

Basic research on the accessibility of Japanese dental services using the geographic information system

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We calculated the geographic accessibility of dental clinics in Japan for each prefecture from 2010 to 2020 and examined the correlation between accessibility and dental consultation rate to evaluate the balance of supply and demand for dental services. As an index of accessibility to dental care, we calculated the accessibility index (AI) and the accessibility index rate (AIR) for the population outside a 1,000 meter radius using the geographic information system (GIS). We found that although there were no significant changes in the AI and AIR values during the 10 years from 2010, considerable differences existed among the prefectures. Moreover, multiple regression analysis revealed significant negative correlation between AIR and dental consultations among those over 75 years of age. Based on the above results, we concluded that in order to analyze the supply and demand for dental services, it is necessary to reduce the service area. In addition, there is need to analyze the supply and demand for dental care considering the geographic accessibility of those over 75 years of age. (J Osaka Dent Univ 2021 ; 55 : 41–46)

Key words : Accessibility ; Dental service ; Geographic information system

INTRODUCTION

The total number of dentists in Japan has been increasing annually according to the Survey of Physicians, Dentists and Pharmacists. In 2018, the average dentist-to-population ratio nationwide was 80.5 : 100,000. When comparing the ratios among prefectures, serious maldistribution was confirmed with this number being 54.9 in Shiga compared to 115.9 in Tokyo.¹ Regular dental visits enable dental health care professionals to provide preventive service together with early diagnosis and treatment.² In New Zealand, access to primary health services suffers from a shortage and maldistribution of dental practitioners.³ Stephan reported that accessing health care, including oral care is not equal across the population in Australia.⁴ Current analysis showed that geographical socioeconomic differences in access to dental care exist in Japan.⁵ Access to dental care has a strong rural-urban dimen-

sion.⁶ There is a strong relationship between the degree of urbanization and the concentration of the dental workforce.⁷ People in rural areas are facing more disadvantages in accessing private oral health services than in metropolitan cities.⁸

The definition of accessibility includes availability, accessibility, affordability, acceptability, and accommodation.⁹ There are many definitions related to accessibility in the healthcare context. Although calculating the accessibility to health care services is impossible using only statistical data for each district, merging the open access data with geographic information will help produce meaningful results. The geographical information system (GIS), currently used widely, allows us to visualize spatial relationships using various data, and is effective for analyzing health services. Technology can help us to quantitatively understand the geographic distribution of physicians.¹⁰ Pereira showed that on an individual level, social and economic variables were

associated with a greater prevalence of dental disease. However, this was not observed on a territorial level using GIS.¹¹

In Japan, which has a decreasing birthrate and an aging population, the expansion of regional disparities has become a crucial problem. According to the Japanese National Institute of Population and Social Security Research in 2018, the population in 2040 will decrease in all metropolitan and rural areas compared with 2010. In 2025, the “baby boomer population” who were born between 1947 and 1949 will be over 75 years of age. In areas with a large elderly population, it is predicted that there will be a shortage of dentists when “the regional comprehensive care system” has been established. Therefore, in order to maintain a good distribution of dental services, it is necessary to consider the proper placement of dental clinics. The importance of measuring healthcare accessibility is increasing in the government and among researchers. There is little research analyzing location-based accessibility to dental services in Japan. In discussing demand and supply of dental services, it is insufficient to make conclusions based only on the total number of dentists or dental clinics. We examined the accessibility to dental services in Japan from 2010 to 2020.

MATERIALS AND METHODS

No ethics approval was necessary for this research because all data were collected from open access web-based sources and de-identified data.

Data sources

Population data in 2010 and 2015 were obtained from the Japanese National Census, retrieved from e-Stat website.¹² The estimated population in 2020 was obtained from Regional population projection in Japan : 2015-2045 of National Institute of Population and Social Security. The estimated data was divided into young population, working population and aging population (65 years and over). The 500 meter grid populations for 2010, 2015 and 2020 were available from the digital national land information.¹³

The address for each dental clinic in Japan was obtained from various sources. The address of dental clinics for 2010 and 2014 were obtained from digital national land information.¹³ The present location information of all dental clinics for 2019 were purchased from Kokusai Kogyo, Chiyoda, Tokyo, Japan. Duplicates of all of the dental clinics were checked and the longitude and latitude of each practice were confirmed using Google Maps when necessary. In Nara Prefecture, only 70% of the dental clinics were coded in the digital national land information for 2014. We were able to obtain the data on dental use in each prefecture for 2011 and 2014 from the Patient Survey.¹⁴ The data of dental use and cost per capita among individuals over 75 years of age were obtained from the Report on Medical Care Business for the Elderly.¹⁵ We extracted certain variables such as age,¹⁶ gender,¹⁷ educational level,¹⁸ employment in primary industry,¹² average household spending,¹⁹ income of prefectural residents,¹⁸ elderly in the household,¹⁹ aged employees 75 years of age and over,¹⁸ and people certified for long-term care need²⁰ for each prefecture and merged this information into the dataset.

Data integration and definition of accessibility to a dental clinic

The database was merged using GIS software (ArcGIS Pro, Version 2.5.2; Environmental Systems Research Institute, Redlands, CA, USA). We defined the accessibility by first plotting the 500 meter grid population on the map, and plotting the dental clinic information based on longitude and latitude. We set 1,000 meter circles from each dental clinic. After combining all the circles, we performed area distribution for each prefectural boundary line. We calculated the accessibility to dental clinics based on the population outside of the circle. We excluded Nara in 2014 because the data was largely missing. We then obtained the accessibility index (AI) for each prefecture. Moreover, we calculated the value divided by the population of each prefecture as the accessibility index rate (AIR). These indexes for 2010, 2015 and 2020 were calculated from the population and dental clinic data for 2010,

the population data for 2015 with dental clinic data of 2014, and the estimate population data for 2020 with dental clinic data of 2019.

Statistical analysis

All data analyses including calculation of AI and AIR were completed using Microsoft Excel 2016 version 1908. (Microsoft, Redmond, WA, USA) The correlation between calculated index of AI, AIR and dental use were analyzed using Pearson's correlation coefficient. Simple and multiple regression analyses were carried out to eliminate the confounding variable. In addition, the correlation between the variables was examined to evaluate multicollinearity. Statistical Analysis was performed using SPSS (version 23, IBM, Armonk, NY, USA).

RESULTS

AI and AIR transition from 2010 to 2020 in each prefecture

Figure 1 shows the transition of AI for each prefecture from 2010 to 2020. In Japan, the total number of people living beyond the 1,000 meter radius were 18,015,769 in 2010, 16,853,866 in 2015 and 16,972,665 in 2020. Differences in the AI values were large among the prefectures, with Ibaraki (762,400), Hokkaido (668,547) and Chiba (612,668) being the greatest, and Tokyo (97,783), Osaka (102,221) and Nara (147,403) being the lowest in 2020. Figure 2 shows the AIR for each prefecture. The AIR for the total population was 0.140 in 2010 and 0.135 in 2020, which means that approximately 86.5% of total population was living within 1,000 meters of a dental clinic. In 2020, the AIR was

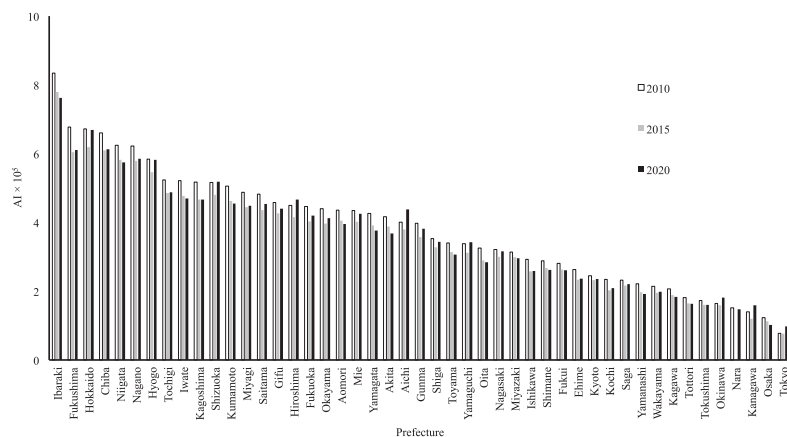


Fig. 1 The accessibility index (AI) for each prefecture for the years 2010, 2015 and 2020.

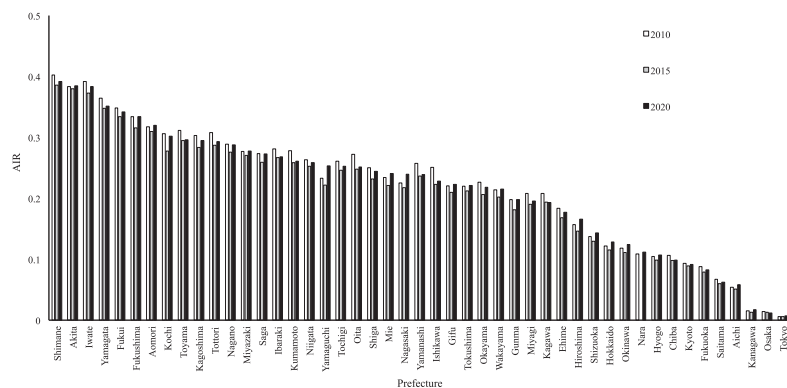


Fig. 2 The accessibility index ratio (AIR) for each prefecture the years 2010, 2015 and 2020.

0.392 for Shimane, 0.385 for Akita and 0.383 for Iwate, while it was 0.007 for Tokyo, 0.0120 for Osaka and 0.017 for Kanagawa.

Correlation of AI and AIR with dental use in 2010 and 2015

Figures 3 A and B shows the correlation between AI and dental use obtained from the Patient Survey among the total population. The correlation coefficient was -0.085 ($p=0.573$) in 2010 and -0.196 ($p=0.192$) in 2015. We found no correlation between AIR and dental use in 2010 ($r=-0.288$, $p=0.052$), or in 2015 ($r=-0.310$, $p=0.036$) (Figs. 3 C and D).

Relationship between dental use and AIR among individuals over 75 years of age in 2020

Figure 4 shows the relationship of dental use with AI and AIR among individuals over 75 years of age. According to the scatter plot, AI had no correlation with dental use ($r=-0.135$, $p=0.366$). On the other hand, AIR had a strong relationship with dental use ($r=-0.762$, $p<0.001$). The correlation of dental use with other parameters among individuals over

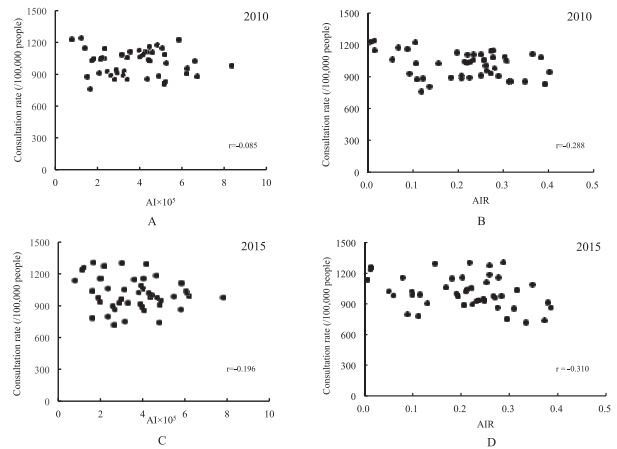


Fig. 3 Correlation between AI or AIR and the dental consultation rate for 2010 (A·B) and 2015 (C·D).

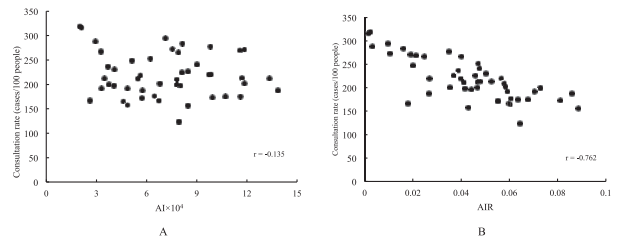


Fig. 4 Correlation between AI (A) or AIR (B) and the dental consultation rate for elderly over 75 years of age.

Table 1 Correlation between dental consultation rate and various factors (Pearson's correlation)

Factor	Correlation coefficient	<i>p</i> -value
AIR	-0.762	<0.001
Aging rate	-0.579	<0.001
Population gender ratio	0.256	0.083
University graduates	0.508	<0.001
Employed in primary industry	-0.694	<0.001
Average household spending	0.418	0.003
Income of prefectural residents	0.441	0.002
Elderly among household	0.056	0.710
Aged employees 75 years and over	-0.483	0.001
People certified for long-term care need	-0.363	0.012

Table 2 Results of multiple linear regression analysis

Factor	B	95% CI	β	P-value	VIF
AIR	-1644.790	-2508.250 -781.330	-0.791	<0.001	4.878
Aging rate	-2.168	-9.976 5.640	-0.147	0.577	7.931
University graduates	-396.687	-6160.992 5367.619	-0.018	0.890	1.957
Employed in primary industry	-3.455	-10.269 3.358	-0.245	0.311	6.620
Average household spending	2.355	-3.271 7.981	0.123	0.402	2.448
Income of prefectural residents	0.000	-0.024 0.024	0.004	0.978	2.017
Aged employees 75 years and over	3057.232	-1451.195 7565.660	0.239	0.178	3.522
People certified for long-term care need	1600.087	-364.701 3564.875	0.315	0.107	4.223

B : Partial regression coefficient, CI : Confidence interval, β : Standard regression coefficient, VIF : Variance inflation factor.

75 of age is summarized in Table 1. There was no correlation between gender and dental use or between the elderly and dental use. To eliminate confounding, multiple regression analysis was carried out that included all the associated parameters. As shown in Table 2, AIR ($p < 0.001$) was the sole significant explanatory variable for dental use among individuals over 75 years of age. The adjusted R^2 was 0.60, and the variance inflation factor was 4.88. In addition, AIR correlates with dental expenditure per capita among the elderly ($r = -0.703$, $p < 0.001$).

DISCUSSION

This study reveals the transition of dental service distribution from 2010 to the present in Japan. The population ratio of people with difficulty in accessing dental care, defined as those living more than 1,000 meter from a dental clinic was determined using GIS software. Approximately 86.5% of Japan's population is living within that radius at present. Our method of evaluating the distribution of the population accessible to dental services conformed with that of other studies.²¹⁻²³ However, caution in interpreting results is needed, as the mode of transportation going to a dental clinic varies in each country.^{4, 24}

We found that the values of AI and AIR in 2015 were smaller than those in 2010 and 2020. However, there were large variations in AI and AIR among prefectures. The maldistribution of dental services in cities versus rural areas was not inconsistent with that in other countries.^{3, 25} The AI and AIR indexes depended on the population and number of dental clinics in each prefecture. However, the number of dental clinics we found from digital national land information did not completely conform with the actual number based on the survey of medical institutions. However, the uneven distribution of dental services is a major issue among districts in Japan. It is crucial to define a useful indicator of dental care accessibility.

The results in this study revealed that there was no specific correlation of AI or AIR with dental use in the total population. However, focusing on the

population over 75 years of age, a significant difference was observed between dental use and AIR. Other than access to dental clinics, major contributory factors affecting the utilization of health care services included education, income and type of employment, which vary with the individual.²⁶ However, with multiple regression analysis significant correlation was found between AIR and dental use among individuals over 75 years old after adjusting for factors that are likely to affect access. The results of this study indicate that distance from a dental clinic is an obstacle for patients. Zainab *et al.* reported that elderly depend more on public transportation than the younger population.²⁴ Though dental use was associated with the AIR among individuals over 75 years of age, how this relates to the prevalence of dental diseases was unclear. Therefore, detailed analysis of dental diseases and accessibility to dental services will be needed, especially as it applies to the elderly.

It should be noted that this is the first study on calculating dental accessibility in each prefecture in Japan using GIS. We suggest that dental accessibility is a relevant indicator for dental use among the elderly. However, the following issues remain. The data for dental clinics were only for private practices, and data concerning transportation was not obtained. AI was calculated using only the distance from clinic to the residence. Also, no data was obtained concerning the number of dentists and staff, the hours of treatment, or the availability of home care. Analysis using these factors should be done as this might modify AI or AIR.

This GIS methodology could help policymakers follow communities over time to show how the patterns of dental service distribution change. To establish a comprehensive regional care system in the aged society, this study could be a guide for distributing dental clinics to provide equal access to all Japanese, especially the elderly.

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The authors declare no conflicts of interest associated with this manuscript.

REFERENCES

- Survey of Physicians, Dentist and Pharmacists. <https://www.mhlw.go.jp/toukei/list/33-20c.html> : accessed on September 20, 2020.
- Susi L, Mascarenhas AK. Using a geographical information system to map the distribution of dentists in Ohio. *JADA* 2002 ; **133** : 636-642.
- Kruger E, Whyman R, Tennant M. High acuity GIS comparison of dentist and doctor surgery locations in Auckland, New Zealand. *Community Dent Health* 2013 ; **30** : 83-87.
- Stephan JW, Kruger E, Tennant M. Public and private dental services in NSW : A geographic information system analysis of access to care for 7 million Australians. *NSW Public Health Bulletin* 2014 ; **24** : 164-170.
- Hanibuchi T, Aida J, Nakade M, Hirai H, Kondo K. Geographical accessibility to dental care in the Japanese elderly. *Community Dent Health* 2011 ; **28** : 128-135.
- Schwarz E. Access to oral health care —An Australian perspective. *Community Dent Oral Epidemiol* 2006 ; **34** : 255-231.
- Emami E, Khiyani MF, Habra CP, Chassé V, Rompré PH. Mapping the Quebec dental workforce : Ranking rural oral health disparities. *Rural and Remote Health* 2016 ; **16** : 3630.
- Kruger E, Tennant M, George R. Application of geographic information systems to the analysis of private dental practices distribution in Western Australia. *Rural and Remote Health* 2011 ; **11** : 1736.
- Penchansky R, Thomas JW. The concept of access : Definition and relationship to consumer satisfaction. *Med Care* 1981 ; **19** : 127-140.
- Ide H, Doi S, Atarashi H, Fujita S, Koike S. The distance and chance of lifetime geographical movement of physicians in Japan : An analysis using the age-period-cohort model. *Human Resources for Health* 2018 ; **16** : 26.
- Pereira SM, Ambrosano GMB, Cortellazzi KL, Tagliaferro EPS, Vettorazzi CA, Ferraz SFB, Meneghim MC, Pereira AC. Geographic information systems (GIS) in assessing dental health. *Int J Environ Res Public Health* 2010 ; **7** : 2423-2436.
- Portal site of official statistics of Japan. National Census. <https://www.e-stat.go.jp/dbview?sid=0003411191> : accessed on September 22, 2020.
- National Land Information Division, National Spatial Planning and Regional Policy Bureau, MLIT of Japan. "Kokudo suchi jyoho download service". <https://nlftp.mlit.go.jp/ksj/index.html> : accessed on September 22, 2020.
- Patient Survey. https://www.mhlw.go.jp/toukei/list/10-20-kekka_gaiyou.html : accessed on September 22, 2020.
- Portal site of official statistics of Japan. Report on medical care business for the elderly. <https://www.e-stat.go.jp/stat-search/files?page=1&toukei=00450390&tstat=000001044948> : accessed on September 24, 2020.
- National Institute of Population and Social Security Research. "Nihon no chiikibetsu syorai suikei jinko". <http://www.ipss.go.jp/index.asp> : accessed on August 24, 2020.
- Vital statistics. <https://www.mhlw.go.jp/toukei/list/81-1a.html> : accessed on October 2, 2020.
- Portal site of official statistics of Japan. "Tokei de miru nihon" <https://www.e-stat.go.jp/regional-statistics/ssdsview/prefectures> : accessed on October 2, 2020.
- Comprehensive Survey of Living Conditions. <https://www.mhlw.go.jp/toukei/list/20-21kekka.html> : accessed on October 2 2020.
- Report on the long-term care insurance. <https://www.mhlw.go.jp/topics/0103/tp0329-1.html> : accessed on October 5, 2020.
- Kohli S, Sahlén K, Sivertum Å, Löfman O, Trell E, Wigertz O. Distance from the primary health center : A GIS method to study geographical access to health care. *J Med Systems* 1995 ; **19** : 425-436.
- Tennant M, Kruger E. A national audit of Australian dental practice distribution : Do all Australians get a fair deal? *Int Dent J* 2013 ; **63** : 177-182.
- Yuen A, Rocha CM, Kruger E, Tennant M. The equity of access to primary dental care in São Paulo, Brazil : A geospatial analysis. *Int Dent J* 2018 ; **68** : 171-175.
- Zainab UI, Kruger E, Tennant M. Major metropolis rail system access to dental care for the retired and elderly : A high-resolution geographic study of Sydney, Australia. *Gero-dontology* 2015 ; **32** : 302-308.
- Thanakanjanaphakdee W, Laohasiriwong W, Puttanapong N. Spatial distribution of dentists in Thailand. *J Int Oral Health* 2019 ; **11** : 340-346.
- Leake JL, Birch S. Public policy and the market for dental services. *Community Dent Oral Epidemiol* 2008 ; **36** : 287-295.