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Geographical accessibility to dental care in the Japanese elderly

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Objective: The current research aims to clarify the factors relevant to elderly people's access to dental care in Japan, particularly focusing on geographical accessibility. ***Methods:*** The sample was taken from among the Japanese elderly, aged 65 and over, who responded to a postal survey conducted in 2003 (n = 2,192). Six types of geographical accessibility to the dental clinics were calculated using Geographic Information Systems. Logistic regression analysis was conducted using 'having a regular dentist' as a dependent variable and geographical accessibility as an explanatory variable. ***Results:*** The results showed an association between having a regular dentist and geographical accessibility only for females. In the univariate model, distance to the closest dental clinics (OR=0.62 (95%CI: 0.43-0.90)), number of dental clinics at the school district level (OR=1.14 (95%CI: 1.03-1.26)), number of dental clinics at the municipality level (OR=1.02 (95%CI: 1.00-1.05)), and density distribution of dental clinics (OR=1.56 (95%CI: 1.11-2.19)) showed significant relations with having a regular dentist. After controlling for demographic, socioeconomic, and health related variables, only the density distribution of dental clinics showed significant relations at the 5% level, although distance and number of dental clinics kept a marginal significance. ***Conclusion:*** The current study verifies that geographical accessibility correlates with access to dental care among women, and that there were large gender differences concerning the issue of geographical access.

Key words: Access to care, geographical accessibility, GIS, Japan, oral health.

Introduction

Within the realm of dental care, access/barrier to care is a particularly serious problem (Daly *et al*., 2002). Access to care may be restricted either due to low income or not being medically insured and, especially in recent years, it has been receiving attention in terms of socioeconomic inequalities in oral health. For example, Wamala *et al*. (2006) analyzed a sample of approximately 40,000 people aged 21-84 in Sweden and found that low socioeconomic status (SES) and poor access to dental care were linked to poor oral health, and that access to dental care may have a stronger intervening capacity in the SES-oral health relation than individual lifestyle.

Geographical accessibility is another important factor that, in addition to SES and other demographic factors, must not be overlooked. Previous research has shown regional disparity in dental consultation behavior, as well as in oral health status. In particular, differences in dental consultation behavior between urban and rural areas have often been reported (Wu, 2007; Adams *et al*., 2004; Abelsen, 2008). However, these studies used only the broad categories of 'urban areas' and 'rural areas' when examining accessibility, and did not directly analyze differences in geographical accessibility to dental care for individuals living in the same area. This type of indirect analysis does not clarify the degree to which geographical accessibility affects consultation behavior, and other confounding factors linked to urbanization cannot be ruled out.

In answer to this problem, a relatively new method of analysis has recently been developed for examining the provision of health care services. Geographic Information Systems (GIS) enables a more detailed spatial analysis, and has been recommended for use in analyzing access to health care (Parker and Campbell, 1998). In this analysis an uneven geographical distribution is often assigned after examining the dentist-to-population ratio (Susi and Mascarenhas, 2002; Mertz and Grumbach, 2001; Krause *et al*., 2005). Horner and Mascarenhas (2007) used spatial analysis to calculate the number of new dental clinics that would be required to assist currently uncovered areas. However, these studies focus mainly on the supply side and do not investigate how uneven geographical distribution of dental clinics relates to actual dental consultation behavior. While a few previous studies have made plots of the spatial relation between dental clinics and patients on the GIS (Borrell *et al*., 2006; Higgs and Richards, 2002; White *et al*., 2000), no research has been done thus far in clarifying the degree to which geographical accessibility or other confounding factors may act as a barrier to dental care access.

The current research attempts to bridge the gap between the epidemiology and geography in research on access to dental care, using Japan as a case study. Its aim was to reveal the relation between geographical accessibility to dental clinics and the dental consultation behavior of the elderly, using GIS to make a spatial analysis of detailed geographical information contained in

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the individual data. To date, there has been no study in Japan that has examined access to dental care, considering both the socioeconomic status and detailed geographical accessibility simultaneously.

Method

Analysis was based on the Aichi Gerontological Evaluation Study (AGES) Project data. The AGES Project is an on-going prospective cohort study that aims to investigate factors related to the loss of healthy years, such as functional decline or cognitive impairment, among non-institutionalized elderly aged 65 years or older. In 2003, a large-scale mail survey was conducted of a random sample of functionally independent, community-dwelling elderly (i.e., who were not eligible for public long term nursing care), in 15 municipalities from three prefectures. The overall response rate was 55.2% and 32,891 elderly completed the survey. A detailed description of the AGES data has been reported in Murata *et al*. (2008). The study protocol and informed consent procedure were approved by the Ethics Committee in Research of Human Subjects at Nihon Fukushi University.

The current research analyzed a small sample of respondents from a larger data set which included residential address data (eight municipalities, n = 10,878). The sample consisted of respondents who submitted completed dental information surveys (one of three types of survey administered) and who answered all questions concerning the variables used in the analysis (n=2,192). The eight municipalities that were investigated were located in the Chita Peninsula region of Aichi prefecture (Figure 1). The Chita Peninsula region is adjacent to Nagoya, the third largest metropolitan city in Japan, and the study examined a wide variety of areas stretching from the outskirts of the city to the fishing villages on the tip of the peninsula.

As an indicator of access to dental care, 'having a regular dentist' was used as the dependent variable. This was elicited by asking "Do you have a regular dentist?" with answers dichotomized into 'yes' (1) or 'no' (0). In general, the term 'regular dentist' means the dentist whom the respondent sees regularly, and is considered to play both treatment and prevention roles in Japan. Having a regular dentist can be considered an estimate of regular dental attendance, although the actual frequency of attendance is not known. In the data sample, 1,886 respondents (86.0%) had a regular dentist and 306 (14.0%) did not (Table 1).

There are many methods for calculating geographical accessibility (Talen and Anselin, 1998). As the most basic geographical accessibility measurement, linear distance from each respondent to the closest dental clinics was calculated using GIS (ArcView9.1). The 'CSV address matching service' (provided by the Center for Spatial Information Science, The University of Tokyo) was used to convert the residential address information of the respondents and the dental clinics into latitude and longitude data. Addresses of the 259 dental clinics in the Chita Peninsula region were collected from i-Townpage, an online phone number database (accessed on 2007.4.25, URL: http://itp.ne.jp/), which provides comprehensive coverage of the dental clinics in the study area. Many dental clinics were located in the northern part of Chita Peninsula region near the city and on the coast along major roads where accessibility can be considered as high.

In addition, five other measurements of accessibility were calculated to give an adequate reflection of the various dimensions of geographical accessibility (Table 2, Figure 1); number of dental clinics (school district level), dental clinics per 100,000 people (school district level), number of dental clinics (municipality level), dental clinics per 100,000 people (municipality level) and density distribution of dental clinics.

The number of dental clinics within the school district and municipality was calculated as an indicator of the amount of choice, considering that residents do not always go to the closest clinic. Dentist-to-population ratio is one of the most frequently used measures that indicate balance between supply and demand in each area. The current study calculated the number of dental clinics per 100,000 people, at the school district and municipality level. Moreover, the density distribution of dental clinics was calculated with the kernel method (de Smith *et al*. 2007), by using the Spatial Analyst option of ArcView, considering both spatial distance and amount of choice. This is an estimate of accessibility that considers the distance decay effect, which states that a greater distance to facilities increases the difficulty in their utilization. The bandwidth of the weighted function was set at 2,000m.

The current analysis included a sample from only eight of the 10 municipalities in the Chita Peninsula region. However, the residents of those municipalities might also visit the dental clinics in the remaining two municipalities. Therefore, linear distance to the closest dental clinics and density distribution of dental clinics were calculated using data on dental clinics in all of the 10 municipalities.

Age (65-69, 70-74, 75-79, 80-84, 85+) and marital status (married, separated/divorced, never married) were included as demographic attributes. Next, equivalent income (less than 1.00 million yen, 1.00-1.99 million yen, 2.00-2.99 million yen, 3.00-3.99 million yen, 4.00 million yen and above) was used as an indicator of SES. In addition, people with psychological distress have been noted to show a tendency for avoiding dental checkups (Thorpe *et al*., 2006). Therefore, the short version of the Geriatric Depression Scale (GDS-15) (0-9 points: good, 10 points or more: poor) was included as an indicator of the mental health of elderly respondents. Furthermore, Daly *et al*. (2002) suggest that physical disability may be a structural barrier to receiving dental care. Therefore, instrumental activities of daily living (IADL) (5 points: good, 4 points or less: poor), which is a part of the Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC) (Koyano *et al*., 1991), was used as an indicator of physical disability, while frequency of going out (once a week or more, almost never) was used to determine whether or not respondents were housebound. Finally, the number of remaining teeth was used for controlling the state of the respondents' teeth. The respondents were asked this in regard to their natural teeth, and they selected from five categories: having 20 or more teeth, having 19 or less teeth with some dentures, having 19 or less teeth without any dentures, having very few teeth with some dentures, or having very few teeth

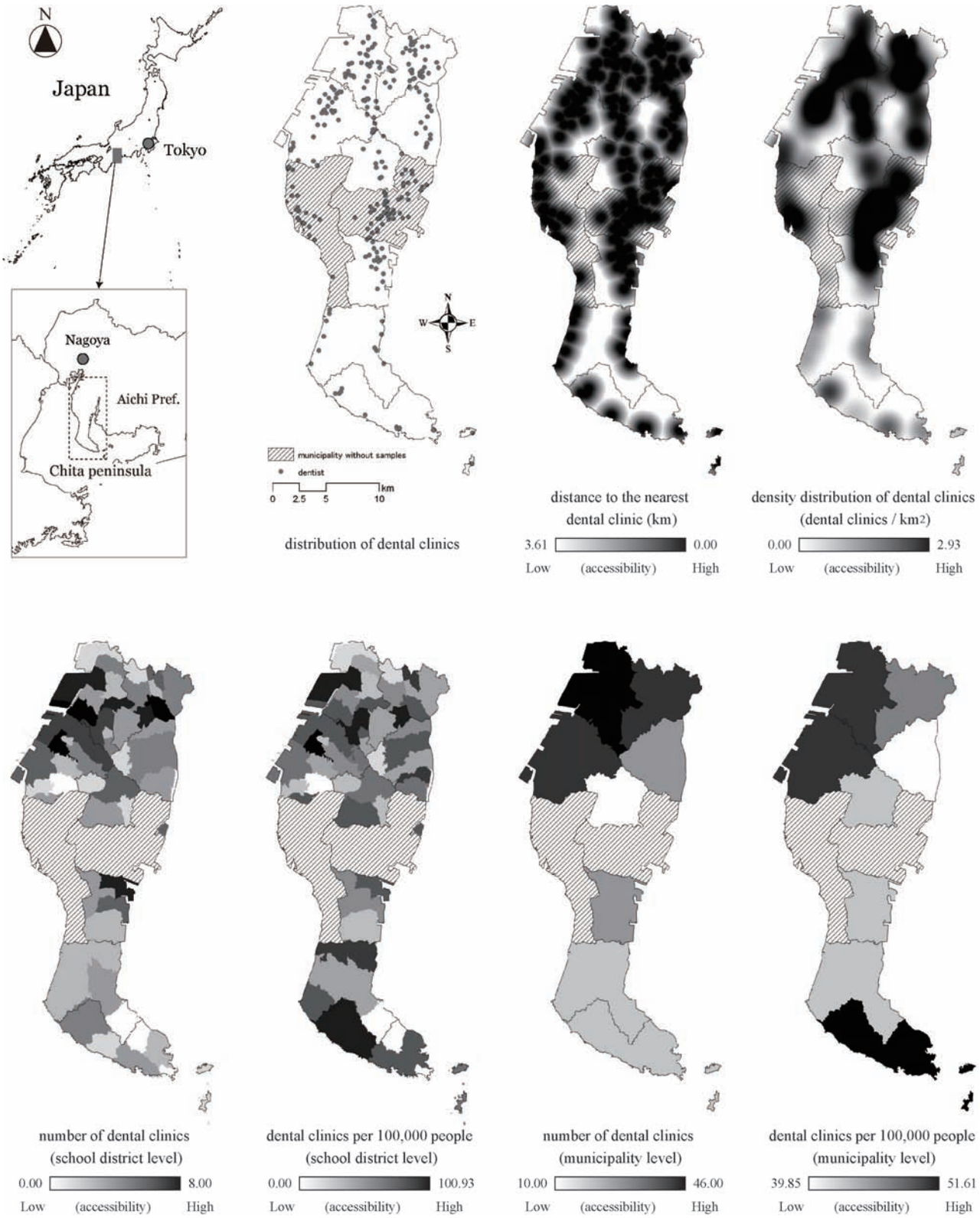

Figure 1. *Maps showing the study area, distribution of dental clinics, and geographical accessibility*

without any dentures. We used a dichotomized variable of the remaining teeth (20 or more, 19 or less) for the analysis. The basic characteristics of the variables are shown in Table 1.

Logistic regression analysis was performed using 'having a regular dentist' as a dependent variable, geographical accessibility as an explanatory variable and age, marital status, equivalent income, IADL, GDS, frequency of going out, and number of remaining teeth as controlled variables. In model 1, only geographical accessibility was included. Model 2 added demographic and socioeconomic status to model 1. Finally, all the variables were included in model 3. The analysis was performed on each of the six measurements of geographical accessibility, with the samples being separated by gender. SPSS 12.0J for Windows was used for analysis.

Table 1. Basic characteristics of respondents

	Male (n=1,205)		*Female (n=987)*	
	n	*%*	*n*	*%*
Having a regular dentist				
No	182	15.1	124	12.6
Yes	1023	84.9	863	87.4
Age				
65-69	487	40.4	391	39.6
70-74	374	31.0	276	28.0
75-79	241	20.0	193	19.6
80-84	75	6.2	74	7.5
>=85	28	2.3	53	5.4
Marital status				
Married	1089	90.4	623	63.1
Separated/divorced	107	8.9	351	35.6
Never married	9	0.7	13	1.3
Equivalent income				
< 1.00 million yen	108	9.0	158	16.0
1.00-1.99 million yen	324	26.9	263	26.6
2.00-2.99 million yen	384	31.9	256	25.9
3.00-3.99 million yen	249	20.7	179	18.1
>= 4.00 million yen	140	11.6	131	13.3
GDS				
Good	1120	92.9	923	93.5
Poor	85	7.1	64	6.5
IADL				
Good	939	77.9	838	84.9
Poor	266	22.1	149	15.1
Going out				
Once a week or more	1156	95.9	955	96.8
Almost never	49	4.1	32	3.2
Remaining teeth				
>=20	421	34.9	322	32.6
<=19	784	65.1	665	67.4

Table 2. Basic statistics of the geographical accessibility measures

	n	*mean*	*standard deviation*	*range*
Distance to the closest dental clinic (km)	2192	0.53	0.45	0.00 - 3.61
Number of dental clinics (school district level)	2192	3.49	1.97	0.00 - 8.00
Dental clinics per 100,000 people (school district level)	2192	45.14	17.61	0.00 - 100.93
Number of dental clinics (municipality level)	2192	17.97	10.77	10.00 - 46.00
Dental clinics per 100,000 people (municipality level)	2192	44.38	3.67	39.85 - 51.61
Density distribution of dental clinics (dental clinics / km^2)	2192	0.88	0.62	0.00 - 2.93

Results

Table 3 shows the results of logistic regression analysis, using linear distance to the closest dental clinics as an indicator of geographical accessibility. Looking only at female participants showed a significant relation between distance and having a regular dentist. Odds ratios were estimated 0.62 (95%CI: 0.43-0.90) in Model 1, 0.63 (95%CI: 0.43-0.92) in Model 2, and 0.69 (95%CI: 0.46-1.03) in Model 3. This suggests that female elderly who do not have a dental clinic nearby are less likely to visit dental clinics regularly. On the other hand, when looking at comparisons with having a regular dentist for only male participants, almost no significant relations were seen in regard to the distance to the closest dental clinics.

Unlike geographical accessibility, male respondents showed much stronger associations concerning equivalent income. Using the ‘less than 1.00 million yen’ category as a reference for equivalent income, higher categories showed odds ratios of around 2.5. This indicates that there

Table 3. Odds ratios (95% confidence intervals) for having a regular dentist (Yes=1) estimated by logistic regression models

Male (n=1,205)	Model 1			Model 2			Model 3		
	OR	95%CI		OR	95%CI		OR	95%CI	
		lower	upper		lower	upper		lower	upper
Distance to the closest dental clinic	0.97	0.69	1.37	1.03	0.72	1.47	1.01	0.71	1.44
Age (65-69)									
70-74				0.99	0.68	1.46	0.96	0.65	1.41
75-79				1.07	0.69	1.68	1.02	0.65	1.62
80-84				*0.59*	*0.32*	*1.08*	*0.56*	*0.30*	*1.05*
>=85				1.41	0.41	4.87	1.34	0.38	4.68
Marital status (married)									
separated/divorced				0.81	0.47	1.39	0.81	0.47	1.39
never married				0.76	0.15	3.87	0.85	0.17	4.38
Equivalent income (< 1.00 million yen)									
1.00-1.99 million yen				**2.50**	**1.47**	**4.25**	**2.51**	**1.48**	**4.28**
2.00-2.99 million yen				**2.26**	**1.36**	**3.76**	**2.30**	**1.38**	**3.85**
3.00-3.99 million yen				**2.65**	**1.51**	**4.66**	**2.69**	**1.52**	**4.75**
>= 4.00 million yen				**2.62**	**1.36**	**5.05**	**2.64**	**1.36**	**5.11**
GDS (good)									
Poor							0.95	0.51	1.75
IADL (good)									
Poor							1.28	0.85	1.94
Going out (once a week or more)									
Almost never							0.58	0.28	1.20
Remaining teeth (>=20)									
<=19							1.12	0.79	1.59

Female (n=987)	Model 1			Model 2			Model 3		
	OR	95%CI		OR	95%CI		OR	95%CI	
		lower	upper		lower	upper		lower	upper
Distance to the closest dental clinic	**0.62**	**0.43**	**0.90**	**0.63**	**0.43**	**0.92**	*0.69*	*0.46*	*1.03*
age (65-69)									
70-74				0.68	0.40	1.15	0.75	0.44	1.27
75-79				*0.59*	*0.34*	*1.03*	0.69	0.39	1.25
80-84				*0.50*	*0.23*	*1.08*	0.73	0.32	1.67
>=85				**0.11**	**0.05**	**0.24**	**0.19**	**0.08**	**0.45**
Marital status (married)									
Separated/divorced				0.96	0.61	1.51	0.95	0.60	1.51
Never married				0.43	0.11	1.68	0.40	0.10	1.58
Equivalent income (< 1.00 million yen)									
1.00-1.99 million yen				1.28	0.70	2.36	1.14	0.61	2.11
2.00-2.99 million yen				0.90	0.50	1.62	0.75	0.41	1.37
3.00-3.99 million yen				1.27	0.65	2.48	1.20	0.60	2.40
>= 4.00 million yen				1.44	0.69	3.01	1.36	0.64	2.92
GDS (good)									
Poor							**0.41**	**0.22**	**0.78**
IADL (good)									
Poor							**0.57**	**0.33**	**0.97**
Going out (once a week or more)									
Almost never							**0.39**	**0.17**	**0.91**
Remaining teeth (>=20)									
<=19							0.92	0.57	1.48

bold: p < .01, **bold:** p < .05, *italic*: p < .10

Table 4. Comparison of the six geographical accessibility measures for having a regular dentist

Male (n=1,205)	Model 1			Model 2			Model 3		
	OR	95%CI		OR	95%CI		OR	95%CI	
		lower	upper		lower	upper		lower	upper
Distance to the closest dental clinic	0.97	0.69	1.37	1.03	0.72	1.47	1.01	0.71	1.44
Number of dental clinics (school district)	0.97	0.89	1.05	0.95	0.87	1.03	0.95	0.87	1.03
Dental clinics per 100,000 people (school district)	1.00	0.99	1.00	1.00	0.99	1.00	1.00	0.99	1.00
Number of dental clinics (municipality)	1.01	0.99	1.03	1.01	0.99	1.03	1.01	0.99	1.03
Dental clinics per 100,000 people (municipality)	1.02	0.97	1.06	1.04	0.99	1.09	1.04	0.99	1.09
Density distribution of dental clinics	0.97	0.76	1.24	0.92	0.72	1.18	0.92	0.72	1.19
Female (n=987)	Model 1			Model 2			Model 3		
	OR	95%CI		OR	95%CI		OR	95%CI	
		lower	upper		lower	upper		lower	upper
Distance to the closest dental clinic	**0.62**	**0.43**	**0.90**	**0.63**	**0.43**	**0.92**	*0.69*	*0.46*	*1.03*
Number of dental clinics (school district)	**1.14**	**1.03**	**1.26**	*1.11*	*1.00*	*1.24*	*1.11*	*1.00*	*1.23*
Dental clinics per 100,000 people (school district)	1.00	0.99	1.01	1.00	0.99	1.01	1.00	0.99	1.01
Number of dental clinics (municipality)	**1.02**	**1.00**	**1.05**	*1.02*	*1.00*	*1.04*	*1.02*	*1.00*	*1.04*
Dental clinics per 100,000 people (municipality)	0.99	0.94	1.04	0.99	0.94	1.04	0.99	0.94	1.04
Density distribution of dental clinics	**1.56**	**1.11**	**2.19**	**1.48**	**1.05**	**2.09**	**1.42**	**1.00**	**2.01**

bold: $p < .01$, **bold**: $p < .05$, *italic*: $p < .10$

is a tendency for respondents with low equivalent income to not visit dental clinics regularly. Female respondents showed no significant association between equivalent income and having a regular dentist.

Some of the other variables showed associations with having a regular dentist. Analysis of only female respondents showed a tendency for older respondents to not have a regular dentist. In Model 2, comparisons against the '65-69' category of age group with '70-74' (OR=0.68 (95%CI: 0.40-1.15)), '75-79' (OR=0.59 (95%CI: 0.34-1.03)) '80-84' (OR=0.50 (95%CI: 0.23-1.08)) '85+' (OR=0.11 (95%CI: 0.05-0.24)) categories all resulted in odds ratios smaller than one. In Model 3, however, only the oldest category showed a significant relation. Additionally, those with poor GDS scores, those with poor IADL scores and those who almost never went out, showed significant associations with having a regular dentist, and odds ratios of less than one. In comparison, analysis of only male respondents showed that respondents in the 80-84 year old group were less likely to have a regular dentist, with no significant relations to the other variables.

Table 4 shows the odds ratios and 95% CI of the all measurements of geographical accessibility. Looking at four of the six measurements of geographical accessibility showed that the greater the accessibility was for female participants, the more likely they were to have a regular dentist. In model 1, with the exception of distance, the number of the dental clinics at the school district level (OR=1.14 (95%CI: 1.03-1.26)), and the number of dental clinics at the municipality level (OR=1.02 (95%CI: 1.00-1.05)), density distribution of dental clinics (OR=1.56 (95%CI: 1.11-2.19)) showed significant relations with having a regular dentist. After controlling for demographic, socioeconomic, and health related variables, only the density distribution of dental clinics showed a significant relation at the 5% level, although distance, number of dental clinics at the school district level, and number of dental clinics at the municipality level had marginally significant associations. This trend was not seen with male participants. Even for female respondents, dental clinics per 100,000 people both at the school district and the municipality level showed no significant relations.

Discussion

An epidemiological survey shows that inequalities in health are recently becoming apparent in Japan (Kondo, 2007). It is possible that access to health care is mediating these inequalities, and therefore this is an important problem from the viewpoint of equality in medical treatment. The entire population of Japan is insured for dental care and equality is supposed to be guaranteed in this system. In addition, amidst a shortage of physicians, dentists are an exception and the excess of dentists is becoming a significant problem (Takahashi *et al*., 2007). For example, according to the OECD Health Data of 2008, as of 2006, there were 2.1 practicing physicians for every thousand people in Japan, putting the country in 20th place out of 24 countries from which data was collected. In contrast, there were 0.7 practicing dentists putting Japan in 7th place for

number of dentists. However, the current analysis shows that geographical and socioeconomic differences in access to dental care also exist in Japan.

The question derived from this study is the issue of gender differences in health care access. The results of this study showed an association between having a regular dentist and geographical accessibility for females only, even after controlling for individual socioeconomic status or health status. Furthermore, among female respondents, in addition to geographical accessibility, associations were found with age, GDS, IADL scores, and frequency of going out, all of which may be considered be strongly linked with their mobility capability.

One possible explanation for this gender difference may be in regard to the means of transportation, especially whether or not the elderly can drive themselves. According to Tanaka (2001), it is less possible for elderly women in Japan to use private cars compared to elderly men, and living conveniences decrease with greater distances. The current study looked at areas, from the suburbs of large cities to rural zones, where cars are the main method of transportation. There are large gender differences in the percentages of people with driving licenses among the elderly in Japan, as shown by calculations based on the statistics of the Ministry of Internal Affairs and Communications and the National Police Agency. Of those aged 65-74, 82% of men and only 32.6% of women have driving licenses, and of those aged 75 and above, 50.5% of men and only 5.3% of women have driving licenses (as of 2007). Consequently, the main method of transportation for some elderly women is as a passenger in a car driven by their spouse, or other family members. It is true that the distance to the closest dental clinic is 0.53 km in mean, and 3.61 km at the maximum, not very far away, but the distance may be a significant problem for regular dental clinic attendance, especially for those who cannot drive a car and cannot receive any transportation support from their family or friends.

Conversely, while men with higher incomes were more likely to have a regular dentist, geographical accessibility showed almost no relevance for men, suggesting that, as long as men can drive their own cars, the location of dental clinics does not pose a significant barrier. Furthermore, it is likely that many men live far from their workplace, and it may still be possible for them to continue to visit a dental clinic near their workplace, even after retirement. These may be contributing factors as to why geographical accessibility is not relevant for elderly men in Japan. In other words, geographical accessibility may only pose a significant problem for those without means of transportation or with poor mobility capability.

According to the data from Japan's Ministry of Health, Labour and Welfare, the per capita medical cost for dental care, among people aged 65 or over, was 29,400 yen a year, as of 2006. Japan has a universal health insurance system including dentistry, and those receiving medical services have to pay only a part of the medical cost: basically 10% for elderly aged 70 or over, 30% for people aged less than 70 years (more specifically, depending on their income and the year). Although this is not expensive in general, the result from male respondents indicates that this might be a barrier to have a regular dentist, especially for the low-income population.

Among the six indicators of geographical accessibility, density distribution of dental clinics showed the clearest relation. However, distance to the closest dental clinics and the number of dental clinics (school district level / municipality level) also showed significant associations at the 10% level in Model 3, suggesting that both distance and selectivity may be important. Conversely, there was no significant relation with dental clinics per 100,000 people; the measurement that is most commonly used to show geographical balance between supply and demand. This may indicate that such a measurement is inadequate in the case of Japan where the dental clinics are in excess and are widely distributed.

Some problems remain which need to be addressed. Although the current study used the question of having a regular dentist as an indicator of regular dental attendance, this is self-reported behavior and does not necessarily reflect an actual behavior. The actual number of dental visits and number of treatments therefore, need to be investigated as dependent variables. In regard to access to dental care, it is also valuable to ask about the importance of the distance to the closest dental clinic, and about the amount they paid for their dental care.

We pointed out the importance of the means of transportation as one of the reasons for the gender difference in the geographical access to dental care. This needs more detailed analysis, while taking actual accessible transportation methods into account. Network distance also needs to be analyzed as measures of geographical accessibility, in order to make its assessment more realistic.

The relatively low response rate (55.2%) was also a limitation of the current study, and this might cause a selection bias. However, Reijneveld and Stronks (1999) examined the impact of response bias, and revealed that the dental care utilization of survey respondents was significantly higher than that of non-respondents. Therefore the respondents of our survey might have higher dental attendance than non-respondents, and in fact, this could have contributed to reducing the statistical power. In addition, the current study focuses only on a limited region of Japan. Further research may be necessary to assess the geographical accessibility, focusing on the centers of major metropolitan areas or very sparsely-populated areas, with consideration given to the improvement of the response rate.

Our study examined the association between distance or income and dental care utilization. However, there are a number of approaches and models that explain the utilization of dental services: psychosocial, interaction, economic, and sociological approaches (Petersen and Holst, 1995). For example, Petersen (1990) proposed a sociological model for explaining dental visits, which stresses the primary effect of material and structural factors and a secondary importance for normative factors. The variables we used are only part of a whole picture, and other psychosocial or sociological factors that may also affect dental care utilization should be considering in any future study.

Conclusion

The current research aimed to clarify the factors relevant to the access of the elderly to dental care in Japan, particularly focusing on geographical accessibility. The results are consistent with previous research, showing the differences in consultation behavior between urban and rural areas (Wu, 2007; Adams *et al*., 2004; Abelsen, 2008). However, as the analyses of these studies were done on the regional level of 'urban area' versus 'rural area', the effects of other confounding factors (such as cultural barriers concerning dentists) cannot be dismissed. By calculating the accessibility of individual samples using stricter standards, the current study verifies that geographical accessibility correlates with access to dental care among women, and that there were large gender differences in the issue of geographical access. In addition to socioeconomic differences, it may also be necessary to focus on geographical differences in oral health.

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References

Adams, C., Slack-Smith, L., Larson, A., O'Grady, M. (2004): Dental visits in older Western Australians: a comparison of urban, rural and remote residents. *Australian Journal of Rural Health* **12**, 143-149.

Abelsen, B. (2008): What a difference a place makes: dental attendance and self-rated oral health among adults in three counties in Norway. *Health & Place* **14**, 829-840.

Borrell, LN., Northridge, ME., Miller, DB., Golembeski, CA., Spielman, SE., Sclar, ED., Lamster, IB. (2006): Oral health and health care for older adults: a spatial approach for addressing disparities and planning services. *Special Care In Dentistry* **26**, 252-256.

Daly, B., Watt, R., Paul, B., Treasure, E. (2002): *Essential Dental Public Health* 1st ed. p378. New York: Oxford University Press.

de Smith, M. J., Goodchild, M. F., Longley, P. A. (2007): *Geospatial analysis : a comprehensive guide to principles, techniques and software tools*. p394. Leicester: Matador.

Higgs, G., Richards, W. (2002): The use of geographical information systems in examining variations in sociodemographic profiles of dental practice catchments: a case study of a Swansea practice. *Primary Dental Care* **9**, 63-69.

Horner, MW., Mascarenhas, AK. (2007): Analyzing location-based accessibility to dental services: an Ohio case study. *Journal of Public Health Dentistry* **67**, 113-118.

Kondo, K. ed. (2007): *Exploring "Inequalities in Health": a large-scale social epidemiological survey for care prevention in Japan*. p182. Tokyo: Igaku-Shoin Ltd. (in Japanese)

Koyano, W., Shibata, H., Nakazato, K., Haga, H., Suyama, Y. (1991): Measurement of competence: reliability and validity of the TMIG Index of Competence. *Archives of Gerontology and Geriatrics* **13**, 103–116.

Krause, D., Frate, DA., May, WL. (2005): Demographics and distribution of dentists in Mississippi: a dental work force study. *Journal of the American Dental Association* **136**, 668-677.

Mertz, EA., Grumbach, K. (2001): Identifying communities with low dentist supply in California. *Journal of Public Health Dentistry* **61**, 172-177.

Murata, C., Kondo, K., Hirai, H., Ichida, Y., Ojima, T. (2008) : Association between depression and socio-economic status among community-dwelling elderly in Japan: The Aichi Gerontological Evaluation Study (AGES). *Health & Place* **14**, 406–414.

Parker, EB., Campbell, JL. (1998): Measuring access to primary medical care: some examples of the use of geographical information systems. *Health & Place* **4**, 183-193.

Petersen, P. E. (1990): Social inequalities in dental health. Towards a theoretical explanation. *Community Dentistry and Oral Epidemiology* **18**, 153-158.

Petersen, P. E., Holst, D. (1995): Utilization of dental health services. In: *Disease Prevention and Oral Health Promotion: Socio-Dental Sciences in Action*; eds. Cohen, L. K., Gift, H. C. pp341-386. Copenhagen: Munksgaard.

Reijneveld, S. A., Stronks, K. (1999): The impact of response bias on estimates of health care utilization in a metropolitan area: the use of administrative data. *International Journal of Epidemiology* **28**, 1134–1140.

Susi, L., Mascarenhas, AK. (2002): Using a geographical information system to map the distribution of dentists in Ohio. *Journal of the American Dental Association* **133**, 636-642.

Talen, E., Anselin, L. (1998): Assessing spatial equity: an evaluation of measures of accessibility to public playgrounds. *Environment and Planning A* **30**, 595-613.

Takahashi, Y., Kazama, N., Yamamoto, A., Sato, M., Hasegawa, T., Okada, H. (2007): Dentistry: from celebrity hospitals to railway underpasses, one in five dentists are considered working poor. *Weekly Toyo Keizai* **6078**, 54-57. (in Japanese)

Tanaka, K. (2001): An evaluation of living convenience based on accessibility by individual attributes: a case study in Iwaki city, Fukushima Prefecture. *Geographical Review of Japan* **74A**, 264-286. (in Japanese)

Thorpe, JM., Kalinowski, CT., Patterson, ME., Sleath, BL. (2006): Psychological distress as a barrier to preventive care in community-dwelling elderly in the United States. *Medical Care* **44**, 187-191.

White, DA., Anderson, RJ., Bradnock, G., Gray, MM., Jenkins, P. (2000): The use of a geographical information system in investigating dental services. *Community Dental Health* **17**, 79-84.

Wamala, S., Merlo, J., Boström, G. (2006): Inequity in access to dental care services explains current socioeconomic disparities in oral health: the Swedish National Surveys of Public Health 2004-2005. *Journal of Epidemiology and Community Health* **60**, 1027-1033.

Wu, B. (2007): Dental service utilization among urban and rural older adults in China: a brief communication. *Journal of Public Health Dentistry* **67**, 185-188.