OSR
ORAL SCIENCES REPORTS

Original Article

Received: March 19, 2025
Revised: May 20, 2025
Accepted: July 8, 2025

Corresponding Author:
Jamaludin Marhazlinda, Department of Community Oral Health & Clinical Prevention, Faculty of Dentistry, Universiti Malaya, Kuala Lumpur 50603, Malaysia
E-mail: marhazlinda@um.edu.my

Oral Sci Rep. 2025; 46(3): 234-246

Forecasting Adult Public Oral Healthcare Utilization in Malaysia via ARIMA

Yeung R'ong Tan, Lokman Najihah, Jamaludin Marhazlinda

Department of Community Oral Health & Clinical Prevention, Faculty of Dentistry, Universiti Malaya, Malaysia

Abstract

Objectives: This study analyzed historical trends in public oral healthcare utilization among the adult population of Malaysia from 1992-2019 and forecasted the future utilization prevalence through 2034.

Methods: Using secondary data from the Malaysian Health Information Management System (HIMS) from 1992 to 2019, this study analyzed the percentage of adults (aged 18-59 years) utilizing public oral healthcare services. The automatic ARIMA function in EViews 12 was used for forecasting, with optimal model parameters selected on the basis of the Akaike and Schwarz criteria. Diagnostic checks validated model adequacy via residual analysis, R-squared, and Prob (F statistics).

Results: Trend analysis revealed distinct periods of change in the prevalence of adult public oral healthcare utilization in Malaysia from 1992 to 2019, characterized by phases of decline, stabilization, gradual growth, and a sharp increase. The ARIMA (3,0,4) model forecasts a decline in the prevalence of adult public oral healthcare utilization from 2.32% in 2020 to 1.83% by 2034, reflecting a gradual reduction in utilization.

Conclusion: Although the trend over 28 years has fluctuated, forecasting analysis projects a gradual decline in utilization prevalence from 2020-2034, reflecting evolving healthcare preferences, increasing private sector alternatives, and infrastructure constraints in the public sector. These findings emphasize the need for proactive policies to address stagnating infrastructure, enhance accessibility, and promote preventive care.

Keywords: adult, ARIMA, Malaysia, oral healthcare utilization, time series forecasting

Introduction

Oral health is crucial for adults, influencing general health, productivity, and quality-of-life.[1,2] Diets high in processed and sugary foods heighten oral health risks.[3] Working adults' poor oral health contributes to substantial individual and national healthcare costs.[4] Despite various initiatives, public oral healthcare (OHC) in Malaysia remains stagnant, hindered by socioeconomic inequalities, limited access, and low oral health literacy.[5,6] Evidence-based reforms are needed to integrate oral with general healthcare and enhance targeted outreach.

Malaysia's dual healthcare system consists of a subsidized public sector and a fee-based private sector.[7] Recognized by the World Health Organization (WHO) for achieving Universal Health Coverage (UHC) since the 1990s,[8] the public sector provide nominal fees, including exemptions for vulnerable groups like the poor, disabled, and elderly.[7] Public sector employees benefit from the electronic-guarantee-letter (e-GL) for basic care, while private sector employees may receive employer-sponsored benefits such as panel clinics or reimbursements.[7] Others pay minimal out-of-pocket costs for public sector care.[7] Malaysia lacks healthcare social insurance, and private insurance, though available, is rarely used.[7] Furthermore, limited funding and infrastructure strain its capacity amid growing demand from an aging population. This system includes an extensive network of dental care facilities in health clinics, standalone clinics, hospitals, schools, and urban and rural transformation centers (UTCs and RTCs).[9] Mobile dental clinics and teams further enhance access for underserved populations in suburban and remote areas.[9] Public sector dental services for adults include treatment such as extractions, fillings, and scaling, alongside group initiatives via community talks and outreach programs to promote awareness and prevention.[9]

OHC utilization refers to the actual use of dental services based on oral health needs or preferences.[10] It is influenced by factors such as income, employment, and healthcare infrastructure.[5,6,11,12] Regular check-ups and early interventions align with global goals for better oral health, including a caries-free future.[13] However, only 13.2% of adults reported utilizing dental services in the National Health and Morbidity Survey (NHMS) 2019,[5] despite initiatives like free check-ups and awareness campaigns.[9] Many continue to self-medicate for dental issues rather than seek professional care.[6]

Recent trends in OHC utilization in Malaysia reveal progress and ongoing challenges. National health surveys from 2006 to 2023 highlight evolving patterns in OHC-seeking behavior.[14-21] Peaks in reported oral health problems occurred in NHMS 2006 and NHMS 2019, alongside increased OHC utilization in NHMS 2019 (23.7%) and NHMS 2023 (25.7%).[17,18] Government dental clinics remained primary providers, despite the temporary rise in self-care noted in NHMS 2011 and NHMS 2015.[15,16] Disparities persist, with rural adults reporting more dental problems (6.2%) than urban adults (5.3%).[6] While 46.4% of adults with dental problems sought care, self-medication, ethnicity, education, and income disparities influenced access in rural areas, with the wealthiest 20% more likely to seek care than the poorest 20%.[6]

NOHSA 2020 highlighted significant oral health challenges among Malaysian adults, with 94.6% needing treatment, 17 in 20 experiencing dental caries, and 9 in 10 having unhealthy periodontium.[21] Among older adults, edentulism and tooth loss worsen the burden, with only 34.3% retaining 20 or more teeth.[21] Despite the availability of public OHC services, access remains challenging due to constrained resources, limited funding, and infrastructural capacity.[5,6,22]

Time-series forecasting is crucial for healthcare planning, enabling the prediction of future demand and optimal resource allocation. Example of techniques include exponential smoothing,[23] regression-based models,[24] and machine learning methods.[25] Each method has trade-offs: exponential smoothing captures short-term patterns but oversimplifies;[23] regression models are interpretable but struggle with nonlinear dynamics;[24] machine learning handles complexity but lacks transparency and requires large datasets.[25] This study adopts the ARIMA model, suited for univariate time series forecasting where historical data serves as the only input.[26] ARIMA captures temporal patterns, accommodates non-stationarity, and allows confidence interval (CI) construction for uncertainty estimates.[26] Prior studies have demonstrated that historical trends reliably forecast future demand, particularly when long-term data are available.[27-29] Given the dataset's characteristics (moderate size, annual resolution, and finite period), ARIMA strikes a balance between simplicity, interpretability, and reliability.

More complex methods were deemed unsuitable due to data limitations and unnecessary complexity for this study's focus on trend forecasting.[23-25]

The WHO Global Oral Health Action Plan 2023-2030 emphasizes the integration of oral health into primary healthcare systems, promoting UHC to ensure equitable access for the population.[30] It advocates for capacity building in public healthcare systems, including training and infrastructure development, to meet the needs of vulnerable groups. This aligns with the Malaysian National Oral Health Strategic Plan (NOHSP) 2022-2030, which prioritizes improving the accessibility, affordability, and quality of OHC services, particularly for marginalized groups and those with complex care needs.[31] The NOHSP also focuses on developing workforce strategies and expanding oral health services to address the increasing demand driven by demographic shifts.[31]

This study supports these objectives by aiming to (1) investigate trends in adult public OHC utilization and (2) forecast future demand among adults in Malaysia. Accurate forecasts help identify service gaps, optimize resources, and develop sustainable plans for the OHC system.[32] While existing research on OHC utilization focuses on high-income countries, evidence from middle-income settings like Malaysia remains limited. By establishing baseline projections, this study provides evidence-based insights for policy development, program evaluation, and effective resource allocation.

Materials & Methods

Study Design and Data Sources

This study employed univariate time series analysis to examine trends and forecast adult public OHC utilization in Malaysia until 2034. Data from 1992 to 2019 were sourced from the Annual Reports compiled by the Health Information Management System (HIMS) under the Ministry of Health Malaysia (MOH).[9,33] These reports are based on standardized national data collected by trained and calibrated dental personnel following established protocols.[34] Data integrity is ensured through multi-level verification at clinic, district, state, and national levels, along with periodic audits and statistical checks by the Health Informatics Centre.[34] These measures ensured the integrity, consistency, and reliability of the dataset.

The analysis focused on the percentage of adults (aged 18-59 years, as defined by HIMS) receiving primary OHC in public facilities.[9] This age range aligns with Malaysia's legal definition of adulthood.[35] In this study, "Adult Public Oral Healthcare Utilization" refers to the percentage of this population utilizing public OHC services in Malaysia.[9]

Data Preprocessing

The dataset covered years 1992-2019, arranged chronologically in a Microsoft Excel file before being imported into EViews 12 for analysis. Inclusion criteria comprised national-level data for adults aged 18-59, with complete, continuous, and structured annual observations from 1992-2019 suitable for ARIMA modeling. State-level data, inconsistent definitions, and data from 2020 onward were excluded to avoid distortion from COVID-19-related service disruptions.

In time series analysis, the sample consists of individual data points, relying on historical patterns and data availability rather than a fixed sample size.[36,37] Including as many data points as possible ensures robust, reliable results, making a specific sample size unnecessary.[36,37] Data accuracy and consistency were verified by HIMS personnel responsible for data collection before entry into the database.

Missing data were addressed via linear interpolation, a widely accepted technique that minimizes errors even when up to 60% of values are missing.[38,39] However, no missing data were identified in this dataset. If missing data were present, sensitivity analyses would be conducted to ensure the chosen method did not alter the findings significantly.[40] Outliers were detected via correlation plots and logarithmically transformed to stabilize variance and reduce skewness. The final dataset underwent normality assessment using Jarque-Bera test ($p>0.05$) to confirm a normal distribution.[41] Box plots revealed no extreme values within the data, ensuring the integrity of the dataset for subsequent modeling.[42]

Forecasting Models and Analysis

The automatic ARIMA function in EViews 12 was used to forecast utilization prevalence (2020-2034). ARIMA requires stationary data, where mean and variance remain constant over time, ensuring stable data generation and accurate forecasting. EViews 12 automates differencing and selects optimal autoregressive (AR) and

moving average (MA) terms using Akaike information criterion (AIC) and Schwarz criterion (SC), streamlining model selection.

The ARIMA model captures time-series dynamics through three parameters: AR (p) for lagged observations, integrated (d) for differencing to achieve stationarity, and MA (q) for lagged residuals, forming the ARIMA (p, d, q) equation:

$$\Phi(B)\ (1 - B)^d Y_t = \Theta(B)\ \varepsilon_t$$

In this equation, Φ(B) and Θ(B) are polynomials representing the autoregressive and moving average components, respectively. B is the backward shift operator, where BYt equals Y_{t-1}. The error term, ε_t, is assumed to follow a white noise process, ensuring no autocorrelation in the residuals.

Automatic ARIMA was chosen over manual ARIMA which require manual differencing and parameter selection to reduce subjectivity and misspecification risk.[36,43] Automating these processes and selecting optimal parameters based on AIC and SC minimizes overfitting and effectively models trends and autocorrelations, making it well-suited for public health forecasting.[43,44]

Model evaluation and validation

The adequacy of the ARIMA model was validated through diagnostic checks, including residual analysis, to assess independence and homoscedasticity. Goodness-of-fit metrics (AIC and SC) were evaluated to confirm model robustness. Diagnostic checks using R-squared and Prob (F-statistics) confirmed model accuracy.[45]

Durbin-Watson statistic tested for autocorrelation while Jarque-Bera test assessed residuals' normality.[41,46] The Autoregressive-Conditional-Heteroscedasticity (ARCH) test, which is appropriate for time-series data exhibiting potential time-varying volatility tested for homoscedasticity.[47,48] These statistical tests validated model assumptions, which are detailed in the supplementary material.

Final Model and Forecasting

Using the finalized ARIMA model, forecasts for adult public OHC utilization were generated for 2020-2034. To verify the model's reliability, the results included the forecasted utilization prevalence and diagnostic plots, such as actual versus forecasted values and residual diagnostics. All analyses were conducted via EViews 12.

Results

This study analyzed trends in adult public OHC utilization in Malaysia from 1992-2019 and forecasted future utilization through 2034.

Adult Public OHC Utilization Trends from 1992-2019

Adult public OHC utilization demonstrated four distinct phases:

- Steady decline from 6.90% in 1992 to 5.38% in 1997, indicating a decline of 22.03% over five years.
- Stabilization from 1997-2002.
- Gradual growth from 4.94% in 2002 to 7.30% in 2012, a steady growth of 47.77% over the decade.
- Sharp increase from 7.30% in 2012 to 10.10% in 2019, representing an increase of 38.36%.

Figure 1 illustrates these trends, highlighting the significant periods of decline, stabilization, and growth over the 28-year period.

Model Selection and Diagnostics

The lowest AIC, indicating high accuracy, identified ARIMA (3,0,4) as the best-fit model (Supplementary Table 1). The log-transformed series was stationary without differencing, validating the AR and MA components. This model effectively captures trends and seasonality in healthcare utilization data.

Model Performance, Diagnostic Tests, and Statistical Significance

Key diagnostics confirm the robustness of the ARIMA (3,0,4) model. Table 1 presents parameter estimates, standard errors, t statistics, and significance levels. The high R-squared (0.936) and adjusted R-squared (0.910) indicate strong explanatory power. Low standard error (0.063) and significant F statistic ($p<0.001$) affirm reliability. Durbin-Watson statistic (2.02) suggests minimal residual autocorrelation, confirming the model's validity for forecasting public OHC utilization in Malaysia. The Jarque-Bera test for normality yielded a statistic of 1.28 ($p=0.526$), indicating normally distributed residuals. ARCH test showed homoskedasticity (F-statistic=2.19, $p=0.151$; Obs*R-squared=2.17, $p=0.140$). Detailed results of these diagnostic tests are provided in the supplementary material.

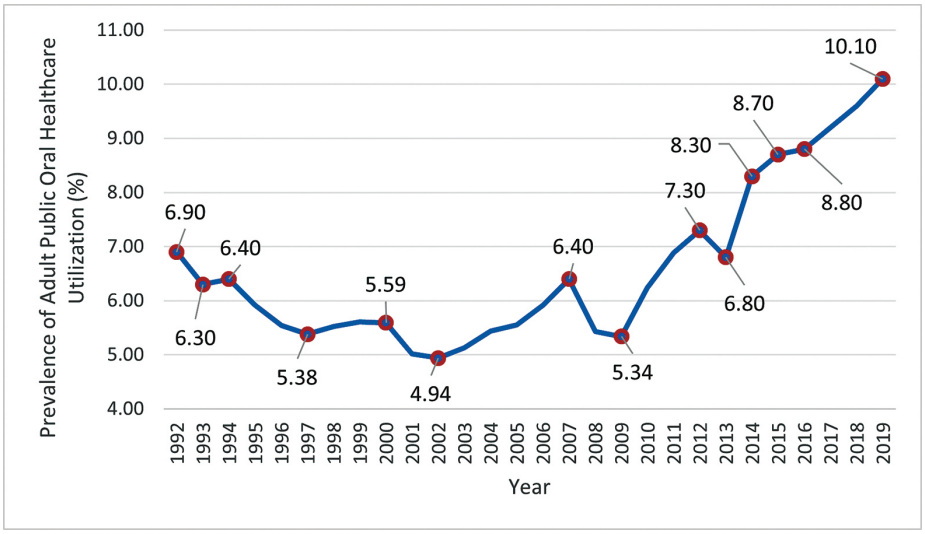


Figure 1: prevalence of adult public oral healthcare utilization (1992-2019).

Adult Public OHC Utilization Forecast from 2020-2034

The forecasted adult public OHC utilization in Malaysia indicates an initial upward trend, peaking in 2026 before gradually declining toward the end of the 15-year projection period (Table 2).

The forecasted adult public OHC utilization in Malaysia reveals three distinct phases:

• Steady increase from 2020-2026, rising from 10.40% to 11.64%, indicating sustained growth.

• Gradual decline from 2027-2029, decreasing from 11.60% to 11.29%, signaling the onset of a downward trend.

• Pronounced decline from 2030 to 2034, with utilization falling from 11.03% to 9.53%.

The forecast includes 95% CIs, providing a measure of reliability to the projections. Near-term estimates (±0.52% in 2024), show greater certainty, while wider intervals (±0.95% by 2034), reflect increased long-term uncertainty.

The error measures further demonstrate the strong predictive accuracy of the ARIMA model and highlight the model's reliability for forecasting trends over the short to medium term. Details regarding these error measures are provided in the supplementary material.

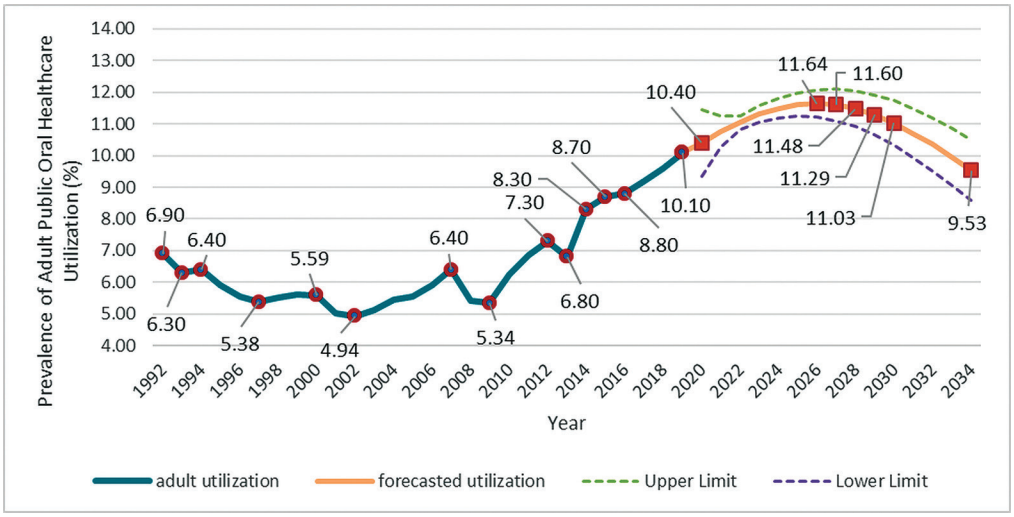


Figure 2: Trend and forecasted prevalence of adult public oral healthcare utilization (1992-2034).

Table 1: Equation outputs of the fitted ARIMA model for the adult public oral healthcare utilization.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.052	0.372	5.509	<0.001
AR(1)	1.317	0.001	1300.410	<0.001
AR(2)	0.322	0.024	13.658	<0.001
AR(3)	-0.666	0.002	-279.619	<0.001
MA(1)	-0.860	186.749	-0.005	0.996
MA(2)	-0.940	2512.185	<0.001	1.000
MA(3)	0.578	1550.757	<0.001	1.000
MA(4)	0.273	1242.440	<0.001	1.000
SIGMASQ	0.003	2.795	0.001	0.999
R-squared	0.936	Mean dependent var		1.862
Adjusted R-squared	0.910	S.D. dependent var		0.211
S.E. of regression	0.063	Akaike info criterion		-2.041
Sum squared resid	0.076	Schwarz criterion		-1.613
Log likelihood	37.577	Hannan-Quinn criterion		-1.910
F-statistic	34.944	Durbin-Watson statistic		2.029
Prob(F-statistic)	<0.001			

Table 2: Forecasted prevalence of adult public oral healthcare utilization in Malaysia from 2020 to 2034.

Forecasted Years Ahead	Prevalence of adult public oral healthcare utilization in Malaysia (%)	95% Confidence Interval	
		Upper Limit	Lower Limit
2020	10.40	9.36	11.44
2021	10.76	10.28	11.24
2022	11.05	10.83	11.27
2023	11.31	11.05	11.57
2024	11.49	11.18	11.80
2025	11.61	11.24	11.98
2026	11.64	11.21	12.07
2027	11.60	11.10	12.10
2028	11.48	10.92	12.04
2029	11.29	10.66	11.92
2030	11.03	10.33	11.73
2031	10.71	9.94	11.48
2032	10.35	9.52	11.18
2033	9.95	9.05	10.85
2034	9.53	8.58	10.48

Discussion

This study examined trends and forecasted the future utilization of adult public OHC services in Malaysia, using automatic ARIMA univariate time series analysis to generate forecasts through 2034.

Trends in Adult Public OHC Utilization (1992-2019)

Adult public OHC utilization trends in Malaysia from 1992-2019 followed four phases: initial decline (1992-1997), stabilization (1997-2002), gradual growth (2002-2012), and sharp increase (2012-2019).

From 1992-1997, utilization dropped from 6.90% to 5.38%, likely due to limited access, low awareness, and economic barriers. NHMS 1996 reported that 57.5% of sick individuals did not seek care, often deeming it unnecessary. Early oral health surveys and the absence

of comprehensive strategies, such as NOHP 2011-2020, reflected limited policy focus on adult care at the time.[49]

Between 1997 and 2002, utilization fluctuated between 5.38% and 4.94%, reaching its lowest in 2002, which likely reflected resource constraints, economic challenges, or absence of large-scale interventions. Although NOHSA 2000[19] provided useful data, structured efforts to enhance public OHC utilization were still evolving. The low utilization in 2002 likely reflected resource constraints, limited awareness, and economic challenges during Malaysia's recovery from the 1997-1998 Asian financial crisis, with restricted healthcare spending and a public dentist-to-population ratio of 1:8,371, indicating limited service capacity.[50,51] Less widespread awareness campaigns also reduced public engagement.[49] Hence, continuous monitoring is essential to guide resource allocation and ensure equitable access during economic uncertainties.

From 2002-2012, utilization rose from 4.94% to 7.30%, with a dip from 6.40% to 5.34% between 2007 and 2009, likely linked to the global financial crisis.[52] Indirect costs such as transport and income loss may have deterred non-urgent care.[52] Subsequent increases were driven by policy initiatives, such as NOHSA 2010[20], and NOHP 2011-2020,[53] which improved service delivery through integrated systems, online appointments, automated reminders, and performance monitoring.[49,53] UTCs and RTCs enhanced accessibility.[49]

Utilization accelerated after 2012, from 7.30% in 2012 to 10.10% in 2019, driven by major public OHC reforms, including infrastructure expansion, targeted health promotion, and technological integration. Mobile dental clinics under the 12th Malaysia Plan improved rural access,[49] while outreach programs such as *Program Pergigian Mesra Rakyat,*[49,54] reflected targeted population approach. Digital tools such as the 'MyGusi' and 'MyOrtho' in 2018 further increased accessibility to specialized care.[49]

Importantly, OHC utilization does not necessarily reflect treatment needs, as it depends on accessibility, awareness, SES, and individual behaviors.[5,6] Therefore, compatibility between adult treatment needs and actual oral health service utilization must be cautiously interpreted. While NOHSA 2020 found 94.6% of Malaysian adults require professional care,[21] lower utilization rates suggest unmet needs and barriers to care. Integrating epidemiological data with utilization trends is crucial to address these gaps effectively. These findings highlight the need for policies to improve equitable access and meet actual oral health needs.

Adult Public OHC Utilization Forecast from 2020-2034

Forecasts reveal an initial upward trend, peaking in 2026 and a gradual decline from 2020 to 2034. The early peak may reflect demographic shifts, including a growing and aging population,[55] as older individuals face higher risks of oral health issues, particularly those with diabetes.[56] Years of health promotion, policy initiatives, and continued subsidization of basic dental care likely improved public awareness and access,[49] while modest infrastructure improvements and rising demand contributed to higher utilization.[7,9]

From 2027 onward, utilization begins to decline. This reduction may reflect changes in healthcare policies, demographic shifts, increased reliance on private dental services, or accessibility challenges. Between 2016 and 2023, the private sector's share of dentists increased from 36.1% to 46.55%, while the public sector declined from 63.9% to 53.45%.[51] Although the public dentist-to-population ratio improved from 1:6,725 (2016) to 1:4,588 (2023), it lagged behind the private sector's expansion.[51] The population-to-dental-unit ratio in the public sector reflects systemic strain, improving from 1:12,037 in 1992 to 1:7,460 in 2006, then worsening to 1:17,501 in 2011 before recovering to 1:12,431 in 2019.[9] This indicates stagnant infrastructure development amid rising demand. While the growth of private clinics may reduce public sector congestion, improving access for those unable to afford private care, it is crucial to enhance public infrastructure to ensure quality care and meet the rising demand from an aging population. Without such improvements, the public sector may still struggle to support vulnerable groups despite reduced congestion.

Delayed public OHC access can worsen untreated conditions, leading to advanced conditions, which escalate treatment costs and systemic healthcare burdens.[57,58] Low-income groups, lacking resources for private care, are particularly vulnerable. Addressing this decline is vital to prevent rising disease complications and healthcare costs. Given the stagnant infrastructure and increasing reliance on private services, targeted policies are essential to

address growing inequalities in OHC access and prevent adverse health outcomes.

Policy Implications

Despite NOHSA 2020 findings that 94.6% of Malaysian adults require professional intervention,[21] utilization is expected to drop, suggesting worsening access barriers, potentially leading to unmet oral health needs and an increased burden of untreated dental conditions. Targeted policies to enhance affordability, accessibility, and awareness are essential to address these challenges.

Economic factors may contribute to declining public dental service utilization. Despite subsidized OHC,[7] out-of-pocket costs for specific treatments, transportation and lost work time, may deter care-seeking,[5,6,12] especially for lower-income populations prioritizing other financial obligations.[6,12] The economic downturn and rising cost of living exacerbate this problem, necessitating expanded subsidies, financial assistance programs, or insurance coverage to maintain accessibility.

Long waiting time in MOH facilities also discourage utilization.[59] Working adults prefer private clinics for faster, more convenient, and perceived better quality of care despite higher costs.[60]

Employer-sponsored dental benefits[61] may further drive working adults towards private dental services. With financial support, individuals may perceive private dental care as more accessible and convenient, reinforcing the preference for private clinics. Consequently, public OHC services are increasingly utilized by populations without such benefits, potentially widening socioeconomic disparities in access.

The public sector workforce challenges compound the issue. Despite increased dentist, limited permanent positions in MOH facilities push contract-based dental officers to private practice.[62-64] This reduces affordable public service capacity and affects those reliant on government clinics. Addressing this workforce imbalance requires sustained investment in infrastructure, adequate staffing and resources to meet patient demand to help mitigate service limitations and improve long-term accessibility.

Beyond financial and workforce challenges, geographic disparities in OHC remain a concern. Rural and underserved adults often lack access to public dental facilities,[6,11] contributing to declining utilization. Expanding mobile clinics, community outreach, workplace-based initiatives, and teledentistry can improve access, particularly for preventive care.

The NOHSP 2022-2030 prioritizes preventive and rehabilitative measures but requires proactive efforts to reverse declining utilization.[31] Strengthening public health campaigns, addressing financial barriers, and sustaining the public dental workforce are crucial. Without targeted interventions, declining service use, oral health disparities and untreated dental conditions may worsen in Malaysian adults.

Integrating OHC into Malaysia's primary healthcare (PHC) framework can address systemic challenges and improve care for conditions like diabetes and cardiovascular diseases.[65] Currently, oral health services operate independently within PHC, limiting holistic care despite partial integration efforts, such as the National Strategic Plan for Non-Communicable Disease 2016-2025 and smoking cessation under the KOTAK program.[49,66] However, collaboration and referrals between medical and oral health services remain inadequate, highlighting the need for governance reforms and multidisciplinary coordination within MOH.[9] Oral health professionals should address systemic health issues, while primary care physicians require basic oral health training.[65,67] The existing *Ikon Gigi* program, which trains community representatives to promote oral health, can be expanded to boost outreach efforts in underserved areas.[68] Continuity of care also requires shared electronic health records. While Malaysia's Teleprimary Care-Oral Health Clinical Information System (TPC-OHCIS)[69] supports integration, its adoption is limited by poor digital infrastructure and stakeholders' preference for systems like the Dental Information System (DIS). Upgrading infrastructure and unifying TPC-OHCIS and DIS can improve data sharing and care coordination. To sustainably integrate OHC into Malaysia's PHC system, increased public funding and public-private-partnerships are needed. Current programs like *PeKa B40* and *Skim Perubatan Madani* support low-income groups through free screenings and treatment for medical conditions,[70] but exclude OHC. Integrating basic oral health packages into these initiatives would address a critical gap, support NCD prevention, and advance UHC goals by improving access for underserved populations.

These policy recommendations should be considered within the context of the study's forecasting approach, which extrapolates from historical utilization data alone. Therefore, continuous data monitoring and incorporating evolving socioeconomic and health system factors are essential for responsive planning.

Strengths and Limitations

Given that our projections are based solely on historical dental utilization data, the following outlines the study's methodological strengths and limitations, which inform appropriate interpretation and future research priorities.

The robustness of the dataset enhances this study's reliability, as it draws from credible national databases systematically collected over 28 years (1992-2019) through an established monitoring system. This long-term consistency ensures accurate reflections of national trends in adult OHC utilization, enabling pattern identification, shift detection, and reliable projections. The dataset's continuity strengthens the study's validity, making its findings valuable for policymakers and healthcare planners.

A key strength of this study lies in its ability to provide macro-level insights into public OHC utilization trends in Malaysia. By leveraging ARIMA modeling on aggregated data, the study identifies distinct periods of growth, stabilization, and decline, offering policymakers a comprehensive view of the overall trajectory of service demand. These insights are instrumental for strategic planning, resource allocation, and national policy development. While the data is aggregated at the national level and lacks subgroup detail, the trends identified can guide high-level decision-making by signaling overall system demands and highlighting the need for targeted follow-up studies.

The model uses only historical utilization data, assuming trend continuity without incorporating external factors. This limits its responsiveness to unexpected shifts such as economic shocks, policy changes, or health crises. Although post-2020 data was excluded to avoid pandemic distortion, this also limits insight into recent system transformations. Additionally, private sector utilization is not captured, potentially underrepresenting total demand. However, modeling 28 years of utilization patterns indirectly captures the impact of major national health policies and programs, such as the NOHP 2011–2020, mobile dental clinic expansion, and increased public sector dental funding under the Tenth and Eleventh Malaysia Plans.[53] These embedded policy signals provide valuable insights into their population-level effects, demonstrating how long-term data can inform planning without explicitly modeling interventions.

The absence of key explanatory variables restricts the model's capacity to identify causal relationships or to predict the effects of targeted policies. Therefore, while the forecast provides valuable insight into expected trends, it should be complemented with ongoing data collection and periodic model updates incorporating broader determinants when available. Hence, the forecasts provide a practical baseline scenario but should be interpreted cautiously, especially for long-term planning.[71]

Nevertheless, univariate time series models like ARIMA are valued for their simplicity and efficiency, with studies demonstrating their ability to outperform multivariate models, particularly when data is limited or complex.[29] In this study, ARIMA's adequacy was validated through rigorous diagnostic checks and residual analysis, confirming robustness and minimizing overfitting risks. Key error measures further demonstrated strong predictive accuracy and reliability, highlighting the model's suitability for short- to medium-term forecasting.

Including 95% CIs enhances the interpretability of projections.[72] Short-term projections (2020-2026) show greater precision, while longer-term forecasts (2027-2034) are more uncertain due to potential demographic, economic, or technological changes.[71] These limitations highlight the need for periodic updates with the latest data and methodologies.[73] Stakeholders should use short-term insights for immediate planning, treat long-term trends as evolving baselines, and incorporate scenario planning to enhance preparedness and responsiveness.[74]

Another limitation is the absence of subgroup analyses (e.g., by SES, geography, or treatment needs) due to data aggregation. This restricts the ability to pinpoint disparities or identify underserved populations. Nonetheless, national trends provide a foundation for targeted research and policy formulation. Future studies should incorporate multivariable approaches with stratified data to enhance forecasting accuracy and support equitable resource distribution.

Conclusions

Trend analysis (1992-2019) revealed phases of decline, stabilization, gradual growth, and sharp increase in Malaysia's adult public OHC utilization. Forecasts predict a gradual decline (2020-2034) due to shifting preferences, private sector growth, and infrastructure constraints. These findings highlight the need for proactive policies to improve access, expand infrastructure, and promote preventive care, providing a foundation for evidence-based policy-making to ensure equitable, sustainable OHC.

Declarations

Ethical considerations

This is a secondary data analysis using data obtained from reports generated by the Health Information Management System (HIMS) under the Ministry of Health, Malaysia. Throughout the study, the tenets of the Declaration of Helsinki were followed. This study was approved by the Medical Ethics Committee of the Faculty of Dentistry, Universiti Malaya (Approval No. DF CO2410/0020 (P)) and the Medical Research and Ethics Committee (MREC), Ministry of Health Malaysia (Approval No. NMRR ID-24-00964-XEE).

Availability of data and materials

The datasets that support the findings of this article are publicly available in the annual reports published by the Ministry of Health Malaysia, which are accessible through their official website.

Consent for Publication

Not applicable.

Competing Interests

The authors declare that they have no competing interests.

Funding

This research did not receive any specific grant or funding from funding agencies in the public, commercial, or not-for-profit sectors.

References

1. Dörfer C, Benz C, Aida J, Campard G. The relationship of oral health with general health and NCDs: a brief review. Int Dent J. 2017;67(Suppl 2):14-8.
2. Koistinen S, Olai L, Ståhlnacke K, Fält A, Ehrenberg A. Oral health-related quality of life and associated factors among older people in short-term care. Int J Dent Hyg. 2020;18(2):163-72.
3. Yannakoulia M, Mamalaki E, Anastasiou CA, Mourtzi N, Lambrinoudaki I, Scarmeas N. Eating habits and behaviors of older people: where are we now and where should we go?. Maturitas. 2018;114:14-21.
4. Zaitsu T, Saito T, Oshiro A, Fujiwara T, Kawaguchi Y. The impact of oral health on work performance of Japanese workers. J Occup Environ Med. 2020;62(2):e59-64.
5. Tan YR, Tan EH, Jawahir S, Mohd Hanafiah AN, Mohd Yunos MH. Demographic and socioeconomic inequalities in oral healthcare utilisation in Malaysia: evidence from a national survey. BMC Oral Health. 2021;21(1):34.
6. Tan YR, Jawahir S, Doss JG. Oral healthcare-seeking behavior of Malaysian adults in urban and rural areas: findings from the National Health and Morbidity Survey 2019. BMC Oral Health. 2023;23(1):719.
7. Jaafar S, Noh KM, Muttalib KA, Othman NH, Healy J. Malaysia health system review. New Delhi: World Health Organization, Regional Office for the Western Pacific; 2013.
8. Lo Ying-Ru J, Pascale A. World Health Day 2018 – Lessons from Malaysia on Universal Health Coverage [Internet]. World Health Organization Malaysia; 2018 [cited 2020 Nov 20]. Available from: https://www.who.int/malaysia/news/detail/18-04-2018-world-health-day-2018-%E2%80%93-lessons-from-malaysia-on-universal-health-coverage
9. Oral Health Programme. Annual report 2022 [Internet]. Putrajaya: Ministry of Health Malaysia; 2023 [cited 2023 Jun 12]. Available from: https://hq.moh.gov.my/ohd/images/pdf/annual_rpt/annual_rpt23.pdf
10. Northridge ME, Kumar A, Kaur R. Disparities in access to oral health care. Annu Rev Public Health. 2020;41:513-35.
11. Md Bohari NF, Kruger E, John J, Tennant M. Analysis of dental services distribution in Malaysia: a geographic information systems–based approach. Int Dent J. 2019;69(3):223-9.
12. Azhar N, Doss JG. Health-seeking behaviour and delayed presentation of oral cancer patients in a developing country: a qualitative study based on the self-regulatory model. Asian Pac J Cancer Prev. 2018;19(10):2935-41.
13. The Alliance for a Cavity-Free Future. Alliance for a Cavity-Free Future: Malaysian chapter [Internet]. Alliance for a Cavity-Free Future; 2013 [cited 2020 Oct 7]. Available from: https://www.acffglobal.org/chapters/chapters-spotlight/
14. Institute for Public Health. The Third National Health and Morbidity Survey (NHMS III) 2006: general findings. Putrajaya: Ministry of Health Malaysia; 2008.
15. Institute for Public Health. National Health and Morbidity

Survey 2011 (NHMS 2011) Vol. III: Healthcare Demand [Internet]. Putrajaya: Ministry of Health Malaysia; 2012 [cited 2020 Sep 7]. Available from: http://www.iku.gov.my/images/IKU/Document/REPORT/NHMS2011-VolumeIII.pdf
16. Institute for Public Health; Institute for Health Systems Research. National Health and Morbidity Survey (NHMS) 2015. Vol III: Healthcare Demand [Internet]. Putrajaya: Ministry of Health Malaysia; 2015 [cited 2020 Sep 7]. Available from: http://iku.moh.gov.my/images/IKU/Document/REPORT/NHMS2015-VolumeIII.pdf
17. Institute for Health Systems Research; Institute for Public Health. National Health and Morbidity Survey 2019 (NHMS 2019) Vol. II: Healthcare Demand [Internet]. Putrajaya: Ministry of Health Malaysia; 2020 [cited 2020 Sep 7]. Available from: http://www.ihsr.moh.gov.my/images/publication_material/NHMS2019/hcd2019_report.pdf
18. Institute for Public Health; Institute for Health Systems Research. Fact sheet: National Health and Morbidity Survey (NHMS) 2023 – Non-communicable diseases & healthcare demand [Internet]. Putrajaya: Ministry of Health Malaysia; 2024 [cited 2025 Feb 14]. Available from: https://repository.nih.gov.my/handle/123456789/711
19. Oral Health Division. National Oral Health Survey of Adults (NOHSA 2000). Putrajaya: Ministry of Health Malaysia; 2004.
20. Oral Health Division. National Oral Health Survey of Adults 2010 (NOHSA 2010). Putrajaya: Ministry of Health Malaysia; 2013.
21. Oral Health Programme. National Oral Health Survey of Adults 2020 (NOHSA 2020) [Internet]. Putrajaya: Ministry of Health Malaysia; 2023 [cited 2024 Nov 18]. Available from: https://hq.moh.gov.my/ohp/images/pdf/4.-penyelidikan-kesihatan-pergigian/key-findings-nohsa-2020.pdf
22. Bin Juni MH. Public health care provisions: access and equity. Soc Sci Med. 1996;43(5):759-68.
23. Booranawong T, Booranawong A. Double exponential smoothing and Holt-Winters methods with optimal initial values and weighting factors for forecasting lime, Thai chili and lemongrass prices in Thailand. Eng Appl Sci Res. 2018;45(1):32-8.
24. Harrell FE. General aspects of fitting regression models. In: Regression Modeling Strategies: With Applications to Linear Models, Logistic and Ordinal Regression, and Survival Analysis. 2nd ed. Cham: Springer; 2015. p.13-44.
25. Tealab A. Time series forecasting using artificial neural networks methodologies: a systematic review. Future Comput Inform J. 2018;3(2):334-40.
26. Box GE, Jenkins GM, Reinsel GC, Ljung GM. Time series analysis: forecasting and control. Hoboken (NJ): Wiley; 2015.
27. Chen HM, Shen K, Ji L, McGrath C, Chen H. Global and regional patterns in edentulism (1990–2021) with predictions to 2040. Int Dent J. 2025;75(2):735-43.
28. Huang Y, Xu C, Ji M, Xiang W, He D. Medical service demand forecasting using a hybrid model based on ARIMA and self-adaptive filtering method. BMC Med Inform Decis Mak. 2020;20(1):237.
29. Iwok I, Okpe A. A comparative study between univariate and multivariate linear stationary time series models. Am J Math Stat. 2016;6:203-12.
30. Eaton K, Yusuf H, Vassallo P. The WHO global oral health action plan 2023-2030. Community Dent Health. 2023;40(2):68-9.
31. Oral Health Programme. National Oral Health Strategic Plan 2022–2030 [Internet]. Ministry of Health Malaysia; 2022 [cited 2023 Jun 12]. Available from: https://hq.moh.gov.my/ohd/images/pdf/publication/Snap%20Shot%20NOHSP%202022_2030_FINAL_Edaran%202.0.pdf
32. Meyerhoefer CD, Panovska I, Manski RJ. Projections of dental care use through 2026: preventive care to increase while treatment will decline. Health Aff (Millwood). 2016;35(12):2183–9.
33. Suhana AS. Health Information Management System (HIMS) modul: Myhealthrecord [Internet]. Kuala Lumpur: Universiti Malaya; 2003 [cited 2024 Nov 18]. Available from: https://api.semanticscholar.org/CorpusID:215899609
34. Abdullah ZS. Hospital information systems implementation framework: critical success factors for Malaysian public hospitals [Internet]. Sarawak (MY): Curtin University; 2013 [cited 2025 May 22]. Available from: https://core.ac.uk/download/pdf/195632127.pdf
35. Government of Malaysia. Age of Majority Act 1971. Federal Constitution; 1971.
36. Hyndman RJ, Athanasopoulos G. Forecasting: principles and practice. Melbourne: OTexts; 2018.
37. Hyndman RJ, Kostenko AV. Minimum sample size requirements for seasonal forecasting models. Foresight. 2007;6(6):12–5.
38. Twumasi-Ankrah S, Odoi B, Pels WA, Gyamfi H. Efficiency of imputation techniques in univariate time series. Int J Sci Environ Technol. 2019;8(3):430-53.
39. Salgado CM, Azevedo C, Proença H, Vieira SM. Missing data. In: Secondary analysis of electronic health records [Internet]. Cham: Springer International Publishing; 2016 [cited 2023 Dec 7]. p.143-62. Available from: http://link.springer.com/10.1007/978-3-319-43742-2_13
40. Molenberghs G. Incomplete data in clinical studies: analysis, sensitivity, and sensitivity analysis. Drug Inf J. 2009;43:409-29.
41. Jarque CM, Bera AK. A test for normality of observations and regression residuals. Int Stat Rev. 1987;55(2):163-72.
42. Mowbray FI, Fox-Wasylyshyn SM, El-Masri MM. Univariate outliers: a conceptual overview for the nurse researcher. Can J Nurs Res. 2019;51(1):31–7.
43. Agung IGN. Advanced time series data analysis: forecasting

using EViews. Hoboken (NJ): John Wiley & Sons; 2019.
44. Box GEP, Jenkins GM. Time series analysis: forecasting and control [Internet]. San Francisco: Holden-Day; 1976 [cited 2025 May 26]. Available from: https://books.google.com.my/books?id=1WVHAAAAMAAJ
45. Ozili PK. The acceptable R-square in empirical modelling for social science research. Soc Res Methodol Publ Results [Internet]. 2022 [cited 2024 Oct 13]. doi: 10.2139/ssrn.4128165.
46. Durbin J, Watson GS. Testing for serial correlation in least squares regression I. In: Breakthroughs in statistics: methodology and distribution. New York: Springer; 1992. p. 237-59.
47. Engle RF. Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom inflation. Econometrica. 1982;50(4):987-1007.
48. McLeod AI, Li WK. Diagnostic checking ARMA time series models using squared-residual autocorrelations. J Time Ser Anal. 1983;4:269-73.
49. Oral Health Programme. Milestones in Dentistry (3rd ed) [Internet]. Ministry of Health Malaysia; 2019 [cited 2025 Apr 1]. Available from: https://hq.moh.gov.my/ohp/images/pdf/1.-penerbitan-utama/milestone/milestones_01122023.pdf
50. Suleiman AB, Lye MS, Yon R, Teoh SC, Alias M. Impact of the East Asian economic crisis on health and health care: Malaysia's response. Asia Pac J Public Health. 1998;10(1):5-9.
51. Malaysian Dental Council. MDC annual statistic [Internet]. Official Website of the Malaysian Dental Council; 2025 [cited 2025 Apr 5]. Available from: https://hq.moh.gov.my/ohd/mdc/
52. Sánchez Recio R, Alonso Pérez De Ágreda JP, Rabanaque MJ, Aguilar Palacio I. Understanding the effect of economic recession on healthcare services: a systematic review. Iran J Public Health [Internet]. 2022 [cited 2025 Mar 14]. doi: 10.18502/ijph.v51i3.8925.
53. Oral Health Programme. National Oral Health Plan for Malaysia 2011–2020 [Internet]. Ministry of Health Malaysia; 2011 [cited 2024 Nov 3]. Available from: https://hq.moh.gov.my/ohd/images/pdf/nohp20112020.pdf
54. Oral Health Programme. Guidelines: Oral Healthcare for Young Adults in Malaysia [Internet]. Ministry of Health Malaysia; 2019 [cited 2021 Mar 17]. Available from: http://ohd.moh.gov.my/images/pdf/xtvtnsop/ohyoung.pdf
55. Department of Statistics Malaysia. OpenDOSM [Internet]. Putrajaya: Ministry of Economy Malaysia; 2025 [cited 2025 Apr 5]. Available from: https://www.dosm.gov.my/portal-main/home
56. Agarwal R, Baid R. Periodontitis and diabetes: a bidirectional, cyclical relationship - a brief review. Acta Med Int. 2017;4(2):46.
57. Aida J, Takeuchi K, Furuta M, Ito K, Kabasawa Y, Tsakos G. Burden of oral diseases and access to oral care in an ageing society. Int Dent J. 2022;72(Suppl 1):S5-S11.
58. Kasusu Klint N, Satu L, Risto T. Costs of dental care and its financial impacts on patients in a population with low availability of services. Community Dent Health. 2019;36(2):131-6.
59. Toh LS, Sern CW. Patient waiting time as a key performance indicator at orthodontic specialist clinics in Selangor. Malays J Public Health Med. 2011;11:10.
60. Cerina. Government and private dental service in Malaysia: what's the difference and which one is better? [Internet]. LookP; [cited 2021 Mar 18]. Available from: https://www.lookp.com/blog/government-and-private-dental-service-malaysia
61. Board on Health Promotion and Disease Prevention, Committee on Assuring the Health of the Public in the 21st Century. The future of the public's health in the 21st century. Washington (DC): National Academies Press; 2003.
62. Boo S-L. More contract doctors quit in 2022 than in two previous years combined [Internet]. CodeBlue Health and Human Rights; 2023 [cited 2024 Oct 24]. Available from: https://codeblue.galencentre.org/2023/02/more-contract-doctors-quit-in-2022-than-in-two-previous-years-combined/
63. Boo S-L. Contract doctors' future now questionable, civil service permanent appointments halted from February [Internet]. CodeBlue Health and Human Rights; 2024 Jan 24 [cited 2024 Oct 24]. Available from: https://codeblue.galencentre.org/2024/01/contract-doctors-future-now-questionable-civil-service-permanent-appointments-halted-from-february/
64. Jinah N, Lee KY, Zakaria NH, Zakaria N, Ismail M, Mohmad S. Contract doctors' strike in Malaysia: a content analysis of the perception of medical fraternity and stakeholders on Facebook. PLoS One. 2023;18(9):e0292213.
65. Prasad M, Manjunath C, Murthy A, Sampath A, Jaiswal S, Mohapatra A. Integration of oral health into primary health care: a systematic review. J Fam Med Prim Care. 2019;8:1838.
66. Ministry of Health Malaysia. National Strategic Plan for Non-Communicable Disease (NSP-NCD) 2016-2025. Putrajaya: Ministry of Health Malaysia; 2016.
67. Villa A, Da Costa J, Duong M-L, Frazier K, Urquhart O. Oral-systemic health considerations in dental settings. J Am Dent Assoc. 2022;153(4):388–9.
68. Oral Health Programme, Ministry of Health Malaysia. Garis panduan pelaksanaan Program Ikon Gigi. Putrajaya: Ministry of Health Malaysia; 2019.
69. Ismail S, Sutan R, Ibrahim R, Rathi FZM. Psychometric properties of the Teleprimary Care Oral Health Clinical Information System (TPC-OHCIS) Questionnaire using the Rasch model. Cureus. 2024;16(6):e63064.
70. Nor Mukshar AN, Mohd Puad NA, Ahmad KA. Ciri-ciri

skim takaful kesihatan mikro: kajian persepsi dalam kalangan B40: characteristics of micro health takaful schemes: a perception study among B40. J Muwafaqat. 2023;6(2): 133-56.
71. Ospina R, Gondim JAM, Leiva V, Castro C. An overview of forecast analysis with ARIMA models during the COVID-19 pandemic: methodology and case study in Brazil. Mathematics. 2023;11(14):3069.
72. Hespanhol L, Vallio CS, Costa LM, Saragiotto BT. Understanding and interpreting confidence and credible intervals around effect estimates. Braz J Phys Ther. 2019;23:290-301.
73. Makridakis S, Bakas N. Forecasting and uncertainty: A survey. Risk Decis Anal. 2016;6(1):37-64.
74. Volkery A, Ribeiro T. Scenario planning in public policy: Understanding use, impacts and the role of institutional context factors. Technol Forecast Soc Change. 2009;76: 1198-207.

Supplementary Materials

Supplementary Table 1: Model Selection Criteria for ARIMA Models of Adult Public Oral Healthcare Utilization in Malaysia.

ARMA Model	Log Likelihood	AIC*	BIC	HQ
(3,4)(0,0)	37.58	-2.04	-1.61	-1.91
(4,1)(0,0)	35.37	-2.03	-1.69	-1.92
(2,1)(0,0)	33.17	-2.01	-1.77	-1.94
(1,0)(0,0)	30.81	-1.99	-1.84	-1.94
(1,1)(0,0)	31.17	-1.94	-1.75	-1.88
(2,0)(0,0)	31.10	-1.94	-1.75	-1.88
(3,2)(0,0)	33.34	-1.88	-1.55	-1.78
(1,2)(0,0)	31.23	-1.87	-1.64	-1.80
(3,0)(0,0)	31.21	-1.87	-1.63	-1.80
(4,3)(0,0)	34.67	-1.83	-1.41	-1.70
(4,0)(0,0)	31.46	-1.82	-1.53	-1.73
(1,3)(0,0)	31.33	-1.81	-1.52	-1.72
(2,2)(0,0)	31.29	-1.81	-1.52	-1.72
(1,4)(0,0)	32.27	-1.80	-1.47	-1.70
(3,1)(0,0)	31.25	-1.80	-1.52	-1.72
(4,4)(0,0)	35.24	-1.80	-1.33	-1.66
(4,2)(0,0)	32.66	-1.76	-1.38	-1.65
(3,3)(0,0)	32.66	-1.76	-1.38	-1.64
(2,3)(0,0)	31.30	-1.74	-1.40	-1.63
(0,3)(0,0)	26.96	-1.57	-1.33	-1.50
(0,2)(0,0)	25.16	-1.51	-1.32	-1.45
(0,4)(0,0)	26.96	-1.50	-1.21	-1.41
(2,4)(0,0)	26.83	-1.35	-0.96	-1.23
(0,1)(0,0)	17.51	-1.04	-0.89	-0.99
(0,0)(0,0)	4.35	-0.17	-0.07	-0.14

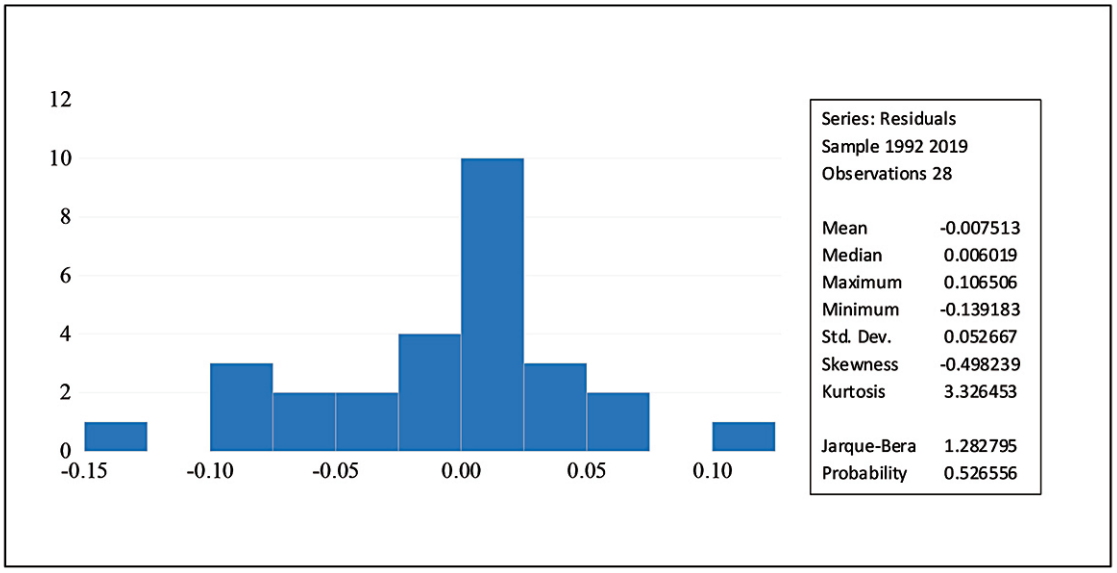
*Akaike's Information Criterion (AIC) was used to compare the models

Supplementary Table 2: ARCH Test for Heteroskedasticity in Residuals of ARIMA Model for Adult Public Oral Healthcare Utilization in Malaysia.

Statistic	Value	Prob.
F-statistic	2.19	0.151
Obs*R-squared	2.17	0.140

Supplementary Table 3: Error Measures and Interpretations for the Forecasted ARIMA Model of Adult Public Oral Healthcare Utilization.

Error Measure	Value	Interpretation
Root Mean Squared Error (RMSE)	0.372	Indicates the average magnitude of forecast errors; lower values reflect higher accuracy.
Mean Absolute Error (MAE)	0.275	Represents the average absolute difference between observed and forecasted values; smaller values are better.
Mean Absolute Percentage Error (MAPE)	4.515%	Shows the average forecast error as a percentage of the actual value; below 10% is generally acceptable.
Symmetric MAPE	4.437%	Similar to MAPE but avoids bias toward over- or under-forecasting; confirms consistent accuracy.
Theil Inequality Coefficient	0.027	Measures the relative forecast accuracy compared to a naive model; values close to 0 indicate high performance.
Theil U2 Coefficient	0.707	Evaluates the forecast's reliability relative to an ideal model; values below 1 suggest good performance.



Supplementary Figure 1: Histogram of Residuals for ARIMA Model of Adult Public Oral Healthcare Utilization Prevalence in Malaysia.