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Assessing Oral Healthcare Accessibility in Elderly through Geographic Information Systems: A Scoping Review

Lenny Lesa[1], Budi Aslinie Md Sabri[2*], Nor Faezah Md Bohari[2]

[1]*Faculty of Dentistry, Universiti Teknologi MARA (UiTM), Sungai Buloh 47000, Selangor, Malaysia*
[2]*Centre of Population Oral Health and Clinical Prevention, Faculty of Dentistry, Universiti Teknologi MARA (UiTM), Sungai Buloh 47000, Selangor, Malaysia*

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ABSTRACT

Objectives: Disparities persist, especially for the elderly, in accessing oral healthcare. GIS was widely used in spatial aspects to examine access to oral healthcare services and highlight multiple factors that might influence access to healthcare facilities. This study aims to conduct a scoping review of the available literature on the accessibility of oral healthcare (OHC) for the elderly population across countries using GIS.

Materials and Methods: Electronic search was performed in the following databases: PubMed, Scopus, Web of Sciences (WOS), and Science Direct. This review included all types of studies that use GIS or a comparative geospatial mapping program in studying the accessibility of oral healthcare for the elderly population, published in the English language, with no restrictions on location or publication date. Excluded were duplicates, non-peer-reviewed papers and studies without full text available. The population included the elderly aged 60 years and above.

Results: Nine studies were included in the final review. All studies are from high-income countries: Australia, the United States, Japan and Great Britain. The spatial analysis techniques utilised here include proximity, overlay, Kernel Density, statistical, and network analysis.

Conclusions: Overall, elderly access to OHC appears sparse in rural regions; public transport, especially bus networks, improves access. Policymakers should enhance dental services in rural areas, integrate transportation with clinics, and improve infrastructure for the elderly by utilising GIS tools to identify underserved regions and increase access to oral healthcare.

[1*] Corresponding author. *E-mail address*: budiaslinie@uitm.edu.my

1. INTRODUCTION

"Health for all" is a concept similar to universal health coverage (UHC), which ensures everyone has access to quality health services whenever and wherever they need them, without financial difficulties (Pandey, 2018). UHC is a fundamental human right; therefore, governments are responsible for providing essential healthcare regardless of gender, age, religion, ethnicity, or financial status (O'Connell et al., 2014; WHO, 1946). However, disparities in access to health and oral health care persist, particularly in the elderly, due to various barriers or difficulties (Ahmed et al., 2001; Gopalakrishnan et al., 2019; Luo et al., 2009), who are at a higher risk of illness and death in various types of emergencies (Sanchini et al., 2022). The elderly have been defined as the chronological age, with developing countries typically adopting 60 as the threshold and developed countries 65 years and older for the purpose of policy-making (WHO, 1974). The elderly are a vulnerable population, and their health is influenced by genetic and environmental factors (Li et al., 2021). Ageing is associated with several adverse health effects and rising incidence of non-communicable diseases (Eke et al., 2016; Sapkota et al., 2023). In addition, the elderly live longer and retain their teeth (Eke et al., 2016; Gao et al., 2018), increasing the need for improved accessibility to oral care services (Ahluwalia et al., 2010).

Poor general health is associated with poor oral health, which impacts people's general health and quality of life by affecting oral functions (Griffin et al., 2012). Even though oral conditions affecting the elderly are treatable and preventable, many elderly do not get the necessary care (Razak et al., 2014). This might be because most elderly are not exposed to preventative dentistry at an early age and believe that tooth loss is an inevitable aspect of the ageing process (Razak et al., 2014). Others have developed a tolerance for poor oral health and seek treatment only in emergencies (Razak et al., 2014).

Many factors can potentially influence the use of health care services, including the type of illness, medical insurance, income, gender, geographic location, education level and socio-economic status (Ahmed et al., 2001). The government is indeed responsible for the provision of healthcare services, which is vital for maintaining and improving health status; nevertheless, disparities in healthcare access persist, particularly in terms of availability, affordability and quality, affecting different population subgroups throughout the country (Mosadeghrad, 2014). Previous studies conducted in Malaysia and the United Kingdom found that oral healthcare services were distributed unevenly between urban and rural areas, particularly private dental clinics that are more concentrated in urban areas (Jo et al., 2020; Md Bohari et al., 2019). These studies have used Geographic Information Systems (GIS) to assess the accessibility of oral healthcare services.

GIS has been widely used in spatial aspects to examine access to oral healthcare services and highlight multiple factors that might influence access to healthcare facilities, including distance, socioeconomic status, and transportation (Jo et al., 2021b, 2021c; Metcalf et al., 2013; Zainab et al., 2015). It provides accurate measurements of geographical access and analyses social and economic inequities (Comber et al., 2011). GIS helps identify areas with poor accessibility and quantify affected populations, addressing areas with high demand for healthcare and limited transit mobility for public service improvement (Stentzel et al.,2016). GIS spatial analysis is classified into six types. Temporal analysis helps identify patterns in specific data types, for example, incident data. Proximity analysis determines which features are close to other features.

Overlay analysis examines interactions between overlapping geographic phenomena. Statistical analysis identifies and quantifies patterns or relationships in data, extracting additional information that may not be obvious from maps and predicting data values at unknown locations or model relationships among data variables. Network analysis determines solutions to complex routing problems to help locate the most cost-effective path for delivering resources. Lastly, 3D analysis enables users to visualize and analyze data in 3D to solve more complex analysis questions (ESRI, 2023). These types of spatial analysis

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techniques are often used in combination to gain a more comprehensive understanding of spatial relationships and patterns

This study aims to conduct a scoping review of the available GIS-based research to assess the accessibility of oral healthcare (OHC) for the elderly population across countries. By examining how GIS methodologies assess and illustrate disparities in access, this study will explore geographic variations in rural and urban socioeconomic factors affecting the elderly population. The scoping review method was selected for the present study because it is valuable for mapping the literature on evolving or emergent topics and identifying knowledge gaps in the use of GIS to assess the accessibility of oral healthcare services (Mak & Thomas, 2022). A narrative review on the utilisation of GIS within the broad theme of dental public health research was published in 2021, highlighting the application of GIS methods to measure accessibility to health facilities (Nayak et al., 2021). Therefore, the present review focused on using GIS to assess the accessibility of OHC for the elderly.

2. MATERIAL AND METHODS

The scoping review followed the methodological framework that Arksey and O'Malley suggested (Arksey & O'Malley, 2005). A scoping review protocol is available upon request from the corresponding author. The design encompassed a series of five sequential processes, namely: (1) identifying the research question, (2) identifying relevant studies, (3) selecting studies, (4) charting the data, and (5) collating, summarizing, and reporting the results.

2.1 Identifying the Research Question

There are no restrictions on the types of studies that will be included that use GIS or a comparative geospatial mapping program to study the accessibility of oral healthcare for the elderly population across countries. Formulated based on the PCC strategy, the research question for this study is: What is the accessibility of oral healthcare for the elderly population across countries, and what are the spatial analyses used in assessing accessibility? The population (P) included the elderly population aged 60 years and above. Concept (C) accessibility of the OHC, and context (C) is the OHC systems across different countries.

2.2 Identifying Relevant Studies

A detailed electronic search was performed in the following databases: PubMed, Scopus, Web of Sciences (WOS), and Science Direct. In each database, the search was conducted systematically and independently by the main author using key phrases and Boolean logic: ("GIS" OR "ArcGIS" OR "Geographic information systems" OR "Geographic mapping" OR "Spatial analysis" OR "Geospatial analysis") AND ("Oral healthcare" OR Dental OR "Oral Health" OR "Dental clinic" OR "Dental Facilities" OR "Dental Office")) AND (Access* Or "Health Services Accessibility") AND (Elderly OR Aged OR Older OR Geriatric). A predefined search filter was applied to include only studies published in English. The review timeline was not restricted; regular updates were also performed to include the latest articles on the topic of interest, with data collection conducted from 1 December 2023 to 31 May 2024.

2.3 Study Selection

Following the search, all identified citations were collated and uploaded to EndNote 20, and duplicates were removed. Following the pilot test, two independent researchers conducted study selection and article extraction in two phases based on the inclusion criteria for the review. In the first phase, titles and abstracts were screened to identify preselected studies, and those that were not eligible were excluded. The full articles were retrieved if the titles/abstracts of the studies did not contain adequate information to support the decision for inclusion and exclusion. In the second phase, the full texts of all included studies were

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evaluated based on the same eligibility criteria. Any disagreements that arise between the reviewers at each stage of the selection process will be resolved through discussion with the third reviewer until a consensus is reached.

2.4 Data Extraction, Collating, Summarizing, and Reporting the Results

Then, the two researchers independently extracted the data from each selected study using an Excel spreadsheet developed by the reviewer. Extracted data included authors, year, title, study region, objective of the study, type of OHC whether public (run by the government) or private (independent or chain), study population, oral healthcare (OHC)-to-elderly population ratio, Proximity of OHC to elderly population in Euclidean distance or buffer analysis (in m/km radius buffer), OHC to Public Transport, elderly to Public Transport, description of OHC based on urban or rural region, and socio-economic status.

3. RESULTS

The steps we took for the study selection process are shown in Figure 1. They were in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Review (PRISMA-ScR) reporting standard, which is the standard way to do scoping reviews (Tricco et al., 2018). A total of 296 articles were obtained through database searches. After removing 120 duplicates and 129 articles whose title or abstract did not fulfil the inclusion criteria, 46 studies were suitable for further screening. The full text of one article could not be obtained. The articles were subjected to a comprehensive screening process, resulting in 37 papers that did not match the inclusion criteria being omitted from the full-text review. Finally, only nine articles were used in this scoping review. All studies are from high-income countries, namely Australia (Almado et al., 2015; Kamil et al., 2021; Patel et al., 2019; Zainab et al., 2015), United States (Borrell et al., 2006), Japan (Hanibuchi et al., 2011) and Great Britain (Jo et al., 2021a, 2021b, 2021c). Studies reported the geographical distribution of OHC in terms of the oral healthcare (OHC)-to-elderly population ratio, the proximity of OHC to the elderly population, OHC to Public Transport, elderly to Public Transport, the description of OHC based on urban or rural region, and socio-economic status.

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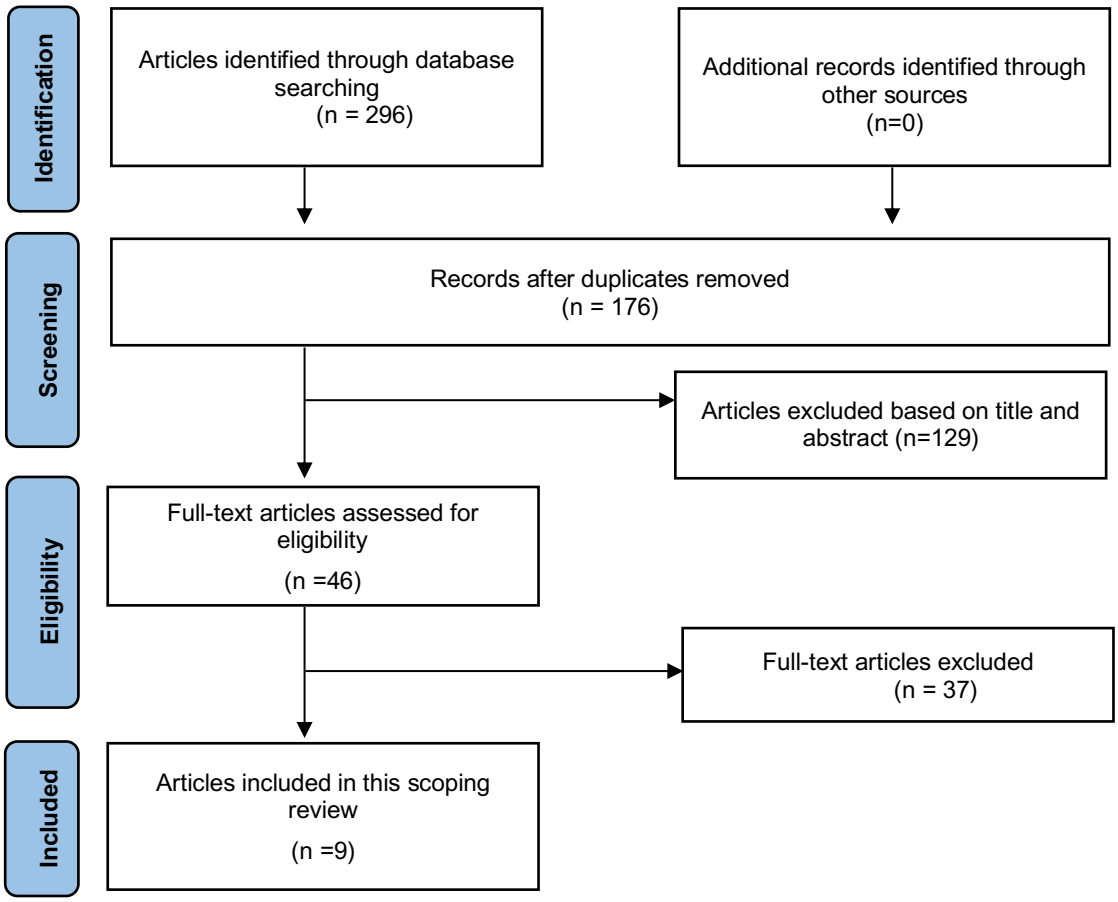

Fig. 1. PRISMA-ScR diagram of the search and study selection

Table 1 presents the characteristics of the studies included in the review. Except for one American study conducted before 2010, most studies (n = 8) were conducted after 2010. Four studies only mention the OHC type. Four studies use Aeronautical Reconnaissance Coverage Geographic Information System (ArcGIS), a subscription-based software developed by the Environmental Systems Research Institute (ESRI), and four studies use Quantum Geographic Information System (QGIS), a free and open-source software. The spatial analysis techniques utilised here include proximity, overlay, Kernel Density, statistical, and network analysis. Overlay and proximity analysis were the most commonly used; network analysis was employed in only one study.

Table 2 outlines the study population and key findings described in the papers. Data were provided at national (n = 5) and local (n = 4) levels. Even though multiple terminology was employed to describe the elderly, the study population was collected from 65-year-olds and older. A study conducted in Australia classified individuals aged over 65 years as retirees, while those aged over 85 years were categorised as older adults or elders. In Japan, the term "elderly" is commonly employed, although studies conducted in the United Kingdom or Great Britain tend to utilise the term "older adults." The density data for OHC were reported in three studies, proximity to OHC in five studies, and access to public transport in three studies. Studies that measured the distance or proximity of OHC from the population or the public transport represented the data in Euclidean distance (straight line distance) from the determined radius's population centre. However, one study from the United Kingdom used Lorenz curves to represent the distribution of dental practices by the older adult population.

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Table 1. Characteristics of Studies Included in Scoping Review

No	Author	Title	Country	Year	Study Purpose	Type of OHC	Type of GIS Analysis Used
1	Almado, Kruger et al.(Almado et al., 2015)	Application of spatial analysis technology to the planning of access to oral health care for at-risk populations in Australian capital cities	Australia	2015	To apply spatial analysis tools to measure the spatial distribution of fixed adult public dental clinics in the eight metropolitan capital cities of Australia	Public	Proximity, Overlay, Kernel Density and statistical analysis
2	Borrell, Northridge et al.(Borrell et al., 2006)	Oral health and health care for older adults: A spatial approach for addressing disparities and planning services	United States: Manhattan, Bronx	2006	To examine the geographic distribution of New York City adults aged 65 and older by Race/ethnicity and poverty status and to analysed seniors' access to dental care as defined by the location of dental providers and their proximity to the subway system lines in Manhattan and the Bronx	-	Overlay Analysis
3	Hanibuchi, Aida et al.(Hanibuchi et al., 2011)	Geographical accessibility to dental care in the Japanese elderly	Japan: Chita Peninsula region of Aichi prefecture	2011	To clarify the factors relevant to elderly people's access to dental care in Japan, particularly focusing on geographical accessibility		Proximity, Overlay, Statistical analysis.
4	Jo, Kruger et al.(Jo et al., 2021c)	Public transport access to NHS dental care in Great Britain	Great Britain	2021	To examined the spatial accessibility of the population of Great Britain to public transport in providing access to oral healthcare	Public	Proximity, Overlay and statistical analysis
5	Jo, Kruger et al (Jo et al., 2021b)	GIS mapping of healthcare practices: do older adults have equitable access to dental and medical care in the UK?	United Kingdom	2021	To identify and compare access to dental and general practices and to ascertain if there exists a socioeconomic distribution of dental and general practices among older adults.		Proximity, Overlay and statistical Analysis
6	Jo, Kruger et al (Jo et al., 2021a)	Disparities in the geographic distribution of NHS general dental care	England	2021	To assess the geographic distribution of NHS dental practices in England in relation to		Proximity, Overlay and statistical Analysis

		services in England			deprivation and rurality.		
7	Kamil, Kruger et al (Kamil et al., 2021)	Distribution of Australian dental practices in relation to the ageing population	Australia	2021	To analyse and map the distribution of the ageing population, by sociodemographic profiling, in private and public dental practices in Australia	Private and Public	Proximity and Overlay analysis.
8	Patel, Tennant et al.(Patel et al., 2019)	Understanding the role of the public transport network in the greater Sydney area in providing access to dental care	Australia : Sydney	2019	To examine the spatial accessibility of the aged and older adult population of the greater Sydney region to the bus public transport network, and the proximity of this transportation route to public and private dental services.	Private and public	Proximity, Overlay and Network Analysis
9	Zainab, Kruger et al (Zainab et al., 2015)	Major metropolis rail system access to dental care for the retired and elderly: a high-resolution geographic study of Sydney, Australia	Sydney, Australia	2015	To examined the spatial accessibility of the Sydney Dental Hospital, to the people of metropolitan Sydney, using a geographic information systems approach	-	Proximity, Overlays and statistical Analysis

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Table 2. Study Population and Key Findings

No.	Country	National	Local	Study Population	OHC density per elderly population: (ratio)	Proximity of OHC to the elderly population	OHC to Public Transport	Elderly to Public Transport	Urban/Rural	Socioeconomic Status (SES)
1	Australia(Almado et al., 2015)	x		Retirees (>65): 1.2 million Elderly (>85): 0.15 million. The sample comprised individuals living within a 25-kilometer radius of the Primary Post Office (GPO) in the eight capital cities of Australia during the 2006 census: Sydney (NSW), Melbourne (VIC.), Adelaide (SA), Hobart (TAS.), Perth (WA), Brisbane (QLD), Canberra (ACT), and Darwin (NT).	-	Areas with More Than 40% Living Within 2.5 km of a Government Dental Clinic Low SES Populations: NSW, VIC, QLD, and SA High SES Populations: NSW Areas with the Lowest Percentage Living Within 2.5 km of a Government Dental Clinic: Low SES Populations: TAS High SES Populations: NT	-	-	Urban	√
2	Australia(Kamil et al., 2021)	X		Australian Census of Population and Housing (2016). Population data included only people aged 65 years and older.	All ratios are per 100 population NSW: Private: 1:4 Public: 1:131 VIC Private: 1:5 Public: 1:120 QLD Private: 1:5 Public: 1:120 SA Private: 1:6 Public: 1:116 WA Private: 1:4	Within 5km practice (%) NSW: Private: 87.9 Public: 54.3 VIC Private: 88.2 Public: 55.6 QLD Private: 85.1 Public: 45.2 SA Private: 88.2 Public: 53.6 WA Private: 88.1 Public: 39.4	-	-	Rural and urban	√

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				Public: 1:118 TAS Private: 1:10 Public: 1:108 NT Private: 1:4 Public: 1:22 ACT Private: 1:4 Public: 1:122	TAS Private: 68.1 Public: 39.1 NT Private: 75.1 Public: 58.3 ACT Private: 99.9 Public: 66.7				
3	Great Britain(Jo et al., 2021c)	x	The 2011 Census data for England, Scotland, and Wales, including adults aged 65 and older, was obtained from the Office for National Statistics. A 400-meter buffer was created around bus and tram stops, and an 800-meter buffer around train, metro, and light rail stops.	-	-	Within 400 m of bus/tram Scotland: 99.5% England: 99.1% Wales: 100% Within 800 m of train/metro/light rail Scotland: 52.7% England: 53.1% Wales: 100%	Within 400 m of bus/tram Scotland: 91.0% England: 89.4% Wales: 80.5% Within 800 m of train/metro/light rail Scotland: 31.6% England: 29.6% Wales: 27.0%	Rural and urban	
4	United Kingdom(Jo et al., 2021b)	x	Population estimates are based on the 2011 Census. A total of 12,374,961 older adults in the UK were included in this study; 10,353,716 in England, 662,376 in Wales, 1,044,145 in Scotland and 314,724 in Northern Ireland	Dental practices per 100,000 older adults UK: 105.1 England: 101.3 Wales: 139.3 Scotland: 117.7 Northen Ireland: 117.6	-			Rural and Urban	√

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5	England(Jo et al., 2021a)	x		Population data was obtained from the 2011 Census. Older adults (aged >65) Urban: 6,694,776, Rural: 1,964,673).	-	88.8% (n = 7,685,405) of older adults lived within 2.5 km of a dental practice. Urban: 99.1% Rural: 53.5%	-	-	Rural and Urban	√
6	United States: Manhattan, Bronx(Borrell et al., 2006)		x	The 2000 U.S. Census Summary File 3 estimates the 65-year-olds who self-report as Hispanic or non-Hispanic Black and live below the official poverty line in Manhattan and the Bronx.	-	50% of the SDOS client residences are located within two miles of the clinic			-	-
7	Japan: Chita Peninsula region of Aichi Prefecture (Hanibuchi et al., 2011)		x	The sample was taken from the Japanese elderly, aged 65 and over, who responded to a postal survey conducted in 2003, eight of the 10 municipalities in the Chita Peninsula region. (n = 2,192).	Dental clinics per 100,000 people (municipality level): Mean 44.38 (SD: 3.67)	Mean: 0.53 km (SD: 0.45)	-	-	Urban	√
8	Australia: Sydney (Patel et al., 2019)		x	The older population within 50 km of Sydney's General Post Office (GPO) included 544,095 people, with 475,661 aged over 65 (retirees) and 68,434 aged over 85 (older adults). Public dental clinics: 44 Private Dental Clinic: 1982	-	-	Within 250m High-frequency Bus stops: 79% Within 500m High-frequency Bus stops: 89%	Within 250m High-frequency Bus stops: i.Retirees: 28% ii.Older adults: 30% Within 500m High-frequency Bus stops:	Urban	√

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					i.Retirees: 52% ii.Older adults: 55%		
9	Australia: Sydney(Zainab et al., 2015)	X	From Census 2006. Retirees and elders living within 50 km of the Central Post Office of Sydney Retirees (aged >65): 449,200 Elders (aged >85): 58,800.	-	Within 1 km of the train station: Retirees: 32% Elders: 36% Within 2 km of the train station: Retirees: 25% Elders: 23%	Urban	√

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Studies on elderly dental care access in Australia, New York City, Japan, and the UK highlight notable disparities. In Australia (Almado et al., 2015; Kamil et al., 2021), especially in Tasmania and the Northern Territory, many elderly individuals live over 5 km from a dental clinic. In New York City (Borrell et al., 2006), 50% of SDOS clients reside within two miles of a clinic. In Japan's Chita Peninsula (Hanibuchi et al., 2011), the average distance to a dental clinic is 0.53 km. In England (Jo et al., 2021a), most elderly residents live within 2.5 km of an NHS dental practice; however, rural areas remain underserved, with only 53.5% living within that range.

Three studies examine public transport accessibility to dental clinics for the elderly, highlighting its importance for dental care access in Great Britain (Jo et al., 2021c), and Sydney (Patel et al., 2019; Zainab et al., 2015). Most NHS dental clinics in Great Britain are conveniently located near public transport; however, older adults generally find it easier to access bus or tram stops than train, metro, or light rail stations. In Sydney, half of retirees and older adults live within 500 meters of a high-frequency bus stop. In contrast, 32% of retirees and 36% of elders live within 1 km of a train station, highlighting the need for the train system to be made more accessible for the elderly.

4. DISCUSSION

This scoping review highlights a critical gap in our understanding of oral healthcare (OHC) accessibility, particularly in relation to geographical distribution and public transport access for the elderly. The review contributes to the development of OHC access initiatives by examining spatial patterns across multiple high-income countries, including Australia, the UK, Japan, and the US. The focus on high-income nations can be attributed to their ageing populations, with Japan recognized as a super-aged society (McCurry, 2015). However, OHC accessibility remains a pressing issue in low- and middle-income countries (LMICs), where more than two-thirds of the world's older population is projected to live in these regions by 2050 (United Nations, 2020).

Although the studies reviewed focus on high-income nations, they still reveal substantial variations in dental service distribution. A consistent pattern across studies is the urban-rural divide, where elderly individuals in urban areas have significantly better access to dental services than their rural counterparts. In England, for example, 88.8% of older adults live within 2.5 km of a dental practice, but a stark contrast exists between urban (99.1%) and rural (53.5%) accessibility levels(Jo et al., 2021a). Similarly, in Australia, public dental clinics are less evenly distributed than private clinics, limiting accessibility for low-income and rural elderly populations (Kamil et al., 2021). In Japan, the average distance to the nearest dental clinic is only 0.53 km, but this study was conducted in the Chita Peninsula, Japan's third-largest urban area, which may not reflect national trends (Hanibuchi et al., 2011). These findings suggest that healthcare infrastructure, economic development, and geographic location significantly influence elderly dental access, even in well-developed health systems.

Access to oral healthcare is a complex issue, involving both spatial (availability and accessibility) and aspatial (affordability and acceptability) components (Gulliford et al., 2002). Most studies assess geographic accessibility using Euclidean distance-based measurements, applying 2.5 km to 5 km buffers to examine elderly access to dental clinics. Similarly, public transport accessibility varies by mode, with bus stops having a 250–400m buffer and train stations ranging from 800m to 2 km. Given that older adults, especially those over 75, are more reliant on public transport due to driving limitations, this aspect is crucial for assessing real-world accessibility (Patel et al., 2019). However, distance-based approaches alone do not fully capture healthcare accessibility barriers. Nevertheless, many studies have used spatial statistical analysis to go beyond simple distance measures and provide a more nuanced understanding of spatial patterns, correlation, and variations (Borrell et al., 2006; Hanibuchi et al., 2011; Jo et al., 2021a; Kamil et al., 2021; McCurry, 2015; Metcalf et al., 2013; Tricco et al., 2018). It aids planners and researchers in

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identifying unique accessibility challenges, formulating targeted interventions, and making informed decisions to improve overall accessibility (Nsaif et al., 2020; Rezayee, 2020).

5. LIMITATIONS

The literature search was limited to PubMed, Scopus, WOS, and ScienceDirect, excluding other databases. Although comprehensive search terminology was used, some articles might have been missed. Searches were conducted only in English, and heterogeneous reporting on oral healthcare accessibility across countries limited the ability to comparing findings.

6. CONCLUSION

Access to dental care for the elderly varies significantly across Australia, New York City, Japan, and the UK. Rural populations face the most challenges due to the distribution of clinics and limitations in transportation. Public transport is crucial for improving access, as bus networks generally provide better service than train systems. However, many elderly individuals still struggle with issues related to distance and mobility. To enhance access to dental care, policymakers should focus on expanding dental services in rural areas, integrating public transport with dental clinics, and improving transit infrastructure to be more accommodating for the elderly. GIS is a valuable tool for healthcare planners, policymakers, and researchers in assessing and identifying underserved areas and planning to improve access to oral healthcare and essential services.

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CONFLICT OF INTEREST

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AUTHORS' CONTRIBUTIONS

All authors participated in designing the study. Lenny Lesa conducted the literature search and data extraction. All authors contributed to the data analysis and synthesis of data. All authors reviewed and critically contributed to the drafting of the manuscript. All authors have approved the final version of the manuscript.

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7. APPENDIX

A. About the authors

Budi Aslinie Md Sabri is an Associate Professor at the Centre of Population Oral Health and Clinical Prevention Studies, Faculty of Dentistry, Universiti Teknologi MARA (UiTM). Her research focuses on Social behavioural science, Dental Education, tobacco-related research, and Health systems research. She can be reached at budiaslinie@uitm.edu.my

Lenny Lesa is a Dental Officer with the Ministry of Health. She completed her Doctorate in Dental Public Health (DrDPH) in 2024. Her research focuses on the application of geospatial analysis in oral health, particularly in evaluating dental care accessibility among vulnerable groups, including older adults and individuals with special needs. She can be contacted via email at lennylesa@moh.gov.my

Nor Faezah Md Bohari is a lecturer at the Centre of Population Oral Health and Clinical Prevention Studies, Faculty of Dentistry, Universiti Teknologi MARA (UiTM). Her research interests include geomapping in health research, oral health equity, oral healthcare for children and individuals with special needs, tobacco and vape-related research, and health services research. She can be reached at norfaezah6843@uitm.edu.my

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