. The horizontal solid line and corresponding dashed lines represent the net drift and its 95% CI, while the curve and corresponding shaded area represent the local drift and its corresponding 95% CI

female over the age of 15, with an annual increase of 2.34% (95% CI: 2.10% to 2.59%) in male and 0.25% (95% CI: 0.13% to 0.39%) in female (Fig. 2). Local drift showed that the incidence of male LOCC increased significantly under 95 years, and increased faster in under 40 years and over 80 years. The incidence of LOCC in female aged 20–44 years and 70–89 years increased significantly, and the other age groups maintained a stable trend (Fig. 2).

Longitudinal age curves revealed that the incidence of LOCC was observed to be lower in younger age groups, especially in people under 40 years old, and then increases with age, reaching a peak in the age group of 90–94 years old, and then decreasing (Fig. 3A). At the same time, the incidence of LOCC showed a significant gender difference, compared with female, male had a higher incidence and were more likely to suffer from LOCC (Fig. 3A).

The period rate ratios exhibited a rising period effect on the risk of LOCC among male, with the risk increasing progressively across successive periods. The period effect indicated that the risk of LOCC in female started to decrease around 1990, but began to rise again after reaching an inflection point in 2004 (Fig. 3B). In general, the cohort effect of males showed a sharp upward trend, and the cohort effect of females increased slightly, albeit with fluctuations (Fig. 3C).

The Wald test validated the statistical significance of these trends and effects in the APC model, confirming

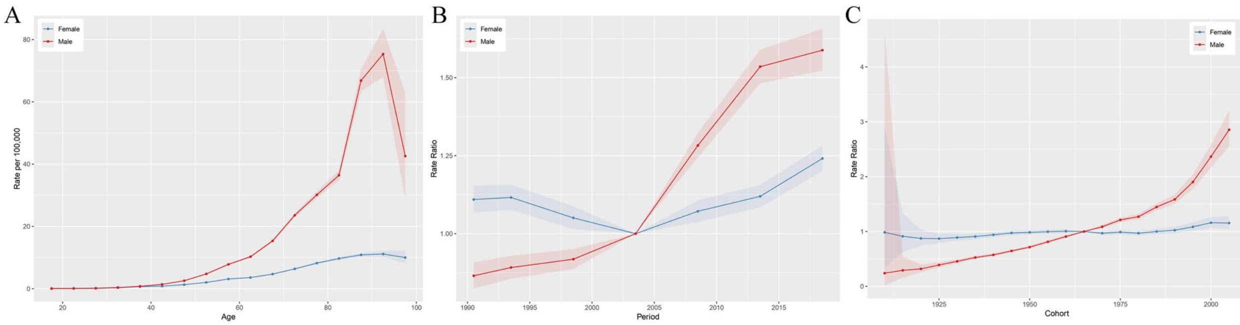

Fig. 3 The age–period–cohort analysis of LOCC in China. **A** Longitudinal age curve; (**B**) Period rate ratio; (**C**) Cohort rate ratio

the robustness of the patterns observed in the age, period, and cohort effects, as detailed in supplementary Table S1.

Projection up to 2036

According to the forecast, the number of LOCC in China will continue to rise in the next 15 years. Specifically, between 2022 and 2036, the number of new cases is expected to increase from 43,079 to 65,587 for males, reflecting a 52.25% rise, and from 15,502 to 28,780 for females, representing an 85.27% increase, as detailed in Fig. 4 and Supplementary Tables S2, S3. Additionally, between 2022 and 2036, the ASIR of LOCC is expected to increase from 4.15 per 100,000 to 4.55 per 100,000 for males, and from 1.42 per 100,000 to 1.85 per 100,000 for females, as detailed in Fig. 5. This increase represents a continued overall increase in LOCC incidence, consistent with trend observed in historical data from 1990 to 2021.

Decomposition of changes in LOCC cases, 1990 to 2021

The results of the decomposition analysis showed that changes in the number and proportion of new LOCC cases among males and females from 1990 to 2021 were influenced by three population-level determinants: population aging, population growth, and epidemiological changes, using 1990 as the baseline, as detailed in Supplementary Tables S4, S5. From 1990 to 2021, 47.99% of the increase in the number of new cases of male LOCC was attributed to population aging, followed by epidemiological changes (i.e., an increase in most age-specific incidence rates) (39.13%), and population growth (12.89%) (Fig. 6A). 66.31% of the increase in the number of new cases of female LOCC was attributed to population aging, followed by population growth (19.79%), and epidemiological changes (13.90%) (Fig. 6B). It is noted that during the period 1997–2013, changes in the epidemiology of changes in female contributed to the reduction of new cases of LOCC.

Discussion

This study comprehensively investigated the incidence trends of LOCC in China from 1990 to 2021 and explored the causes of these trends. The findings of this study highlight the growing burden of LOCC in China, driven largely by demographic and epidemiological changes. The substantial increase in LOCC incidence, particularly among males, suggests that certain risk factors-such as tobacco use, alcohol consumption, and

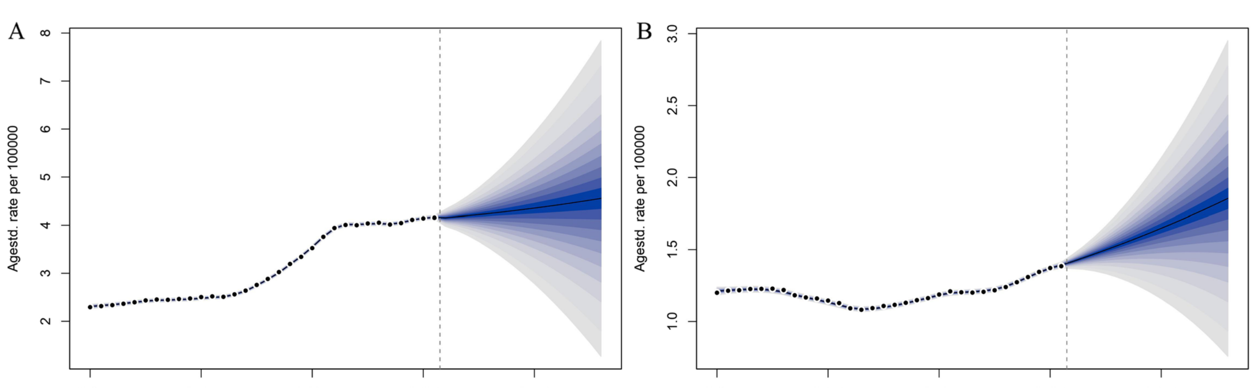

Fig. 4 Projected incidence cases for LOCC in China

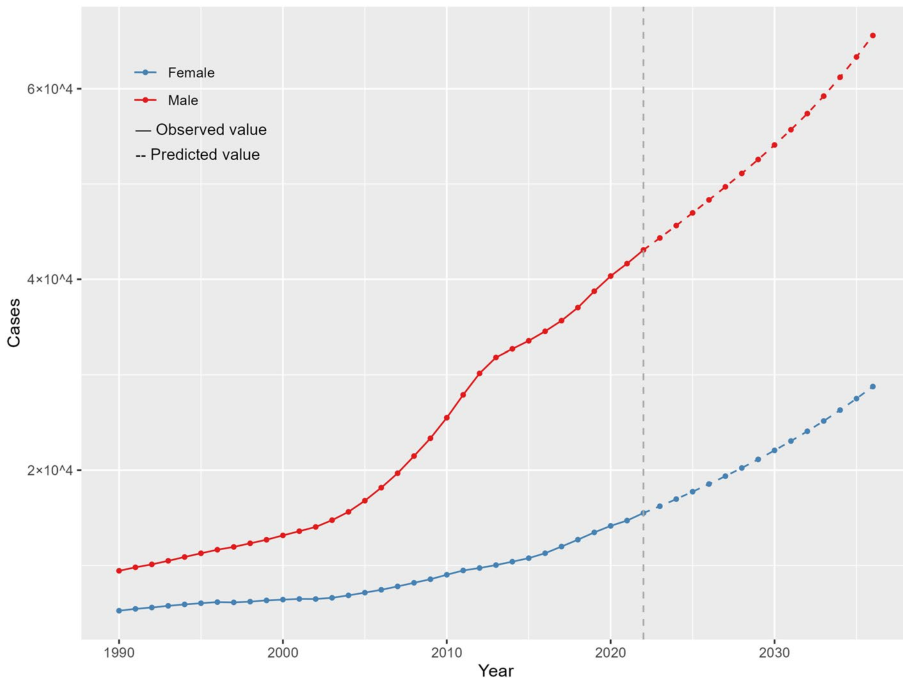

Fig. 5 Projected incidence rates for LOCC in China. **A** Male. **B** Female

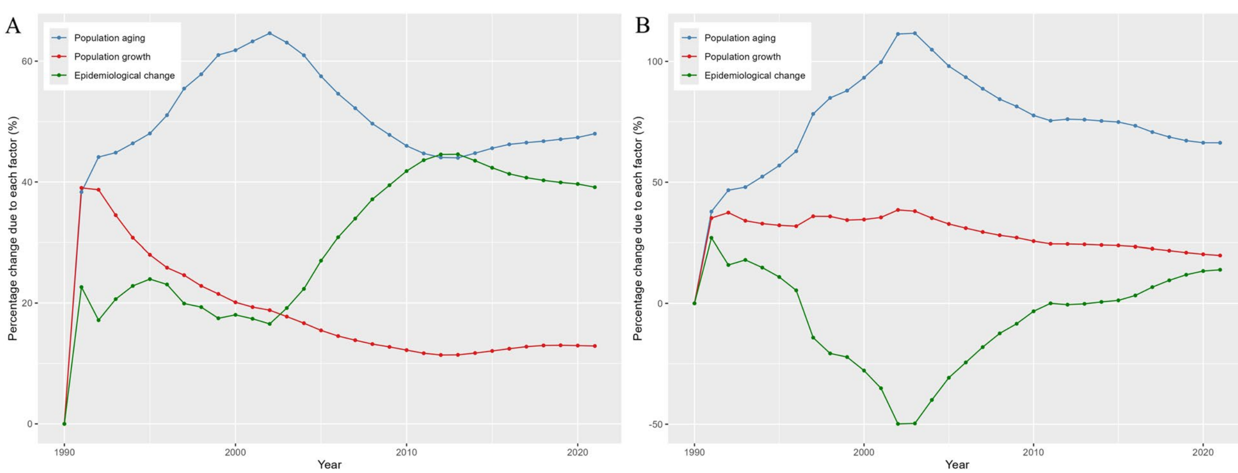

Fig. 6 Contribution of changes in population aging, population growth, and age-specific incidence rate to changes in incident cases of LOCC from 1990 to 2021 in China. (The decomposition was conducted using the number of incidence cases in 1990 as the reference for each year) (**A**) Male. (**B**) Female

betel nut chewing-remain prevalent, especially among younger and middle-aged adults [16]. This observation is consistent with global literature, where these risk factors have been well-documented contributors to oral cancer development [17]. Additionally, the rising incidence in females, albeit at a slower pace, calls attention to emerging risk factors, including the increasing consumption of tobacco and alcohol by women in recent decades [18, 19].

The results from the APC model reinforce the importance of both age, period and cohort effects in shaping LOCC trends. The significant net drift observed in both genders suggests that LOCC incidence is increasing from 1990 to 2021, with males showing a sharper rise.

This pattern likely reflects both the cumulative exposure to carcinogenic factors over time and improved diagnostic capabilities [20, 21]. In particular, the higher rates observed among older age groups may be explained by the latency period of LOCC, where risk factors accumulate over decades before manifesting clinically [22]. In 1999, China's elderly population (aged ≥ 65 years) was 86.79 million, or 7% of the total population, signaling the country's entry into an aging society. By the end of 2017, this number had grown to 158.31 million (11.4%), and it is projected to peak at around 385 million by 2058 before slightly declining to 308 million by 2100 [23]. Aging as a major factor contributing to the rising incidence of cancer [24]. Furthermore, the younger age groups showing the fastest growth in LOCC incidence is concerning, pointing to a possible shift in exposure to risk factors at earlier stages of life [25]. Research indicates that the awareness and usage rates of e-cigarettes among adolescents in China have been rising steadily year by year [26]. In addition, HPV infection has become prevalent among young people. A survey revealed that male HPV-infected patients in the Qingyuan region of China are primarily aged between 21 and 40, and the HPV infection rate increases with age [27]. Chewing betel nut has become popular among young people in China, with the initiation age for chewing being relatively early. Younger individuals, those with lower education levels, and those with a smoking habit are at higher risk of betel nut abuse [28].

Cohort effects are the effects of specific historical or social phenomena on the developmental trajectories of individuals who experience them, resulting in intergenerational differences in risk profiles that can be attributed to factors such as environmental exposures and lifestyle changes [29]. The cohort effect showed that the later born cohort exhibited a higher risk of LOCC incidence relative to the previous birth cohort. This may be due to the increased accessibility and prevalence of tobacco products, making them more accessible to youth [18]. The period effect for males demonstrates a continuous upward trend, indicating that changes in healthcare systems and public health interventions may not yet have fully mitigated the impact of these risk factors [30]. In contrast, the period effect for females shows a dip between 1997 and 2013, likely linked to improvements in female health awareness and public health campaigns that reduced risk factor exposure during this time.

Our projections up to 2036 indicate a continued rise in both the absolute number of new cases and the ASIR for LOCC. These findings are consistent with the demographic shift towards an aging population in China, as the proportion of the population over 60 years is expected to grow significantly in the coming decades [9]. The projections also suggest that males will continue to bear a disproportionate share of the LOCC burden, necessitating targeted intervention strategies.

The decomposition analysis further emphasizes the role of population aging in driving the increase in LOCC cases, accounting for nearly half of the rise in male cases and over two-thirds in female cases. This finding is in line with other research on cancers, where aging has been a major contributor to the increasing incidence of cancers [24]. Population aging is the largest contributor to the increase in global cancer incidence, accounting for 56.5% of cases [24]. However, the significant role of epidemiological changes, particularly in males, underscores the persistent exposure to modifiable risk factors such as e-cigarettes, HPV infection [26, 27]. According to statistics, young adults in China are becoming an important and influential consumer demographic for e-cigarettes [31]. E-cigarettes can induce DNA damage in oral epithelial cells, enhance the drug resistance of oral cancer cells, promote the formation of cancer stem cells, and cause microbial dysbiosis, playing a role in the occurrence and progression of oral cancer [32]. Furthermore, the use of e-cigarettes is associated with an increased prevalence of high-risk HPV infection [33]. Half of the cases of head and neck squamous cell carcinomas (HNSCCs) in the United States are caused by high-risk HPV infections [34]. The HPV infection rate in China was highest among individuals aged 20 and under, with a higher infection rate observed in males [35, 36]. The population attributable fraction (PAF) of HPV-related malignant tumors in the oropharynx, oral cavity, and larynx is higher in males than in females [37].

The slight decrease in LOCC incidence in females between 1997 and 2013 attributed to epidemiological changes suggests that public health interventions, when effectively targeted, can lead to meaningful reductions in cancer risk. This trend suggests that targeted public health interventions, such as anti-tobacco campaigns, alcohol reduction initiatives, and improved early detection methods, can lead to meaningful reductions in cancer risk [38].

It is essential to propose specific and actionable preventive measures targeted at high-risk populations to further reduce the incidence of LOCC. The key high-risk groups include tobacco and alcohol users, betel nut chewers, and individuals with HPV infections, particularly those in younger age groups who are increasingly vulnerable to these risk factors. Launch community-focused campaigns to educate the public on the dangers of tobacco, alcohol, betel nut chewers and HPV, their role in the development of LOCC, and its link to other health issues. For high-risk populations, implementing HPV screening and early detection of HPV-related LOCC can lead to more effective treatment and better outcomes [39]. For young people, both males and females, early HPV vaccination programs should be carried out to prevent high-risk HPV strains associated with LOCC [40]. In response to increasing population aging, it is critical to adapt public health policies to manage the increasing burden of LOCC. One important approach is to enhance regular screenings for LOCC in elderly individuals, especially those with a history of smoking, drinking, or other known risk factors [41]. Further, improving access to healthcare for the elderly, including through mobile health units or telemedicine, can help ensure that older adults in both urban and rural areas receive the necessary screenings and follow-up care [42]. Moreover, policymakers must consider the economic burden that an aging population places on healthcare systems and allocate appropriate resources for both the prevention and treatment of LOCC in the elderly [24].

There are several limitations to this study. First, although the Global Burden of Disease (GBD) database provides comprehensive data, it may not capture all regional variations in risk factors across China. Second, while the APC model adjusts for age, period, and cohort effects, it cannot fully account for potential confounders such as changes in diagnostic techniques or healthcare access over time. Third, future projections based on Bayesian APC models are subject to uncertainty, particularly in light of unforeseen changes in public health policies or emerging risk factors, such as the rise of HPV-related oral cancers in younger populations.

Conclusion

In conclusion, this study provides a comprehensive analysis of the trends and future projections of LOCC incidence in China. The increasing burden of LOCC, particularly among older populations, calls for more aggressive public health interventions targeting high-risk groups. Future strategies should focus on reducing tobacco and alcohol consumption, promoting early detection through screening programs, and addressing the growing healthcare needs of China's aging population. Additionally, gender-specific interventions, particularly focusing on the growing incidence in females, are warranted to curb the rise of LOCC in China.

Given the substantial contribution of population aging to LOCC incidence, it is crucial for policymakers to integrate cancer prevention strategies with broader efforts to address aging and chronic disease management. The findings from this study can inform public health planning and resource allocation, ensuring that China's healthcare system is prepared to meet the rising demand posed by the increasing cancer burden.

Abbreviations

ASIR	Age-standardized incidence rate
AAPC	Annual average percentage change
APC	Age-period-cohort
ASIR	Age-standardized incidence rates
CI	Confidence interval
GBD	Global Burden of Disease
HPV	Human papillomavirus
LOCC	Lip and oral cavity cancer
UI	Uncertainty interval

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12903-025-05764-2.

Supplementary Material 1: Appendix S1. GBD data collection, modeling/analysis, and dissemination.

Supplementary Material 2: Appendix S2. The decomposition method.

Supplementary Material 3: Table S1. Wald Chi-square tests for estimable parameters in the APC model.

Supplementary Material 4: Table S2. Estimated age-specific LOC cases in China male from 1990 to 2036 based on Bayesian APC prediction model.

Supplementary Material 5: Table S3. Estimated age-specific LOCC cases in China female from 1990 to 2036 based on Bayesian APC prediction model.

Supplementary Material 6: Table S4. Contribution of changes in population aging, population growth, and epidemiological change of LOCC cases in China male from 1991 to 2021. 1990 was used as the reference year.

Supplementary Material 7: Table S5. Contribution of changes in population aging, population growth, and epidemiological change of LOCC cases in China female from 1991 to 2021. 1990 was used as the reference year.

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Authors' contributions
LX and CMH, are responsible for writing, analysis, interpretation, revision and final approval of present article. YLS, are responsible for interpretation, revision and final approval of present article. ZS, ZJS, are responsible for interpretation, revision and final approval of present article. All authors have read and approved the final manuscript.

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Data availability
The datasets generated for this study can be found in the GBD (http://ghdx.healthdata.org/gbd-results-tool).

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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