of childbearing age living within 30 min of the nearest obstetrics facility. Each 1-km^2 mesh within a 30-min drive was colored brown, within a 30–60-min drive was red and further than a 60-min drive was orange. Non-residential areas and non-reported areas were colored gray. The color scheme was chosen with reference to the ColorBrewer system [27].

We used MarketPlanner GIS (version 3.3.3, PASCO, Tokyo, Japan) for geographic analyses except for the selection of obstetrics hospitals in Scenario 3. MarketPlanner GIS version 3.2.6 with road network data version 2013 was used to estimate access time. Its estimation is based on actual travel speed or predefined speed based on the classification of the road (10–80 km/h) according to the software's proprietary database.

In scenario 3, location-allocation analysis was undertaken to decide which hospitals should be retained using ArcGIS software (version 10.0, ESRI Japan, Tokyo, Japan). Location-allocation analysis is a tool in the ArcGIS Network Analyst extension that can determine the optimal locations for facilities to maximize coverage of the surrounding population [28] so that they can be allocated most efficiently [29].

Results

Status of obstetrics hospitals in Japan as of 2011

Of the 1075 study subject obstetrics hospitals, the 95 general PMCs and 279 regional PMCs had higher numbers of staff and deliveries than the 701 other hospitals. The regional and general PMCs also had a lower number of deliveries per obstetrician and a greater proportion of deliveries by cesarean section (Table 2). Distribution of hospital volume (number of delivery per hospitals per month) and staff level (obstetricians and midwives) of obstetrics hospitals were skewed to the right (Fig. 1). Graphical presentations of access status to current obstetrics hospitals (n = 1075, Fig. 2) and academic hospitals and PMCs (n = 405, Fig. 3) are shown. Of the 15–49 year-old female population, 95.0 % currently have access to an obstetrics hospital within a 30-min drive, with 82.7 % having access to an academic hospital or PMC.

Intensification of obstetrics hospitals and access to obstetrics hospitals

The effects of intensification on hospital volume and staff level were estimated at the target levels of 985, 788, 591 (representing a national estimate of 1000, 800 and 600 obstetrics hospitals). For each target level of intensification, the number of deliveries and staff levels of obstetricians and midwives per hospital were the same for each scenario after intensification, but the number of deliveries and the number of staff that would need to be absorbed by retained institutions were larger when intensification emphasized hospital volume (Table 3). With regard to population coverage and inequity among municipalities, if intensification occurred without considering the MSAs (Scenario 1), access would fall in an indirectly proportional relationship. However, when MSAs were taken into account, impaired access could be avoided until intensification to 591 obstetrics hospitals (55.0 % from the 2011 level, equivalent to a national estimate of 600). At this level of intensification, coverage was calculated to be 87.6 % for Scenario 1, compared with 90.5 % for Scenario 2 and 93.9 % for Scenario 3 (Fig. 4).

The Gini coefficient of 0.239 would rise to 0.473 when hospitals were intensified to PMCs and academic hospitals, indicating that the level of inequity would widen. Scenario 1 showed a directly proportional increase, but Scenarios 2 and 3 demonstrated a slower pace of increase in the Gini coefficient at intensification from the current level to academic hospitals and PMCs only, meaning that a greater extent of inequity can be avoided when MSAs and access are both taken into account (Fig. 5).

Table 2 Characteristics of institutions included in the study

	All hospitals providing obstetrics services (n = 1075)	Obstetrics hospital type			*P* value
		General perinatal medical centers (n = 95)	Regional perinatal medical centers (n = 279)	Other obstetrics hospitals (n = 701)	
Total hospital beds[a] (SD)	380.5 (252.2)	738.6 (276.9)	518.3 (212.8)	277.0 (183.4)	<0.001
Obstetricians, number (SD)	5.5 (4.6)	12.3 (6.9)	7.0 (4.7)	4.0 (2.7)	<0.001
Midwives, number (SD)	15.3 (11.8)	31.5 (15.4)	20.0 (12.0)	11.3 (7.9)	<0.001
Deliveries per month, number (SD)	44.1 (39.3)	75.7 (59.8)	50.5 (38.7)	37.3 (32.8)	<0.001
Cesarean sections per month, number (SD)	11.3 (11.0)	26.2 (18.2)	14.5 (10.8)	7.7 (6.4)	<0.001

Data are presented as the mean (standard deviation, SD)

[a] Total number of hospital beds including non-obstetrics beds

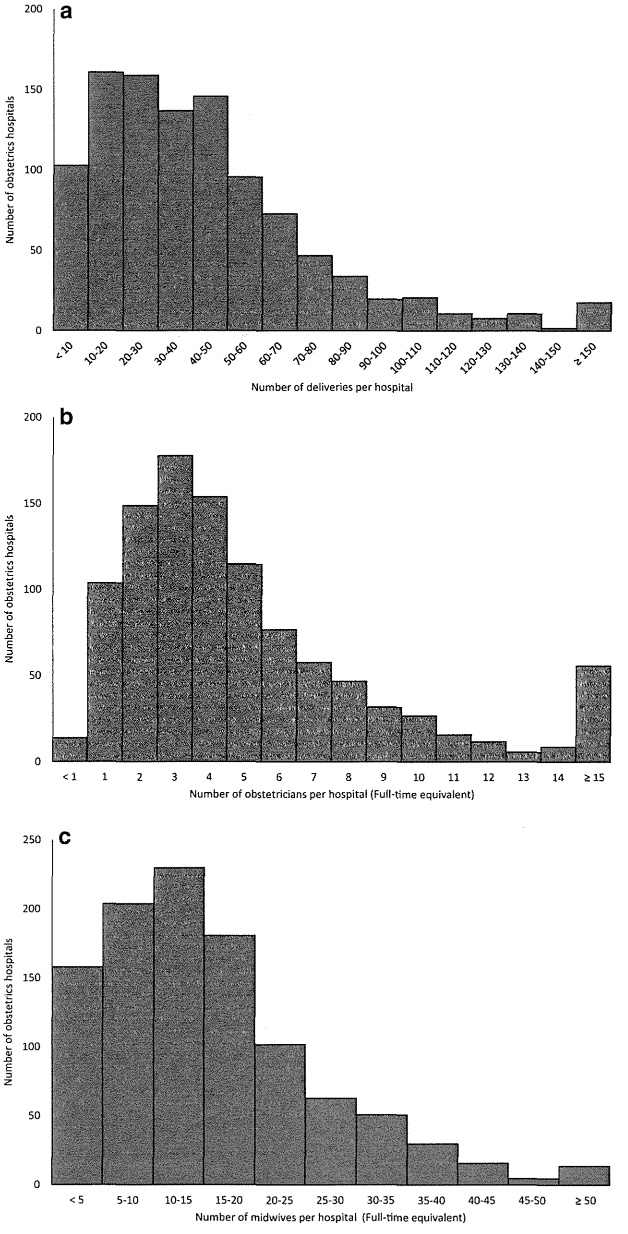

Fig. 1 Distribution of the number of deliveries and staff per obstetrics hospital. Frequency distribution of the number of deliveries (**a**), obstetricians (**b**) and midwives (**c**) staff per hospital per month as of September 1–20, 2011 is shown. Staff numbers per hospital are represented as full time equivalents

Discussion

Although there is a trade-off between intensification of facilities and access to hospitals, the negative effect of intensification could be alleviated to a certain extent by considering the distribution of obstetrics facilities rather than simply considering hospital volume. However, striking the right balance between hospital volume and access is critical. On one hand, intensification by hospital volume alone will bring more deliveries and more medical staff to the retained hospitals, which will likely improve the quality of obstetrics services and reduce staff workload. On the other hand, too much emphasis on hospital volume will likely impair service delivery, particularly in already underserved areas, as those obstetrics hospitals located in resource-scarce (predominantly rural) areas tend to be lower volume and their closure

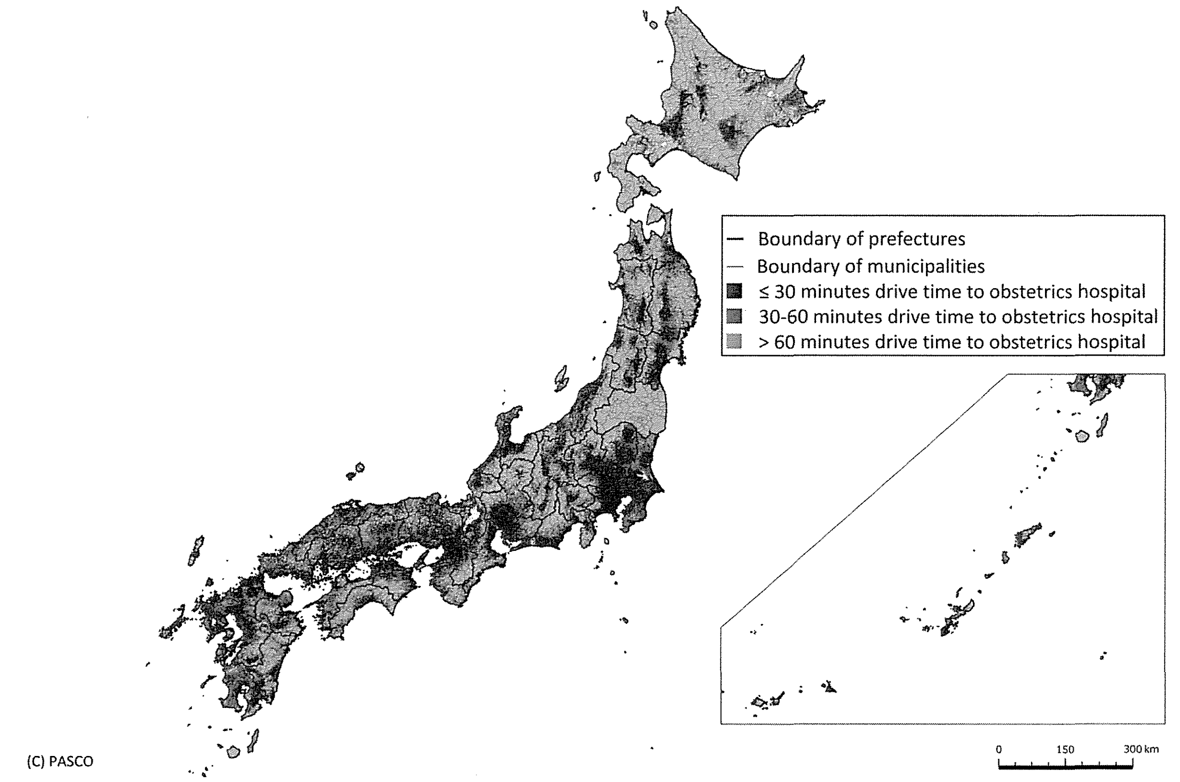

Fig. 2 Access to obstetrics hospitals. Access to the nearest obstetrics hospital as of 2011. In each 1-km^2 mesh, *brown* represents a driving time of ≤30 min, *red* a time of 30–60 min, *orange* a time of >60 min and *gray* represents non-residential and non-reported areas

creates a disproportionately greater impact on accessibility than closure of urban facilities. This is partly because when MSAs, designed to combine several municipalities into a self-contained service area, are taken into account in Scenario 2, we found that preservation of some low- and middle-volume rural hospitals maintains access while allowing intensification to almost half the current level.

Although this study was conducted in one country, our findings have global implications. Some studies have used GIS to simulate obstetrics facilities [30, 31], but their focus has been on access alone and not the influence of intensification of obstetrics facilities. Studies that have been undertaken in developing countries where obstetrics facilities may be scarce have mostly sought to identify means of increasing obstetrics coverage [32–35]. As the fertility rate declines in many more developed countries, the selection and concentration of obstetrics facilities will happen regardless of the number of obstetricians available to staff them. As the Japanese fertility rate is among the lowest in the world, our experience could provide a model for other more developed countries. Furthermore, as economic development matures, other less developed countries will ultimately face the same issues in the future. Our calculations of the numbers of deliveries and obstetrics staff that would need to be reallocated or redeployed according to each scenario, and modeling of different means of undertaking intensification, could inform public and political debate about the need for intensification of clinical services, which is a global issue. Healthcare policy makers, in Japan and other countries, must also consider means of incentivizing obstetricians to work in rural obstetrics facilities, to improve communication between hospitals, clinics and midwife-led services, and create healthcare management organizations that ensure optimal obstetrics care, considering not only the clinical services provided but also their accessibility.

Our study has several limitations. First, we employed driving time to define an outcome measure. This was estimated by GIS software, which does not take the

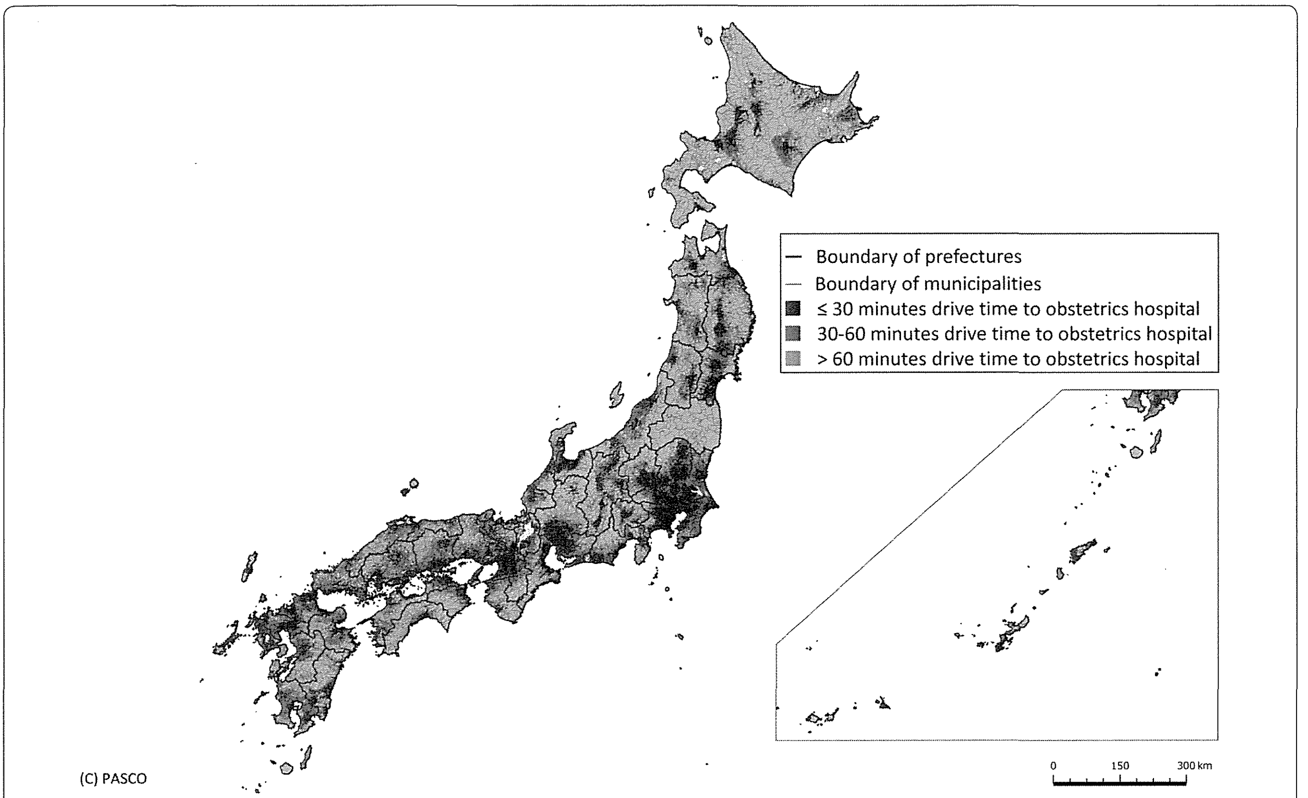

Fig. 3 Access to academic hospital obstetrics departments or perinatal medical centers. Access to the nearest general or regional perinatal medical center or academic obstetrics hospital as of 2011. In each 1-km^2 mesh, *brown* represents a driving time of ≤30 min, *red* a time of 30–60 min, *orange* a time of >60 min and *gray* represents non-residential and non-reported areas

Table 3 Estimated hospital volume after intensification

Number of obstetrics hospitals (national estimate)	985 (1000)	788 (800)	591 (600)	405
Number of hospitals to be absorbed	90	287	484	670
% of obstetrics hospitals in 2011 (1075)	92	73	55	38
No. of births/hospital after intensification	47.7	58.8	78.3	114.3
No. of obstetricians/hospital after intensification	5.9	7.3	9.8	14.3
No. of midwives/hospital after intensification	16.4	20.5	27.3	39.9
Scenario 1				
No. of births absorbed by other hospitals	280	3317	9984	24,213
No. of obstetricians in closed hospitals	164.6	699.7	1451.9	2420.0
No. of midwives in closed hospitals	461.7	2196	4485.8	7346.0
Scenario 2				
No. of births absorbed by other hospitals	414	4165	12,662	24,213
No. of obstetricians in closed hospitals	174.7	774.4	1644.1	2420.0
No. of midwives in closed hospitals	475.1	2284.2	4998.3	7346.0
Scenario 3				
No. of births absorbed by other hospitals	3336	12,724	18,254	24,213
No. of obstetricians in closed hospitals	383.0	1247.8	1825.1	2420.0
No. of midwives in closed hospitals	1001.2	3486.3	5287.7	7346.0

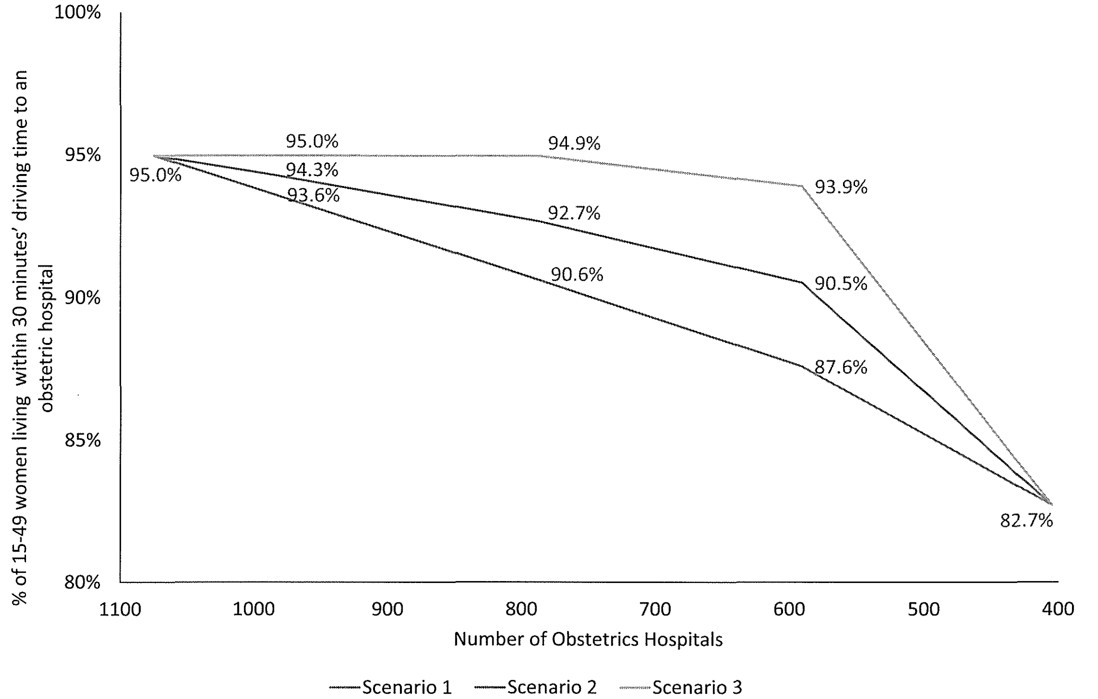

Fig. 4 Extent of intensification and coverage of the female population of reproductive age. Intensification of obstetrics hospitals, access to the nearest obstetrics hospital and population coverage. Change in population coverage within 30-min access of the nearest obstetrics hospital based on three possible scenarios for intensification of obstetrics hospitals: Scenario 1 considered only the number of deliveries per hospital; Scenario 2 gave priority to retaining at least one hospital in each medical service area (MSA) and the number of deliveries per hospital in each MSA was considered; Scenario 3 aimed to maximize population coverage without considering the number of deliveries per hospital

traffic situation completely into account. Additionally, the clinical significance of longer driving times is not clear. A study of inter-facility neonatal transport found that neonatal mortality did not differ significantly between ≤30- and 30–60-min transfers [36]. Second, our intensification scenarios were based on the volume of deliveries as well as MSAs; however, management, administrative and cultural differences between organizations would likely influence the actual merger of hospitals. Reopening obstetrics hospitals or building obstetrics hospitals in new areas is another strategy that could improve access, but we did not take these factors into account.

Conclusions

Closing hospitals or curtailing local obstetrics services is unpopular with the public. Policy makers planning intensification of obstetrics facilities must balance any negative impact on access against improved clinical outcomes and reduced costs. It is essential to consult residents of

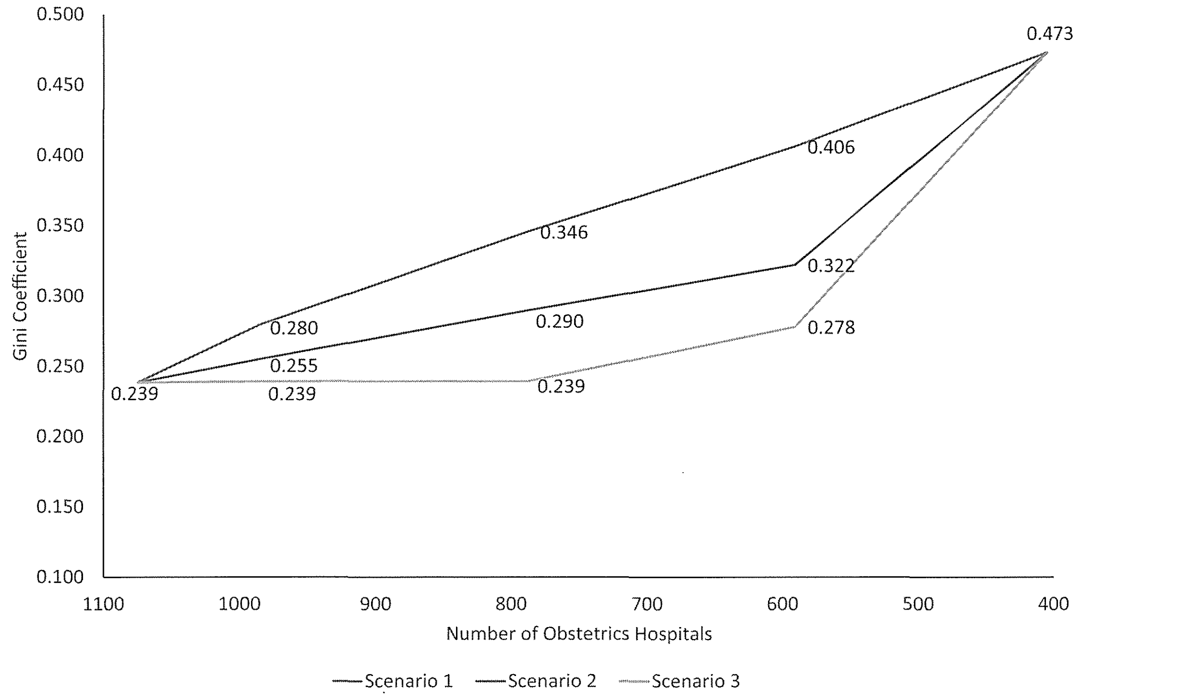

Fig. 5 Extent of inequity between municipalities assessed by the Gini coefficient. Intensification of obstetrics hospitals, access to the nearest obstetrics hospital and level of inequity between municipalities. Inequity in 30-min driving-time access to obstetrics hospitals was calculated for municipalities using the Gini coefficient. In this model, the same three intensification scenarios were used to intensify towards 405 obstetrics hospitals

hospital catchment areas when reorganizing services. A simulation provides an evidence base to inform debates on what is frequently a highly controversial issue.

Abbreviations
GIS: Geographic Information System; MSA: Medical Service Area; PMC: perinatal medical center.

Authors' contributions
SKo conceived the study, performed the analysis and drafted the manuscript. SKo and MM designed the study. SKo, MM, HI, SKa, HA, and HY interpreted the results and wrote the manuscript. All authors read and approved the final manuscript.

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Competing interests
The Department of Health Management and Policy, Graduate School of Medicine, University of Tokyo, where Soichi Koike is based, is an endowed department. It receives funds from Nissay Information Technology Co., Ltd., Chugai Pharmaceutical Co., Ltd., Shionogi & Co., Ltd., Asahi Kasei Pharma Corporation, CRECON Research & Consulting Inc., and Otsuka Pharmaceutical Co., Ltd. The other co-authors declare that they have no competing interests.

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Projected future distribution of dentists in Japan

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Keywords
dentists; supply and distribution; Markov process.

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Abstract

Objectives: Appropriate health policies for the supply of dentists have been an ongoing issue in many developed countries. The purpose of this study was to estimate the future distribution of dentists with different working statuses in Japan and to discuss policy implications about the supply of dentists in any country.
Methods: This was a retrospective cohort study using data from the National Survey of Physicians, Dentists and Pharmacists for 1972–2012. Based on data from the 2010 and 2012 surveys, we calculated by means of a Markov model the future number of dentists with different working statuses until 2042 according to sex.
Results: We estimated that the total number of active dentists will decrease from 2012 to 2042. The number of active dentists per 1,000 population was predicted to reach a peak in 2018, decrease by 4.2% from 2012 to 2038, and thereafter slightly increase. With regard to working status, the number of dentists with their own practices per 1,000 people was predicted to have reached a peak in 2014 and decrease by 22.0% until 2042. We estimated that the number of dentists used in dental clinics per 1,000 population will increase continuously between 2012 and 2042 by 20.0%.
Conclusions: Our study suggests that maintaining this supply of dentists may lead to maldistribution of their working status in the future.

Introduction

Securing personnel resources and achieving their appropriate allocation are important policy issues in establishing national health-care systems. Regarding dental care, it is necessary to estimate the number of dentists required in a national setting toward improving the dental health service system.

Health policy with respect to dental supply has been an ongoing issue in many developed countries. Based on predictions of an oversupply, most countries in Northern Europe have decreased the numbers of their dentists; Southern European countries have increased their numbers of dentists for several decades, which has resulted in a surplus (1,2). The United States and Australia formerly reduced their supply of dentists. However, they have recently encountered problems with respect to disparities of dental care availability and access to dental services, so they have begun establishing new dental schools to increase the supply of dentists (3–5).

In Japan, policies for the supply of dentists have undergone changes over recent decades. Of the 29 dental schools in Japan, 22 were established between 1969 and 1981. During that period, the number of dentists increased rapidly, and the government's goal of 0.5 dentists per 1,000 people was achieved in 1984 (6). Thereafter, the government changed its policy from one of increasing to reducing the supply of dentists (7). Reportedly, the number of dentists in Japan was estimated to be excessive in the future (8–10), so the government has attempted to control the supply by decreasing admission quotas and reducing the annual number of successful candidates in national dentistry examinations. The number of newly registered dentists decreased from approximately 2,700 in 2006–2,000 in 2014 (11).

The working status of dentists includes their places of work (clinics, hospitals, and academic institutions) and employment status (employer or employee). However, no country has taken dentists' working status into consideration in controlling the number of dentists. Recently, situation in the working status of dentists has undergone change in many developed nations. For example, in the United States and the European Union, the proportion of female dentists has

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gradually increased (12,13). A similar tendency has been observed in Japan: the proportion of female dentists increased from 11.7% of all dentists in 1978 to 20.2% in 2008, and the proportion of new female entrants was about 40% (14). The working patterns of female dentists are generally different from those of males: the number of female dentists in part-time employment was greater than that for male dentists, and more female dentists left their jobs at least once during their careers (14,15).

In Japan, a 1 year compulsory postgraduate clinical training program for dentists was introduced in 2006, and currently, most new entrants start their careers in academic or general hospitals for their clinical training. In this context, the future supply of dentists needs to be precisely reevaluated according to current changes in the workforce environment for dentists under the restraining policy for the supply of dentists.

To date, several reports have estimated the future numbers of dentists worldwide (1–10). Regarding working status, only one Japanese study has determined the distribution of physicians by taking their working status into account (16). However, to our knowledge, no study has undertaken a prediction of the distribution of dentists according to their changes in working status. To secure dental care availability, it is essential to make estimates of the future number of dentists and their working status for the purpose of policies that achieve an adequate supply of these health professionals.

Using data from the National Survey of Physicians, Dentists and Pharmacists (NSPDP) in Japan, the present study aimed to make future estimates of dentists for different working statuses by means of a Markov model. This study also discusses the potential health policy implications of the results, which could be helpful for any developed nation in the future.

Methods

Data source

This study was a retrospective cohort study, which made secondary use of official survey data of the Japanese government. We used data from the NSPDP, which is undertaken by the Ministry of Health, Labour and Welfare, Japan, for 1972–2012. Under the Dental Practitioners Law, all dentists are obliged to report their working status every 2 years, and the response rate to the NSPDP was approximately 87% (17). The data included the dentist's registration number, year of registration, year of birth, sex, a main working status self-reported, specialty, and municipality codes for the workplace. The data did not include personal identifiable information, such as names and address details. Using the unique registration numbers, the data for each dentist in each survey year could be linked, and we established longitudinal data for each dentist. We excluded data where there was a lack of registration number or where duplicated registration numbers occurred.

We categorized working status, it was reported a main working status if dentists worked in multiple setting, into the following six groups: a) ownership of practice; b) employment in dental clinic; c) hospital practice; d) employment in academic institution (including practitioners, university teachers, and graduate school students); e) other (engaged in public health, researcher, or practice in nursing home); and f) not reported. If dentists worked in multiple setting, they reported a main working status. Dentists whose status was "not reported" were defined as those who had responded to the NSPDP at least once in other year of research but did not respond in the year of research.

Changes in distribution of working status

To examine the changes in distribution of working status over time, we selected dentists at 0, 5, and 10 years after registration for the years 1982, 1992, 2002, and 2012. We compared the changes in the distribution of the working status of those dentists for those four study years.

Estimation of future number of dentists

We compared working status between a) male and female dentists with n-years experience in 2010 and b) those with $(n + 2)$ years experience in 2012 ($n = 0, 1, \cdots, 38$). The probabilities for change in the dentists' working status between 2010 and 2012 were calculated for each of 78 patterns with years of experience and sex. Using the 78 patterns of transition figures, we then built a Markov model to estimate the future numbers of dentists and future trends in their working status. A Markov model estimates future states using transition probabilities from one state to another state according to a number of factors. It is widely used in workforce studies forecasting human labor market (18,19). To estimate the future numbers of dentists, we assumed the following settings:

- The probabilities for change in working status for 2010–2012 did not subsequently vary.
- The probabilities for change for dentists with more than 39 years of experience were assumed to be equal to those for dentists with 38 years of experience.
- The number of dentists in 2012 was set as the base population.
- For 2011 and 2012, the numbers of new entrants were used to predict the number of new entrants for the estimation period.
- The data for 2002–2012 were used to identify the retirement year of the dentists. Dentists who did not report their status for more than two consecutive surveys were defined as retirees. We calculated the median age of the retirees as over 65 years. When the median age of a

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certain registration year cohort reached the median age of retirees, all dentists in the registration year cohort were excluded in the next estimation.

For each registration year cohort, the distribution of dentists' working status in the year N was calculated by multiplying the number of dentists in the year $N-2$ by the probability of change in working status ($N = 2014, 2016, \cdots, 2042$). We obtained the total number of dentists in the year N to determine the number of dentists in all registration year cohorts in that year N. By repeating these processes, we obtained a prediction for the total number of dentists by working status for each year up to 2042.

We calculated the number of active dentists by determining the number of those who were in any working status – excluding those not reported. We computed the number of dentists per 1,000 population and the number of dentists for each working status per 1,000 population. We obtained future population figures from the report on Population Projections for Japan (January 2012) from the National Institute of Population and Social Security Research (20).

In addition, we incorporated a sensitivity analyses to change the fourth assumption. The number of newly registered dentists changed from 2,000 to 1,200, which was the number recommended by a governmental panel of dental health experts to retain current number of dentists per 1,000 people (10).

We performed all data analyses using software R version 3.1.1.

Results

We obtained 1,027,520 *data points* for 1972–2012. Of that number, we excluded 2,186 *data points* according to our exclusion criteria and finally obtained a total of 1,025,335 *data points* (111,391 dentists) for our analysis. The average duration of observation was 19.3 years. The median age of retirees over 65 years old was 68 years. The number of new entrants in 2011 was 2085 (male, 1291; 61.9%); in 2012, it was 2057 (male, 1215; 59.1%).

The distribution of the working status of dentists changed from 1982 to 2012. For male dentists with 0 years of experience, the proportion of dentists working in academic institutions increased from 30.3% in 1982 to 79.6% in 2012, whereas the proportion of those used in dental clinics decreased from 40.4% in 1982 to 12.3% in 2012. For dentists with 5 years of experience, the proportion of those with their own practice decreased from 54.6% in 1982 to 7.3% in 2012, whereas the proportion used in dental clinics increased from 17.0% in 1982 to 50.6% in 2012. For dentists with 10 years of experience the proportion with their own practice decreased from 70.6% in 1982 to 38.9% in 2012, whereas the proportion of those used in dental clinics increased from 10.6% in 1982 to 33.6% in 2012. The change in the distribution of the working status of female dentists showed a similar tendency to that of male dentists.

Table 1 shows the characteristics of dentists who responded to the 2010 and 2012 surveys. The mean age of male dentists was significantly higher than that of females, and the mean age of both male and female dentists in 2012 was significantly higher than in 2010. Among male dentists, the proportion of those in their 50s was highest. Among female dentists, the proportion of those in their 30s was highest.

Figure 1 shows future estimates of the number of dentists for each working status up to 2042. The number of active dentists and dentists with their own practice is estimated to decrease from 2014 to 2042. The number of dentists used in

Table 1 Characteristics of Dentists Responding to the 2010 and 2012 Surveys

	2010 Survey						2012 Survey					
	Male (N = 80,843)		Female (N = 26,406)		Total (N = 107,249)		Male (N = 83,349)		Female (N = 28,042)		Total (N = 111,391)	
Age, average (standard deviation)	47.0	(10.7)	41.2	(10.5)	45.6	(10.9)	48.4	(11.1)	42.2	(10.9)	46.8	(11.4)
Age category, n (%)												
≤29 years	5,157	(6.4)	3,910	(14.8)	9,067	(8.5)	4,734	(5.7)	3,641	(13.0)	8,375	(7.5)
30–39	16,346	(20.2)	9,272	(35.1)	25,618	(23.9)	15,427	(18.5)	9,422	(33.6)	24,849	(22.3)
40–49	22,750	(28.1)	6,703	(25.4)	29,453	(27.5)	21,463	(25.8)	7,192	(25.6)	28,655	(25.7)
50–59	26,070	(32.2)	5,235	(19.8)	31,305	(29.2)	26,854	(32.2)	5,755	(20.5)	32,609	(29.3)
60–69	10,207	(12.6)	1,240	(4.7)	11,447	(10.7)	14,403	(17.3)	1,971	(7.0)	16,374	(14.7)
≥70	313	(0.4)	46	(0.2)	359	(0.3)	468	(0.6)	61	(0.2)	529	(0.5)
Working status, *n* (%)												
Own practice	47,257	(58.5)	4,268	(16.2)	51,525	(48.0)	48,066	(57.7)	4,445	(15.9)	52,511	(47.1)
Employed in dental clinic	12,684	(15.7)	11,054	(41.9)	23,738	(22.1)	13,288	(15.9)	11,725	(41.8)	25,013	(22.5)
Hospital practice	2,130	(2.6)	730	(2.8)	2,860	(2.7)	2,106	(2.5)	746	(2.7)	2,852	(2.6)
Work in academic institution	6,170	(7.6)	3,278	(12.4)	9,448	(8.8)	6,192	(7.4)	3,432	(12.2)	9,624	(8.6)
Other	1,290	(1.6)	738	(2.8)	2,028	(1.9)	1,367	(1.6)	760	(2.7)	2,127	(1.9)
Not reported	11,312	(14.0)	6,338	(24.0)	17,650	(16.5)	12,330	(14.8)	6,934	(24.7)	19,264	(17.3)

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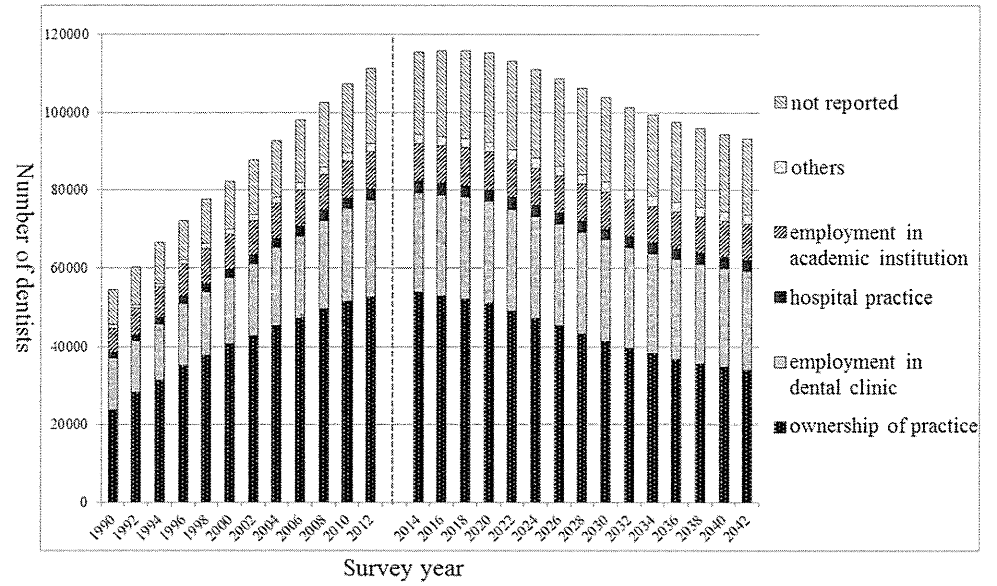

Figure 1 Estimates of the future number of dentists for each working status (1990–2012, trends; 2014–2042, estimates).

dental clinics, working in academic institutes, and with other statuses is estimated to remain almost unchanged.

Figure 2 shows the estimated number of future dentists per 1,000 people for each working status up to 2042. The number of active dentists per 1,000 population was 0.72 in 2012; it will reach a peak of 0.75 in 2018 and then decrease to 0.69 in 2036. Thereafter, it is estimated to increase again to 0.70 in 2042. With regard to working status, the future number of dentists with their own practice per 1,000 people is predicted to decrease by 22.0% (from 0.41 to 0.32) between 2012 and 2042. The number of dentists used in dental clinics per 1,000 people is predicted to increase from 0.20 in 2012 to 0.24 in 2042 – a 20.0% increase.

Figure 3 shows the estimated number of future male dentists for each working status up to 2042. The number of active male dentists and male dentists with any working status is estimated to undergo a constant decrease from 2012 to 2042.

Figure 4 shows the estimated numbers of female dentists for each working status up to 2042. The number of active female dentists and female dentists with any working status is

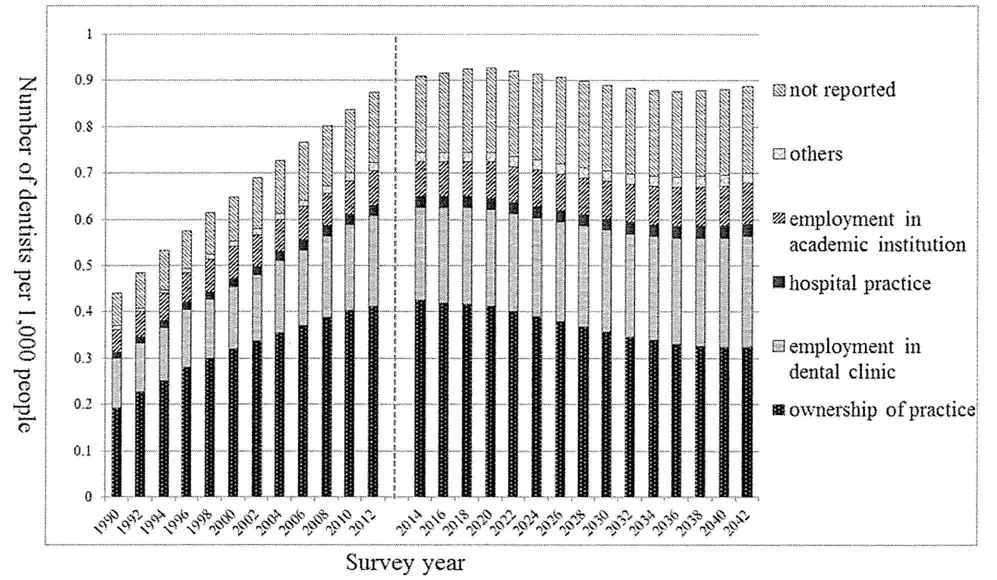

Figure 2 Estimates of the future number of dentists per 1,000 population for each working status (1990–2012, trends; 2014–2042, estimates).

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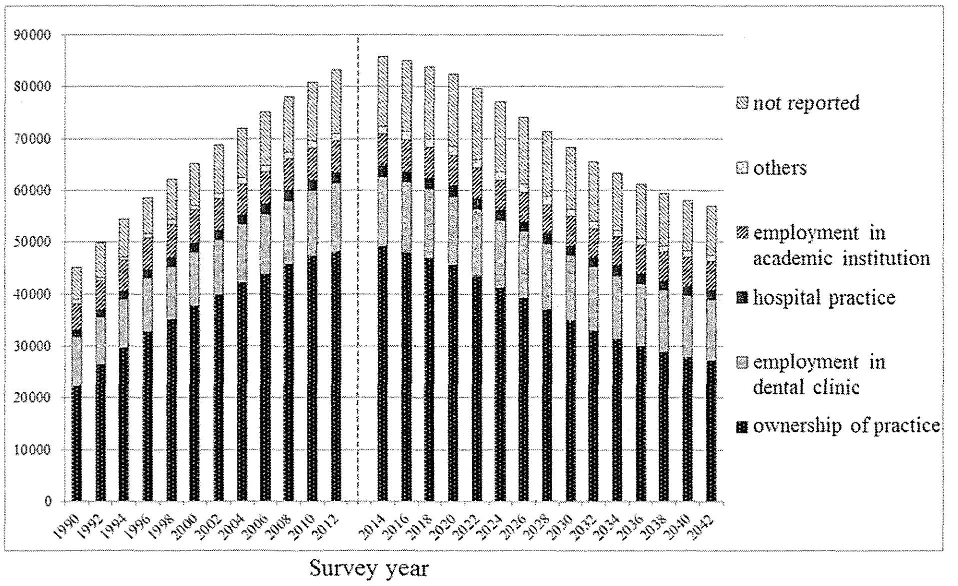

Figure 3 Estimates of the future number of male dentists for each working status (1990–2012, trends; 2014–2042, estimates).

estimated to increase, but the number of female dentists is estimated to remain unchanged after 2038.

The sensitivity analysis changing the forth assumption, it shows the numbers of dentists with their own practice per 1,000 were estimated to decrease from 2014 to 2042, similar to primary model projection. The numbers of active dentists and dentists with employment in dental clinics was estimated to decrease from 2014 to 2042, the number of dentists with hospital practice and employment in academic institutes were estimated to decrease from 2012 to 2042, they described a different trend from primary model projection.

Discussion

This study found that the overall number of active dentists in Japan is estimated to decrease between 2012 and 2042. We predict that the number of active dentists per 1,000 people will decrease from 2012 to 2038, and it will increase slightly

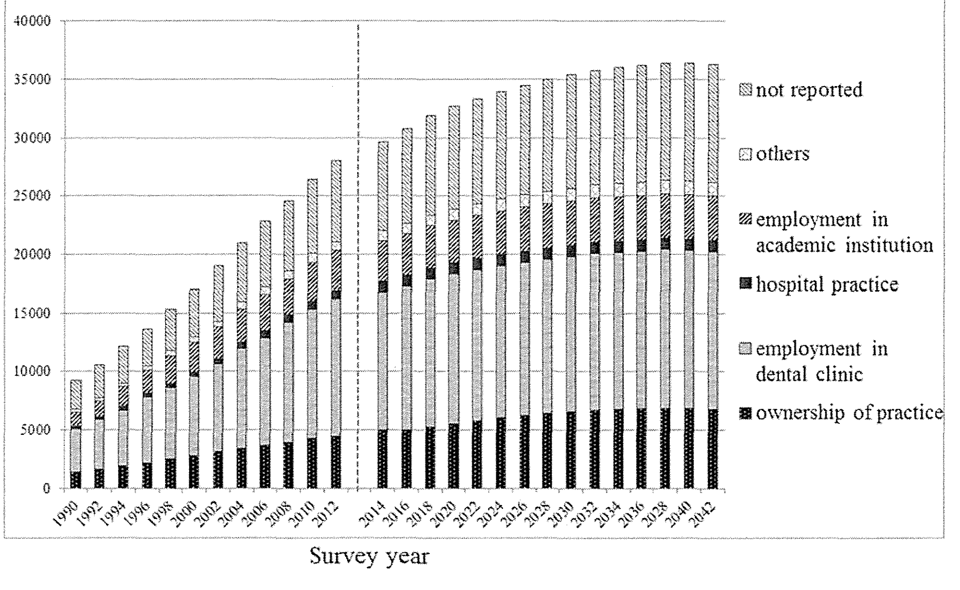

Figure 4 Estimates of the future number of female dentists for each working status (1990–2012, trends; 2014–2042, estimates).

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from 2039. The future number of dentists with their own practice per 1,000 population is predicted to decrease, and the number of dentists used in dental clinics per 1,000 people is predicted to increase between 2012 and 2042.

The number of new registered dentists in Japan between 1979 and 1994 was annually more than 3,000; by contrast, that figure dropped to 2,000 annually in 2011 and 2012. This reduction is the main cause of the estimated decline in the future number of dentists. The different trend in the number of dentists with their own practice and used in dental clinics is due to the change in the distribution of working status and increase in the number of female dentists. Younger dentists are less likely to have their own practices. Female dentists are less likely than males to have their own practices. This tendency is similar to that in other countries (15,21). In addition, the Japanese population is estimated to decrease from 128.1 million in 2010 to 105.3 million in 2042 – a 17.8% decrease. This decrease in the denominator causes the relative increase in the number of active dentists per 1,000 people, which flattens the trend in the number of active dentists per 1,000 population.

In this analysis, our future estimates indicate a decline in the number of dentists with their own practices. This decrease suggests the possibility of a reduction in the number of dental clinics. The growing number of dentists used in dental clinics may lead to a relative increase in the number of dentists per clinic, which could result in a centralization of dentists to group-practice clinics. Centralization could make dental care even less accessible: one study in the United States found that most group-practice clinics were located in large-population areas (22). Further studies are necessary on the geographic distribution for each dentist's working status.

In Japanese dental workforce, dental hygienists and dental technicians are qualified nationally as auxiliary dental personnel. The number of dental hygienists per 1,000 people was 84.8, and 90.5% of them worked in dental clinics, 5.1% of them worked in hospitals. The number of dental technicians per 1,000 people was 27.1, 70.8% of them worked in dental laboratories, 27.9% of them worked in dental clinics and hospitals. (23) There was less migration effect because a high language barrier disturbed immigrant to work in clinical setting. Also, the number of dentists leaving from Japan was small, because the Japanese licenses of dentists were not permitted to practice in other countries with different from European countries. To work in other countries, Japanese dentists have to pass the dentistry examination or readmission to dental school in the country.

Regarding demand-side of dental care, Japan has universal health coverage system includes for dental care services, and the cost of national dental care gradually increased from 1.98 billion US dollars in 1995 to 2.23 billion US dollars in 2011 (24). The DMFT index of 12-year-old children decreased from 1.7 in 2006 to1.4 in 2011 (25,26). The percentage of people aged 80 years old and more who remain the number of their own teeth more than 20 increased from 24.1% in 1993 to 38.3% in 2011(25,26). However, this increase caused the number of elder people with periodontal disease increases recently. Furthermore, Japanese society has been aging rapidly. Aged people need more dental care and dental care expenditure, the future demand of dental care will increase (27).

The sensitivity analysis showed a different trend to the primary analysis, with the numbers of active dentists and dentists used in dental clinics per 1,000 population estimated to decrease. We used "1,200 newly registered dentists" in our sensitivity analysis. This figure was recommended by the governmental panel of dental health experts to retain the current number of dentists per 1,000 people (10). However, our projection suggests that 1,200 newly registered dentists may not be enough to retain the current number of dentists per 1,000 people. The primary projection showed an initial decrease, a subsequent increase, and thereafter a flattening in these numbers. These two analyses indicate that the appropriate number of newly registered dentists for Japan may be around 2,000, and suggest that a sharp decrease in the number of newly registered dentists should be avoided to secure the dental workforce in the long term.

This study has some limitations. First, each research year, about 20,000 dentists had "not reported" status; that could have influenced the probability related to change in status. The actual working status of those "not reported" dentists was unknown: they could have died, left their jobs or actually been working. If there was a tendency for some dentists with a particular working status being less likely to report, that could have caused a self-selection bias among the respondents. Second, the five assumptions we made for our estimation could change in the future. In particular, for simplicity, we used only the probabilities of change in working status between 2010 and 2012. The retirement age of the dentists was set at the median age calculated from the data for 2002–2012; however, that may have been different from the actual retirement age. In some countries, male dentists are reported to work longer than female dentists, and dentists with their own practices are reported to work longer than those used in dental clinics (15,28,29). Third, the database does not include information about time worked (part-time of full-time) and capacity to provide visits and service though the information is relevant to understand the dental work force.

Despite these limitations, this study offers useful information in the debate on policies related to an adequate supply of dentists. Our five assumptions will be susceptible to change in the future and periodic reanalysis might be warranted.

Our study on Japan's efforts to control the supply of dentists has important health policy implications for securing personnel resources and their appropriate allocation; this is potentially useful for any type of health-care profession in

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any country. A simple quantitative restriction of the total supply of health-care providers may lead to maldistribution of their working status. Governments should take into account not only the total number of health-care providers but also the distribution of their working status when deciding about the supply of such providers. The workforce projections might help form a basis for further policy efforts, such as incentive programs or alternative providers, to ensure a more equitable distribution of services.

Conclusions

Using national data for Japan, this study estimated that the total number of dentists will decrease and that the number of dentists per 1,000 people will initially decrease but then increase from 2038. The number of dentists with their own practices is estimated to decrease constantly; the number of dentists used in dental clinics is estimated to increase constantly. When policy makers make decisions about supplying health-care providers, it is essential to take into account the distribution of those providers' working status as well as their total number.

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