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ORIGINAL ARTICLE

Projection of the dental workforce from 2011 to 2020, based on the actual workload of 6762 dentists in 2010 in Taiwan

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Background/Purpose: Planning of the dental workforce, especially the number of dentists, requires the data of actual dental workloads. This study attempts to make projections of the dental workforce from 2011 to 2020, based on a survey of the actual workload of 6762 dentists in 2010.

Methods: In 2010, a database of 11,449 current dentists was retrieved from the file of Department of Health, Executive Yuan, Taipei, Taiwan. Questionnaires with the information of each dentist and 10 questions regarding the actual workload were sent to each dentist with a return envelope. The actual workload of the dentists who returned the questionnaires was analyzed. A projection of dental workforce from 2011 to 2020 was calculated, based on the actual workload.

Results: An analysis of the actual dental workload was conducted on 6762 (59.1%) returned questionnaires. The dentist-to-population ratio (defined as the number of dentists

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per 10,000 people) was 5.0 in 2010. The supply of 400 dentists per year remained constant from 2006 to 2010, and is expected to be sustained for the next 10 years. Because the population of Taiwan will begin to decrease within the next 10 years, we estimate that the dentist-to-population ratio will increase to 6.0 by the year 2020 or earlier. After adjusting for working hours, working days, and gender differences, surplus dentists will number approximately 1069 in 2020.

Conclusion: An oversupply of dentists and a decrease in population will result in a surplus of dentists. To make better projections of the dental workforce, surplus dentists can be arranged to care for the aged, disabled people, and underserved people.

Introduction

A strategic plan for the dental workforce is a major concern for the Department of Health, Executive Yuan (Taipei, Taiwan). In 2000 under the supervision of the Department of Health, the National Health Research Institute (NHRI) organized the first consensus conference on the dental workforce.[1,2] Conclusions of the conference are described, as follows. First, the population growth and economic growth demand an increase in the dental workforce. Second, the net increase of dentists per year should be maintained at 270 dentists until 2010. Third, more dental resources should be allocated for aged people and for groups with special dental needs. Fourth, dental assistants should be legalized to provide more auxiliary dental services. However, in the Second Consensus Conference on the Dental Workforce held by the NHRI in 2010, all experts agreed to limit the increase in the number of dentists because of the dramatic decrease in the birth rate.[3] The number of dentists per 10,000 people (defined as "the dentist-to-population ratio" in this study) should be maintained at 5.0—5.3 until 2020. Future dental workforce plans should concentrate on how to balance the demographic distribution of practicing dentists. A new projection of dental workforce from 2011 to 2020 has to be planned.

In the past 50 years, the supply of the dental workforce in Taiwan has been influenced by a variety of factors. Among the most important factors are the double-digit economic growth (from 1970 to 1989),[4] the National Health Insurance (NHI) program (which began in 1995),[5] the demographic distribution of dentists,[6—9] and the health policy on oral diseases.[9] Changes in these factors can affect the supply and distribution of the dental workforce.[4—10] Of these influencing factors, human resources—especially the health workers who directly deliver health services—are a most costly but least readily available resource in a healthcare system.[11] In Taiwan, only dentists can legally conduct dental treatment. Dental auxiliary personnel such as dental assistants and dental technicians are not allowed to perform any intraoral care or treatment. The actual workload of a dentist could be the most important factor in estimating dental workforce requirements in the future.

However, all previous studies on the dental workforce in Taiwan were based on agreements reached by experts[2,3] or based on the analysis of the database created by the Department of Health for administrative purposes.[4—9] The actual workload of each dentist (for example, working hours and days, the number of cases treated, and gender difference) has not yet been studied and analyzed. A questionnaire survey to investigate actual dental workload was conducted in 2010. In this study, a projection of the dental workforce from 2011 to 2020 was performed, based on a survey of the actual workload of 6762 dentists in 2010 in Taiwan.

Materials and methods

To link to health information systems of the World Health Organization (WHO), three core indicators of health workforce (i.e., the number of dentists per 10,000 people; the distribution of dentists by region, place of work, and gender; and the annual number of dental graduates) proposed by the WHO were used in this study.[12] The questionnaires on actual working time were modified from the workload indicators of staffing requirements published by the WHO.[11] On April 13, 2010, the basic information of each dentist (i.e., name, gender, birthday, dental school, dental license, and dental office name and address) was retrieved from the database of health personnel (Department of Health, Executive Yuan Taipei, Taiwan). Basic information was printed on the upper part of the questionnaire. All dentists had to check the accuracy of their own basic information. They could make changes and corrections in the questionnaire. The corrected basic information was used for analyses of age, gender, and demographic distribution of the dentists. The lower part of the questionnaire was composed of ten questions that focused on the active dental workload (i.e., average working hours per day, average working hours per week, average patient number per week, number of days off per week, number of holidays other than weekends per year, and number of dental assistants), category (i.e., general practitioner or specialist), dental income satisfaction, any income from sources other than the dental profession, and preferred age of retirement. After answering all questions, the dentist was to sign the questionnaire and return it by prepaid mail. Participants were informed of the purpose of the survey and consented to participate by signing and returning the form.

Between July 30, 2010 and September 16, 2010, a total of 11,449 dentists received the questionnaires which were sent out. To encourage a higher response rate, a personal

call was made to each dentist if he or she did not send back the questionnaire within two weeks. Continuous calls, faxes, and e-mails were required to ensure that the questionnaire was returned on time. The actual dental workload data were analyzed and used for the adjustment of the dental workforce projection.

The annual population changes in Taiwan were cited from the official reports published by the Council for Economic Planning and Development, Executive Yuan (Taipei, Taiwan).[13] The total number of dentists per year was provided by Department of Health, Executive Yuan (Taipei, Taiwan).[14]

Results

Response to questionnaires

Of the 11,449 questionnaires sent to the dentists in Taiwan, 6762 were completed and returned, yielding an overall response rate of 59.1%. Five percent of the returned questionnaires were chosen at random for the calculation of Cronbach's α for reliability. These questionnaires yielded an α score of 0.85, which was within the high reliability range. The errors in the basic information of the dentist registry database were very few. Most errors were related to changes in dental practice, including practicing permit, office name, and address of the dental facility. These were not used for the projection of the dental workforce.

Population changes

From 1946 to 1964, the population of Taiwan doubled from 6,090,860 people to 12,325,025 people; in 1982, it had tripled to 18,515,754 people; and in 2010, it had reached a plateau at 23,162,123 people (Table 1).[13] The baby boom period added 6795,031 newborns who will reach the retirement age of 65 years beginning in 2011. In 2011, older people (i.e., over 65 years of age) made up nearly 10.7% of the population, and in 2020 the percentage of older people will increase to 24.4% of the population. The crude birth rate decreased from 49.97% in 1950 to 7.21% in 2010. It is believed that the crude birth rate will be equal to the crude death rate in 2017, and the population will decrease thereafter.[13]

Dentist-to-population ratio and population-to-dentist ratio

The number of dentists increased annually from 3739 dentists in 1986 to 11,656 dentists in 2010 (Table 1). The average increase in the past decade was 311 dentists per

Table 1 The changes in population and dentists in Taiwan from 1986 to 2010.

Year	Population	Annual change in population	Annual rate of population change (%)	Dentist no.	Annual changes in dentist number	Annual rate of dentist changes (%)	Dentist-to-population ratio[a]	Population-to-dentist ratio[b]
1986	19,509,082	195,257	1.00	3739			1.9	5218
1987	19,725,010	215,928	1.10	4150	411	9.90	2.1	4753
1988	19,954,397	229,387	1.10	4511	361	8.00	2.3	4423
1989	20,156,587	202,190	1.00	4865	354	7.30	2.4	4143
1990	20,401,305	244,718	1.20	5449	584	10.70	2.7	3744
1991	20,605,831	204,526	1.00	5983	534	8.90	2.9	3444
1992	20,802,622	196,791	0.90	6448	465	7.20	3.1	3226
1993	20,995,416	192,794	0.90	6540	92	1.40	3.1	3210
1994	21,177,874	182,458	0.90	6973	433	6.20	3.3	3238
1995	21,357,431	179,557	0.80	7026	53	0.80	3.3	3040
1996	21,525,433	168,002	0.80	7254	228	3.10	3.4	2967
1997	21,742,815	217,382	1.00	7573	319	4.20	3.5	2871
1998	21,928,591	185,776	0.80	7900	327	4.10	3.6	2776
1999	22,092,387	163,796	0.70	8240	340	4.10	3.7	2681
2000	22,276,672	184,285	0.80	8597	357	4.20	3.9	2591
2001	22,405,568	128,896	0.60	8944	347	3.90	4	2505
2002	22,520,776	115,208	0.50	9206	262	2.80	4.1	2446
2003	22,604,550	83,774	0.40	9551	345	3.60	4.2	2367
2004	22,689,122	84,572	0.40	9868	317	3.20	4.3	2299
2005	22,770,383	81,261	0.40	10,140	272	2.70	4.5	2246
2006	22,876,527	106,144	0.50	10,412	272	2.60	4.6	2197
2007	22,958,360	81,833	0.40	10,740	328	3.10	4.7	2138
2008	23,037,031	78,671	0.30	11,093	353	3.20	4.8	2077
2009	23,119,772	82,741	0.40	11,351	258	2.30	4.9	2037
2010	23,162,123	42,351	0.18	11,656	305	2.62	5.0	1987

[a] The dentist-to-population ratio is defined as the number of dentists per 10,000 people.
[b] The population-to-dentist ratio is defined as the number of people serviced by a dentist.

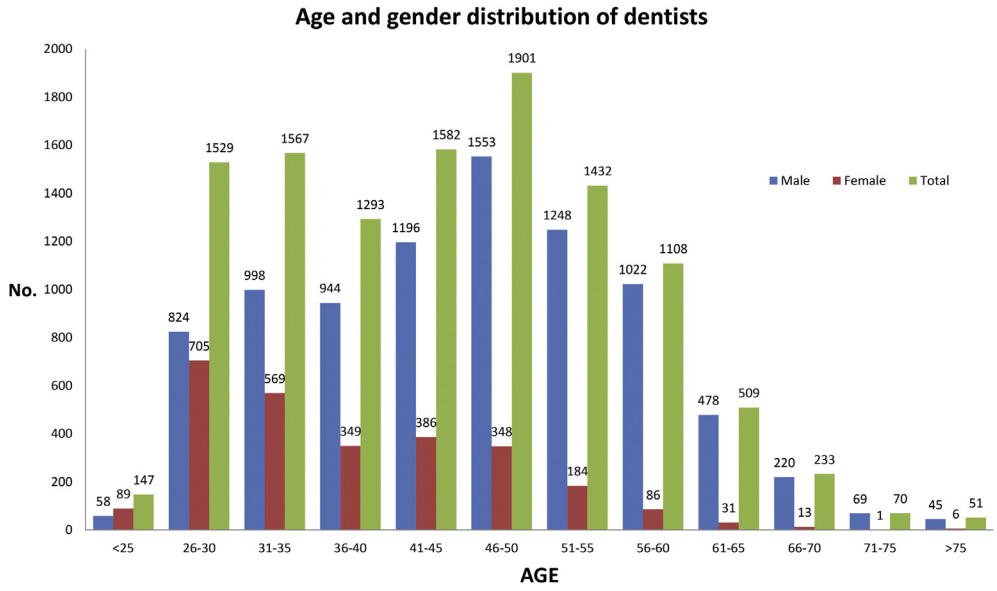

Figure 1 The age and gender distribution of the dentists. The 46—50 year old age group contains the highest number (1901 dentists). Of the 11,449 dentists, 24.2% (2772) are female. The number of female dentists increased as their age decreased, reaching 46.1% in the 26—30-year-old age group.

year. The dentist-to-population ratio (which is defined as the number of dentists per 10,000 people) increased from 2.1 in 1987 to 5.0 in 2010. From 1992 to 2010, the average rate of increase in the dentist-to-population ratio was approximately 0.1 per year. The population-to-dentist ratio (which is defined as the number of people serviced by a dentist) decreased from 4753 people in 1987 to 1987 people in 2010 (Table 1).

Age and gender distribution of dentists

Fig. 1 shows the age and gender distribution of the 11,449 dentists registered by the government until April 13, 2010. The mean age of dentists was 45.3 years. One hundred and forty seven dentists were under 25 years of age and 51 dentists were older than 75 years of age. The 46—50 year old age group included 1901 dentists; in this group, 18.3% of dentists were female. Of the 11,449 dentists, 2772 (24.2%) were female. The proportion of female dentists increased as their age decreased, reaching 46.1% in the 26—30 year old age group. In the 61—65 year old age group, female dentists made up approximately 6% (31/509) of all dentists. Female dentists tended to be concentrated in urban areas. In Taipei, a metropolitan city, 32.1% of dentists were female.

Demographic distribution of dentists

Unbalanced urban—rural distribution of dentists is evident in Taiwan. In 2010, 2618 (22.86%) of 11,449 dentists practiced in Taipei City, which constituted a dentist-to-population ratio of 9.7. Only 96 dentists practiced in Chiayi County, making a dentist-to-population ratio of 1.7. The difference in the dentist-to-population ratio between urban and rural areas is 5.7.

Actual workload of dentists

Table 2 shows the actual workload of 6762 dentists who sent back the questionnaires. The average working hours for a dentist were 8.2 hours per day, which is slightly higher than the 8.0 legal working hours per day. In areas with a lower dentist-to-population ratio, dentists tended to work longer hours (8.5—9.2 hours per day). Female dentists worked 6.9 hours per day, and male dentists worked 8.4 hours per day (Table 2). Thus, female dentists tended to work 18% fewer hours per day than male dentists.

The average working hours per week for all dentists were 42.9 hours, which is higher than the 40 hours of work per week for government employees and the 42 hours of working per week for laborers. Weekly working hours were 44.1 hours for male dentists and 35.2 hours for female dentists. Thus, female dentists worked 20% fewer hours per week than male dentists (Table 2).

On average, each dentist treated 80.2 patients a week. In rural areas, a dentist could treat 120—125 patients per week. In urban areas, the number of patients treated by a dentist dropped to 57.7 patients in Taipei, 60.3 patients in

Table 2 Workload conditions of dentists.

Gender	Working hours/d	Working hours/wk	Patients/wk	Off-days/wk	Holidays/y	No. of assistants
Male	8.4	44.1	83.5	1.7	19.9	1.8
Female	6.9	35.2	58.7	1.8	21.2	1.4
Average	8.2	42.9	80.2	1.7	20.8	1.7

Taichiung, and 66.8 patients in Kaoshiung. Male dentists treated 83.5 patients per week, and female dentists treated 58.7 patients per week. Female dentists treated only 70% of the number of patients that male dentists treated in a week (Table 2).

Each dentist took 1.7 days off per week. No difference was found between male and female dentists in the amount of days off. Other than regular days off during weekends, dentists took an average of 20.8 days holidays annually, with male dentists taking 19.9 days holidays and female dentists taking 21.2 days holidays per year (Table 2).

On average, a dentist hired 1.7 assistants to help perform dental treatment. Dentists in southern Taiwan hired more dental assistants than dentists in northern Taiwan (2.1 assistants vs. 1.4 assistants, respectively). Moreover, male dentists hired more dental assistants than female dentists (1.8 assistants vs. 1.4 assistants, respectively; Table 2).

Selection of dental specialty as daily practice

Fig. 2 shows that 6762 dentists who sent back the questionnaires selected dental specialty to describe their daily practice. Multiple choices for preferred dental practices were offered in this category. Of the 6762 dentists, 5391 (79.7%) dentists chose general practice as their preferred daily practice. Among these dentists, 4,387 (81.4%) dentists also chose one or more dental specialties as a combined practice. The remaining 1371 (20.3%) dentists chose one dental specialty as their preferred daily practice. Among the 1371 specialists, only 66 (1.0%) dentists chose oral pathology as their preferred daily practice (Fig. 2).

Satisfaction with dental income

A 5-point scale was provided for dentists to indicate their level of satisfaction with their dental income, as follows: 5 points, "very satisfactory"; 4 points, "satisfactory"; 3 points, "not bad"; 2 points, "bad"; and 1 point, "very bad". The average score for satisfaction with dental income was 3.1 points (i.e., ranging from "not bad" to "satisfactory"). Male dentists had a mean score of 3.1 which was slightly higher than the mean score of 3.0 for female dentists.

Jobs other than the dental profession

Most dentists were devoted full time to their dental profession. Only 165 (2.5%) dentists had incomes from sources other than the dental profession.

Preferred age of retirement

The preferred mean age of retirement was 60.3 years for all respondents. This result indicates that dentists in Taiwan want to retire approximately 5 years earlier than government employees who usually retire at the age of 65 years. The preferred retirement age was 61.3 years for male dentists and 51.5 years for female dentists.

Development of dental workforce

To make a projection of dental workforce, the two most important baseline data are the dentist-to-population ratios and the actual workload of dentists.[15] Based on these data, we can add more data from the demand or the supply of the dental workforce to modify the dentist-to-population

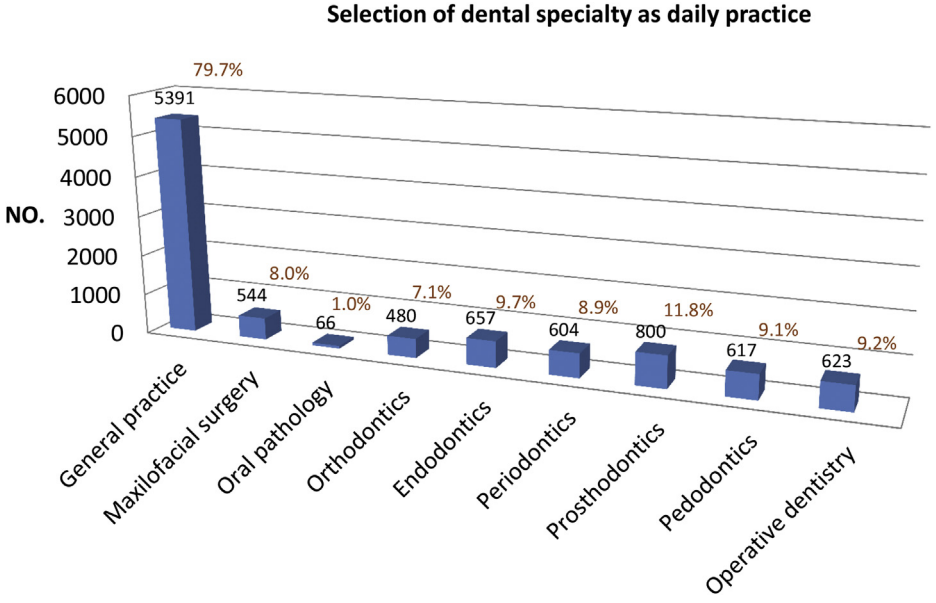

Figure 2 The selection of dental specialty as the daily practice. Of the 6762 dentists, 5391 (79.7%) dentists chose general practice as their daily practice. The five most preferred dental specialties are prosthodontics, endodontics, operative dentistry, pedodontics, and periodontics.

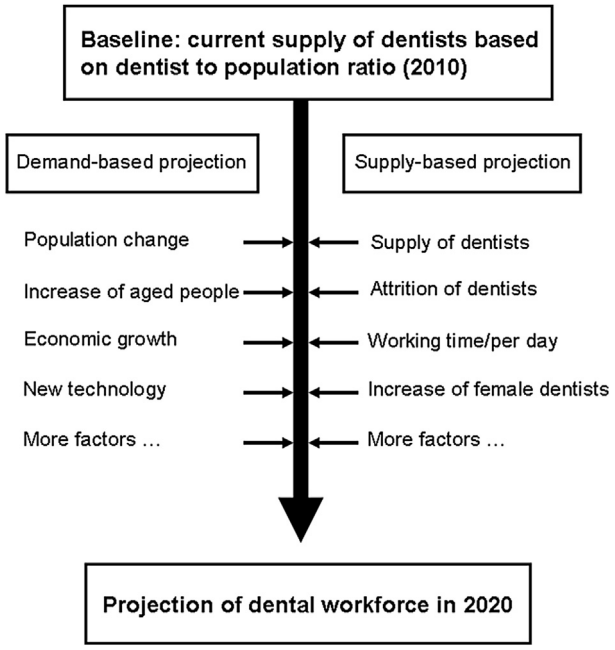

Figure 3 The workforce planning model, based on the dentist-to-population ratio. The dentist-to-population ratio can be adjusted by various factors in the demand-based projection or in the supply-based projection.

ratio and finally complete the projection of the dental workforce in 2020 (Fig. 3).

Supply and retirement of dentists

Table 3 shows the number of dental students enrolled in seven domestic dental school in 2006 and dental graduates from 2006 to 2010. Approximately 390 new dental students enrolled every year from 2006 to 2010 and approximately 8% of the dental students could not graduate on time. Therefore, from 2006 to 2010, the average number of dental graduates was 359 students per year (Table 3). A dental graduate must pass a dental license examination to become a dentist. From 2006 to 2010, the mean yearly pass rate was 72.46%. In general, 391 new dentists—including those who took the dental license examination more than once—were produced each year (Table 4). Only approximately 10—12 dental students who graduate from foreign dental schools successfully pass the dental license examination each year. Thus, the total supply of dentists could have been approximately 400 dentists per year from 2006 to 2010. However, for the same period, the net increase of dentists per year was approximately 303 dentists (Table 1). The attrition of dentists, including retirement, is estimated at approximately 97 dentists per year. From the age distribution of dentists (Fig. 1), 509 dentists in the 61—65 year old age group will retire in the next 5 years (i.e., from 2011 to 2015), and 1108 dentists in the 56—60 year old age group will retire from 2016 to 2020. The annual attrition of dentists could increase to 101.8 dentists from 2011 to 2015 and then to 221.6 dentists from 2016 to 2020 (Fig. 1). The supply of dentists should exceed the attrition of dentists for the next 10 years.

Table 4 Yearly pass rates of the dental license examination from 2006 to 2010.

Year	No. of applicants	No. of passes	Pass rate
2006	600	387	64.50%
2007	541	379	70.06%
2008	572	411	71.85%
2009	544	395	72.61%
2010	461	384	83.30%
Average	544	391	72.46%

Dental workforce projections from 2011 to 2020 based on actual dental workloads

As mentioned previously, if the supply of dentists continues at 400 dentists per year and the population decreases in the next 10 years, the dentist-to-population ratio could increase to 6.0 in 2020 (Fig. 4). The dental workforce projection is influenced by the supply and attrition of dentists every year. The attrition of dentists will increase in the next 10 years (2011—2020) because more dentists from the baby boom period are going to retire. From 2011 to 2015, 509 dentists between 61 years old and 65 years old will retire, yielding a yearly attrition rate of 101.8 (integrated to 102) dentists. From 2016 to 2020, another 1108 dentists will also retire, making a yearly attrition rate of 221.6 (integrated to 222) dentists. Fig. 4 shows the projection of the dental workforce estimated by the supply and attrition numbers of dentists. The dental workforce could reach 14,036 in 2020 with a dentist-to-population ratio of 6.0. If the dentist-to-population ratio of 5.0 meets the dental

Table 3 The number of dental students enrolled in seven domestic dental schools and dental graduates from 2006 to 2010.

No. of students enrolled in the dental schools				No. of graduate students			
Year	Male	Female	Total	Male	Female	Total	Graduation rate (%)
2006	260	140	400	216	125	341	85
2007	248	135	383	199	140	339	89
2008	223	167	390	194	177	371	95
2009	235	160	395	204	157	361	91
2010	217	165	382	211	174	385	101
Average	237	153	390	205	155	359	92

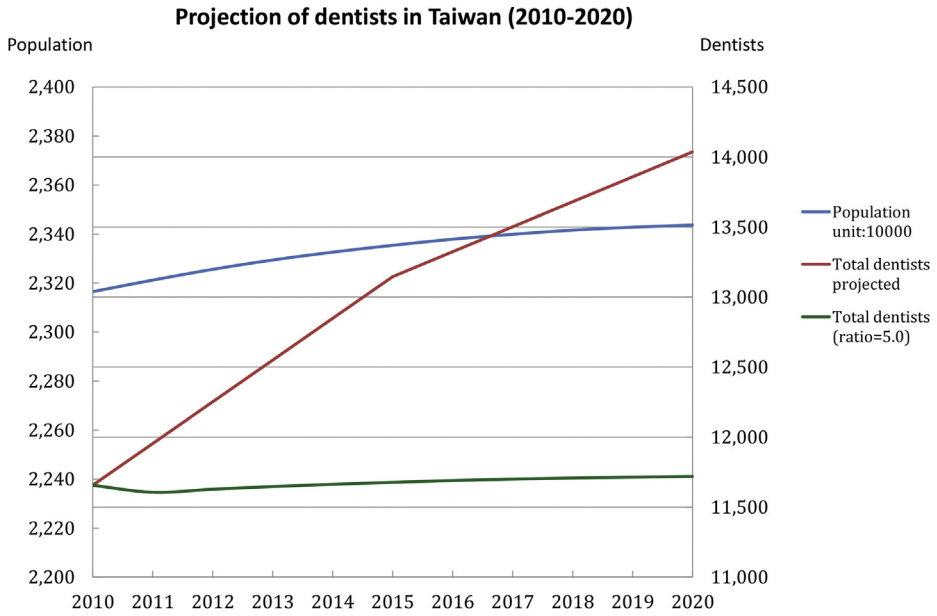

Figure 4 Projection of dentists in Taiwan from 2011 to 2020. The blue line represents the projection of population. The red line represents the number of dentists, based on the supply and attrition model. The green line represents the number of dentists, based on the dentist-to-population ratio of 5.0 throughout the projection period.

demand of patients with adequately high satisfaction, an increase in the dentist-to-population ratio greater than 5.0 could result in a surplus of dentists at the present service level. The difference between the projection of dentists based on the supply and attrition model and the projection of dentists based on a dentist-to-population ratio of 5.0 is illustrated in Fig. 4 as the gap between the red line and green line for each projected year. If everything remains constant for the next 10 years, the number of dentists could reach a surplus of 2317 dentists by 2020. In the next 10 years, certain adjustments for an active workload should be calculated for foreseeable variables (e.g., the reduction of dental working hours per day, the reduction of dental working days per week, and an increase of female dentists).

Adjustment of actual dental workload on the projection of dental workforce

At present, the average working hours for dentists is 8.2 hours per day (Table 2). Legal working hours are 8.0 hours per day. Overworking is common in dental practices. If dental working hours are decreased by 0.2 hours per day by 2020, the extra 0.2 working hours of 11,656 dentists per year could be compensated for by an extra dental workforce. According to the Council of Labor Affairs, Executive Yuan (Taipei, Taiwan)[16] there were 52 Sundays, 52 Saturdays, and 19 National holidays in 2010. In the year of 2010, working days were 242 days (365 days − 52 days − 52 days − 19 days = 242 days). If a dentist works 8.0 hours a day, the total working hours for each dentist will be 1936 hours per year. Reducing the working hours of 11,656 dentists per year by 0.2 hours per day equals to 564,150.4 hours (0.2 hours × 242 days × 11,656 dentists = 564,150.4 hours). These 564,150.4 hours can be compensated for by an increase of 291.4 dentists (564,150.4/1936 = 291.4). Thus, the surplus number of dentists would then decrease by 291—from 2317 dentists to 2026 dentists.

According to Table 2, dentists only took 1.7 days off instead of 2 days off per week. Since 2001, government-service employees work 5 days per week. The policy for nongovernment employees to work 5 days per week will be enforced within 2−3 years. Most dentists will follow this 5-day working policy in the near future. The working hours for 0.3 days equals to 2.4 hours for an 8-hour working day. Working hour loss by taking 0.3 days off will be 1,454,668.8 hours (2.4 hours × 52 weeks × 11,656 dentists = 1,454,668.8 hours) per year. An additional 751 dentists (1,454,668.8 hours/1936 hours = 751.37 dentists) are required to compensate for the lost working hours. Surplus dentists would thus decrease by an additional 751— from 2026 dentists to 1275 dentists.

The total number of dentists will increase from 11,656 in 2010 to 14,036 in 2020. The total increase is 2380, and 1028 (43.2%) dentists will be female. At present, 24.2% of dentists are females. However, the productivity of female dentists was approximately 80% the productivity of male dentists, based on the estimate of the working hours per week. The increase in female dentists should be counted as 822 additions to the dental workforce. An additional 206 dentists are required to compensate for the working hour loss because of an increase in the number of female dentists. The surplus numbers of dentists could thus be decreased by another 206—from 1275 dentists to 1069 dentists.

Discussion

In this study, we tried to make projections of dental workforce from the years 2011 to 2020. The development of

the projection of dental workforce required baseline data of the actual workload of dentists. This was the primary reason we conducted a survey of the actual workload of dentists in 2010. In addition to the baseline information of actual workload of dentists, the most important data are the current dentist-to-population ratio and the supply and attrition of dentists. With these data in hand, we can estimate the future dentist-to-population ratio and assess whether there will be a surplus of dentists in the near future. If there is a surplus of dentists, we can reduce the supply of dentists, decrease the working time of dentists, or make a better arrangement for these surplus dentists to take care of patients with special dental need such as the aged, disabled people, or underserved patients.

Several important factors must be considered for the assessment of the demand for dental service. These factors include dental attendance, treatment hours, and demographic distribution of dentists, oral health, economic growth, insurance coverage, and advanced technology. However, some factors influencing the demand for dental service are not readily available and require further studies in Taiwan. From the patients' viewpoint, the demand for dental service should be adequately fulfilled to obtain a more satisfactory level for the provided dental service.

Some factors related to the supply of dental workforce are the supply and attrition of dentists, working time per day, and increase in the number of female dentists. Controlling the supply of dentists by the government is an easy and effective way to adjust the dentist-to-population ratio and the dental workforce. In Taiwan, dentists can be produced from domestic and foreign dental schools. There are seven domestic dental schools in Taiwan. Dental education takes 6 years to complete. The Ministry of Education controls the enrollment of dental students in domestic dental schools. From 2006 to 2010, approximately 390 new dental students enrolled in seven domestic dental schools per year and 92% of them graduated on time. Thus, a mean of 359 dental graduates was produced per year. Each dental graduate must pass a dental license examination to become a certified dentist. Dental graduates who failed the dental license examination needed to retake the examination until they passed. The yearly pass rate for the dental license was relatively low (72.46%), although domestic dental graduates eventually passed it after several attempts. From 2006 to 2010, the mean yearly pass rate was 72.46%, and therefore 391 new dentists, including those who took the dental license examination more than once, were produced each year. Dental students who graduated from foreign dental schools of developing countries had to pass the qualification test to obtain the right to take the dental license examination, but the pass rate for the dental license was extremely low (36.6%). Only approximately 10—12 foreign dental graduates successfully pass the dental license examination each year. Until 2008, 276 dentists in Taiwan were foreign dental graduates, comprising 2.49% of total dentists. Therefore, the main supply of dentists comes from the seven domestic dental schools. If the restriction policy on foreign dental graduates remains unchanged, the total supply of dentists could be approximately 400 dentists annually until 2020.

The supply and retirement rates of dentists obviously affects the projection of dental workforce in the future. The supply of dentists has been steady at approximately 400 dentists per year from 2006 to 2010. However, for the same period, the net increase of dentists per year was approximately 303. Thus, the attrition of dentists, including retirement, is estimated at approximately 97 dentists per year. From the data of age distribution of dentists in Taiwan, we estimate that the annual attrition of dentists may increase to 101.8 dentists (2011—2015) or even to 221.6 dentists (2016—2020). The supply of dentists should exceed the attrition of dentists for the next 10 years. However, according to the data from the Council for Economic Planning and Development Taiwan,[13] the birth rate dropped to 0.94 in 2010, and thus the crude birth rate will be equal to crude death rate in 2017, at which time point the population should start to decrease. The dentist-to-population ratio will increase continuously even as the population grows very slowly or decreases in size in the next 10 years. This fact indicates the urgent need of making projections of dental workforce from 2011 to 2020.

Since 1995, all residents in Taiwan have been required to join the NHI program. Nearly 99% of dentists joined and work with the NHI program, although orthodontic and prosthetic treatments are excluded from the NHI program. Therefore, satisfaction with the level of NHI dental service could reflect the adequacy of dental care. The people's overall satisfaction rate for NHI services (i.e., quality of service, instrumentation, attitude of dentist, and treatment outcomes) was 77.4% in 2007, a year in which the satisfaction rate for dental services is the highest (80.2%), compared to the satisfaction rate for medical services and Chinese medicine services. Only 1.9% of people are not satisfied with dental services.[17] In 2010, the dental satisfaction rate reached a high record of 82.9%. At present, with the dentist-to-population ratio at 5.0, the provided NHI dental care meets the demand for dental services with a satisfaction rate of more than 80% from the users.

The dentist-to-population ratio is the first core indicator used by the WHO to assess whether the number of health workers relative to the population is adequate. It can be used to monitor the most basic needs of healthcare to be achieved in a country, and can be used for comparative analyses among several countries, although the accessibility, equity, quality, and efficiency of healthcare does not consider this core indicator. Because of its simplicity to apply and its availability in most developing and developed countries, the dentist-to-population ratio of Taiwan was first compared with the ratio of the high-income founding members of the Organization for Economic Cooperation and Development (OECD). The ratio was then compared with the countries in North America, and finally with the countries in the Asian Pacific region. Table 5 shows the dentist-to-population ratios in select countries and regions, which are available in the OECD,[18,19] the World Dental Federation (FDI),[20] and the WHO *Global Atlas of Health Workforce*[21] after 2007. For OECD high-income founding member countries, other than Scandinavian countries and Greece, the dentist-to-population ratios varied mostly from 5.0 to 8.0 with a mean value of 6.1 in 2007. Most European countries have dentist-to-population ratios ranging from 5.07 in The Netherlands (2009), 5.2 in the United Kingdom (2010), 5.2 in Switzerland (2009), 5.3 in Italy (2009), 5.6 in Austria

Table 5 Practicing dentists per 10,000 population in selected countries or regions.

Country	2007	2008	2009	2010
Australia	4.4○	—	6.91△	—
Austria	5.4△	5.5△	5.5△	5.6△
Belgium	8.27△	7.33△	—	—
Canada	5.8*	5.9*	—	—
China	0.12○	—	—	—
Denmark	8.8*	8.5*	—	—
Finland	8.4*	8.3*	—	—
France	6.6*	6.6*	6.5*	6.5*
Germany	8.0*	8.1*	8.2*	—
Greece	12.9*	13.1*	13.1*	—
Hong Kong	2.26○	—	—	—
Iceland	9.4*	9.4*	9.2*	9.4*
India	0.29○	—	—	—
Indonesia	0.6△	—	—	—
Ireland	5.95	6.28△	6.18△	—
Italy	5.77△	4.91△	5.3*	—
Japan	7.4*-	7.7*	—	—
Korea	3.9*	4.15*	4.2*	—
Luxembourg	7.99△	8.1*	8.2*	—
Malaysia	—	1.36△	—	—
Netherlands	5.1*	5.1*	5.07△	—
New Zealand	4.4*	4.5*	—	—
Norway	8.7*	8.8*	8.7*	—
Philippines	1.16○	—	—	—
Portugal	6.3*	6.7*	7.2*	—
Singapore	3.04○	3.15△	3.22△	—
Spain	5.5*	5.6*	5.8*	—
Sweden	8.3*	8.1*	—	—
Switzerland	5.2*	5.2*	5.2*	—
Thailand	1.1○	—	—	—
United Kingdom	4.9*	5.1*	5.2*	5.2*
United States	6.5*	—	—	—

Data source: △WHO Global Health Atlas, *OECD, ○FDI.

(2010), 5.8 in Spain (2009), and 6.5 in France (2010), to 7.33 in Belgium (2008; Table 5).

In 2007 in North America, the dentist-to-population ratio was 5.8 for Canada and 6.5 for the United States, according to data from the OECD.[18] In a longitudinal study and a projection of the dental workforce for the United States, Solomon[22] indicates that the dentist-to-population ratio was lowest at 4.9 from 1960 to 1970, increased to a peak of 5.6 in the late 1980s, after which it began to decline, and finally will reach 4.8 in 2020. The number of dentists increases at the same pace as the growth of the population, resulting in a stable dentist-to-population ratio varying from 4.9 to 5.6 in the United States from 1940 to 2010.

Among countries or regions in the Asia-Pacific region, Japan has the highest dentist-to-population ratio of 7.7 in 2008, and China has the lowest dentist-to-population ratio of 0.12 in 2007. In between are the dentist-to-population ratios of India (0.29 in 2007), Indonesia (0.6 in 2007), Thailand (1.1 in 2007), the Philippines (1.16 in 2007), Malaysia (1.36 in 2008), Hong Kong (2.26 in 2007), Singapore (3.22 in 2009), the Republic of Korea (4.2 in 2009), New Zealand (4.95 in 2007), and Australia (6.91 in 2009). Taiwan had a dentist-to-population ratio of 5.0 (in 2010), which was lower than the ratio in Japan and Australia, but higher than the ration in most Asia-Pacific countries.

In the next 10 years (2011—2020), the economic growth in Taiwan may steadily increase to the level of the OECD countries. The current dentist-to-population ratio of OECD countries was 5.0. For the United States, the dentist-to-population ratio in the past 70 years has fluctuated from 4.9 to 5.6. Therefore, we could assume that in the next decade a dentist-to-population ratio of 5.0 could be maintained to provide adequate dental care in Taiwan.

The increase in dentists and the decrease in population could augment the dentist-to-population ratio up to 6.0 by 2020 in Taiwan, which was almost equal to the dentist-to-population ratio of 6.1 reported in 2009 in the OECD countries.[18] If the economic growth and dental use in Taiwan is not the same as those in the OECD countries, this type of high-dentist-to-population ratio dental workforce should be managed by increasing dental workforce demands (e.g., providing dental care for disabled and elderly persons, demographic balance for dental-workforce shortage areas, oral health promotion or prevention, and increase in population) and by decreasing the dental workforce supply (e.g., decreasing working hours, longer holidays, decreasing the enrollment of dental students, and increasing the outflow to needy countries). However, the complexity and the uncertainty of various factors in the supply and demand model may further complicate the dental workforce projection.

We conclude that a steady supply of 400 dentists per year is expected for the next 10 years from 2011 to 2020. However, the population will grow slowly or even decrease in the same period. The dentist-to-population ratio may reach 6.0 by 2020, which is close to that of the OECD countries. With a current dentist-to-population ratio of 5.0, more than 80% of patients in Taiwan are satisfied with their current dental service. If the dentist-to-population ratio remains constant at 5.0 until 2020, the number of surplus dentists will be 1069, after adjusting for working hours per day, working days per week, and gender differences. Strategic management of surplus dentists should be planned by increasing dental care for the aged, disabled people, and underserved people.

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