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Dentist manpower development and geographical distribution of dentists in Taiwan

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Abstract *Background/purpose:* The development of dentists in Taiwan has been over a century. This study tried to explore the dentist manpower development and the current status of geographical distribution of dentists in Taiwan.
Materials and methods: This study used the secondary data analysis to survey the changes of total dentist number from 1986 to 2018 and the geographic distribution of dentists in different levels of dental institutions in 2019.
Results: The total number of dentists increased from 3739 in 1986 to 14,717 in 2018. The total number of hospital dentists increased from 809 in 1986 to 2121 in 2018. However, the proportion of hospital dentists in the total number of dentists decreased from 21.64% in 1986 to 14.41% in 2018. On the contrary, the total number of dental clinic dentists increased from

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2930 in 1986 to 12,596 in 2018. The proportion of dental clinic dentists in the total number of dentists increased from 78.36% in 1986 to 85.59% in 2018. The northern region of Taiwan and Taipei City had 52.81% (7829/14,825) and 22.29% (3304/14,825) of the total number of dentists in 2019, respectively. Hospital dentists showed a significantly greater imbalance in geographic distribution than overall dentists.

Conclusion: Our results indicate that Taiwan has the problems of oversupply of dentists and imbalance in geographical distribution of dentists. Because continuation of the current dentist manpower development may accelerate the oversupply and geographical imbalance of dentists, a mechanism for controlling the total dentist manpower should be implemented to prevent the deterioration of the problems.

Introduction

The Department of Dentistry of National Taiwan University established in 1953 was the first local institution for dental education established in Taiwan. The earliest dental students in the Department of Dentistry of National Taiwan University were recruited in 1955 to open a new era of dental education in Taiwan. Although dentists are also a type of physician, the physicians under the "Physician Law" in Taiwan did not include dentists at that time. Until 1967, the Legislative Yuan in Taiwan passed the new "Physician Law", and then dentists were recognized as "legal physicians" under the new "Physician Law". However, the new "Physician Law" was formally implemented until 1975, after which the dentist was the only qualified dental practitioner with a dentist license. Since Japanese colonial period in 1916 (Taisho 5), the legal status of a dentist as a "legal physician" determined by "Taiwan Dentist Ordinance" has been delayed for almost 60 years.[1] So we know that the development of dentists in Taiwan has been over a century since the Japanese colonial period when the dentists were first recognized as having a professional position by law.

Since the establishment of the Department of Dentistry of National Taiwan University, after more than 60 years of development, there are now eight universities that have departments of dentistry - four in the northern, two in the central, and two in the southern regions of Taiwan. According to the statistics from the Ministry of Health and Welfare, the number of practicing dentists increased from 8944 in 2001 to 14,717 in 2018, with a total growth rate of approximately 64.5% and an average annual growth rate of 2%～3%. Thus, the dentist manpower growth rate in Taiwan is relatively stable.[2] However, because the practicing styles of dentists and physicians in Taiwan are very different, for dentists more than 85% of them serve in dental clinics, and less than 15% serve in hospitals, but for physicians 36.5% of them serve in private clinics and 63.5% serve in hospitals.[3] A previous study found that the number of dentists in hospitals was 22% of the total number of dentists nationwide in 1986; this proportion decreased to 13% in 2004 and remained stable until 2008. Approximately half of the dentist manpower resources in hospitals concentrate in the northern region of Taiwan. In contrast, there are about 20% dentist manpower resources in the central region and 20% in the southern region of Taiwan. The eastern region and offshore islands have very few dentist manpower resources in Taiwan.[4] Meanwhile, dental clinics designated as training institutions and teaching hospitals (especially medical centers) are usually concentrated in the northern and urban areas of Taiwan.[5] It is consistent with the conclusions of a Japanese study reporting that prefectures with more dentists or dental clinics have a greater ability to offer postgraduate clinical training for dentists.[6]

Therefore, how to balance the dentist manpower resources in different regions of Taiwan becomes a pivotal issue in the future. For example, in 2018, the eighth department of dentistry in a university was established in the southern part of Taiwan, due to the consideration of the balance of distribution of departments of dentistry in Taiwan.[3] Because there were few studies on dentist manpower development and geographical distribution of dentists in Taiwan, this study focused on the analysis of changes of the numbers of dentists who practiced in hospitals or dental clinics over the past 32 years, and compared the numbers of dentists in different levels of dental institutions located in different regions of Taiwan in 2019.

Material and methods

In this study, we adopted the method of the secondary data analysis to collect the information about the numbers of practicing dentists, practicing physicians, and total population in Taiwan from 1986 to 2018, and the information regarding to the numbers of dentists in different levels of hospital and in dental clinics in 2019. These two parts of information were collected from the secondary data analysis. Both of them were open information and described as follows.

Dentist manpower development from 1986 to 2018

This study obtained the following information from 1986 to 2018 based on the data from the Ministry of Health and Welfare survey, including the numbers of dentists and physicians in hospitals or in clinics, and total population at

the end of each year.[2] Based on the information obtained, the following values were calculated: the number of dentists per 100,000 people, the number of physicians per 100,000 people, and the corresponding ratio of the number of dentists to that of physicians.

Geographical distribution of dentists in 2019

In the open information webpages of the Ministry of Health and Welfare by the time of October 2019, the information including the numbers of hospitals of different levels (medical center, regional hospital, and district hospital) and the number of hospitals with a dental department (so-called the hospital dentistry) could be obtained. Meanwhile, the information of hospitals including the city or county locations of hospitals, hospital levels, and the numbers of dentists in each hospital could be further obtained. Besides, the similar information about the total numbers of dentists nationwide by city and county in October 2019 could also be obtained from the Newsletter of Taiwan Dental Association.[7] The population data could be acquired from the open information webpages of the Ministry of the Interior.

All hospitals were classified into three levels: medical center, regional hospital, and district hospital. The whole area of Taiwan was divided into five regions: northern, central, southern, and eastern regions and offshore islands. The northern region included Taipei City, New Taipei City, Keeling City, Taoyuan City, Hsinchu City, and Hsinchu County. The central region included Miaoli County, Taichung City, Changhua County, Nantou County, and Yunlin County. The southern region included Chiayi City, Chiayi County, Tainan City, Kaohsiung City, Pingtung County, and Penghu County. The eastern region included Yilan County, Hualien County, and Taitung County. The offshore islands included Kinmen County and Lienchiang County.

We adopted the statistical methods of a Japanese study described as follows.[8] The number of dentists registered in individual dental institutions was summed by city or county, and the result was defined as the number of dentists in dental institutions. On the other hand, according to the levels of hospitals, the numbers of dentists who registered in hospitals of different levels were divided into three categories and summed by city or county, which was defined as the number of dentists in medical centers, the number of dentists in regional hospitals, and the number of dentists in district hospitals. Using these numbers as indices, this study compared disparities in the number of dentists among different regions of Taiwan and among different cities and counties of Taiwan. As the control index, the number of overall dentists was determined by city or county, based on data from the Newsletter of Taiwan Dental Association.[7] From the difference between the number of overall dentists and the number of dentists in hospitals, the number of dentists in dental clinics could be calculated. Therefore, the number of dentists in dental clinics in different locations could also be compared in this study.

From the numbers of dentists in medical centers, regional hospitals, district hospitals, and dental clinics as well as overall dentists, the ratio of the maximum to minimum number (non-zero), and coefficient of variation were calculated as indicators of the maximum gap and relative dispersion, respectively. Then, Lorenz curves and Gini coefficients were used as indicators of equality of geographical distribution of practicing dentists. In this study, the X axis of the Lorenz curve represented the cumulative percentages of the population sequentially from the city or county with the fewest dentists per population. The Y axis represented the cumulative percentages of dentists in medical centers, regional hospitals, district hospitals, and dental clinics as well as overall dentists. The Gini coefficients were derived from the Lorenz curves.

Based on the data and information collected from the methodologies that just mentioned above, they were stored in excel files and were put into analysis. The results in this study helped us to understand dentist manpower development and the current geographical distribution of dentists in Taiwan, and they became important references for the dentist manpower planning.

Results

The numbers of dentists and physicians in hospitals or clinics and the total population from 1986 to 2018 were obtained and shown in Table 1. We analyzed the tendencies by calculating the average numbers of dentists and physicians, dentists in hospitals or (dental) clinics per 100,000 people, and the corresponding ratio of the number of dentists to the number of physicians to estimate the differences of those tendencies. Besides, a list of 180 hospitals with dental departments for 2019 was collected. The Tables 2 and 3 show the numbers of medical center dentists, regional hospital dentists, district hospital dentists, and dental clinic dentists as well as overall dentists mainly by different regions of Taiwan and by cities and counties, respectively. Moreover, Fig. 1 shows the Lorenz curves of different-typed dentists and overall dentists mentioned above by city and county.

The changes of the total numbers of dentists and physicians from 1986 to 2018

In Taiwan, the total population increased from 19.36 million in 1986 to 23.59 million in 2018 (Table 1). Meanwhile, the total number of dentists increased from 3739 in 1986 to 14,717 in 2018. The increment was about 300—400 dentists per year with a total increase e of 10,978 dentists by 293.61%. To consider the corresponding number of dentists per population, the number of overall dentists per 100,000 people increased from 19.3 in 1986 to 62.4 in 2018, demonstrating an increase of 1.35 dentists per 100,000 people per year (Table 1). In other words, the number of people served by each dentist decreased from 5177 in 1986 to 1603 in 2018.

On the other hand, the total number of physicians increased from 15,767 in 1986 to 47,426 in 2018 (Table 1). The increment was about 900—1000 physicians per year with a total increase of 31,659 physicians by 200.79%. To consider the corresponding number of physicians per population, the number of overall physicians per 100,000 people increased from 81.5 in 1986 to 201.1 in 2018,

Table 1 The changes of the total numbers of dentists and physicians from 1986 to 2018.

Year[a]	Total population	Dentists			Physicians[b]		
		Hospital	Clinic	Total	Hospital	Clinic	Total
1986	19,356,331	809	2930	3739	8483	7284	15,767
1987	19,672,612	887	3263	4150	9739	7306	17,045
1988	19,903,812	966	3545	4511	10,811	7382	18,193
1989	20,107,440	961	3904	4865	11,322	7207	18,529
1990	20,352,966	1112	4337	5449	12,298	7623	19,921
1991	20,556,842	1195	4788	5983	13,063	8052	21,115
1992	20,752,494	1253	5195	6448	13,887	8457	22,365
1993	20,995,416	1281	5259	6540	14,723	8752	23,491
1994	21,177,874	1316	5657	6973	15,359	9083	24,455
1995	21,357,431	1183	5841	7024	14,892	9557	24,462
1996	21,525,433	1136	6118	7254	14,611	10,134	24,790
1997	21,742,815	1153	6420	7573	15,095	10,581	25,730
1998	21,928,591	1190	6710	7900	16,221	10,850	27,168
1999	22,092,387	1227	7013	8240	17,393	10,757	28,216
2000	22,276,672	1268	7329	8597	18,559	10,963	29,585
2001	22,405,568	1295	7649	8944	19,426	11,108	30,562
2002	22,520,776	1326	7880	9206	20,177	11,334	31,532
2003	22,604,548	1292	8259	9551	20,453	11,912	32,390
2004	22,689,122	1309	8559	9868	20,820	12,509	33,360
2005	22,770,383	1316	8824	10,140	21,158	12,903	34,061
2006	22,876,527	1335	9077	10,412	21,756	13,108	34,864
2007	22,958,360	1368	9372	10,740	22,415	13,400	35,815
2008	23,037,031	1421	9672	11,093	23,362	13,737	37,099
2009	23,119,772	1458	9893	11,351	23,918	13,923	37,841
2010	23,162,123	1509	10,147	11,656	24,469	14,380	38,849
2011	23,224,912	1568	10,424	11,992	24,993	14,967	39,960
2012	23,315,822	1647	10,744	12,391	25,536	15,361	40,897
2013	23,373,517	1764	11,030	12,794	26,187	15,737	41,924
2014	23,433,753	1870	11,308	13,178	26,808	16,112	42,920
2015	23,492,074	1918	11,584	13,502	27,567	16,394	43,961
2016	23,539,816	1982	11,930	13,912	28,115	16,688	44,803
2017	23,571,227	2115	12,264	14,379	29,283	17,028	46,311
2018	23,588,932	2121	12,596	14,717	30,098	17,328	47,426

[a] Including Kinmen County and Lienchiang County since 1993.
[b] Very few physicians practiced in institutions that do not belong to hospitals or clinics.

Table 2 Numbers of institutions and their practicing dentists in different levels of hospitals, dentists in clinics, overall dentists in different regions of Taiwan in October 2019.

Region of Taiwan	Medical center		Regional hospital		District hospital		Total hospitals		Clinic dentists	Overall dentists
	Institutions	Dentists	Institutions	Dentists	Institutions	Dentists	Institutions	Dentists		
Northern	12	681	30	382	29	99	67	1162	6667	7829
Central	6	196	19	128	19	62	44	386	2646	3032
Southern	5	314	22	214	20	57	47	585	2959	3544
Eastern	1	22	6	46	9	9	16	77	318	395
Offshore islands	0	0	0	0	2	3	2	3	22	25
Total	24	1213	77	770	79	230	180	2213	12,612	14,825
Maximum gap	9	25	9	79.5	11	43	26	728	858.67	550.67
Coefficient of variation	1.94	2.24	0.88	1.21	0.78	1.12	0.90	1.64	1.37	1.38
Gini coefficient	—	0.57	—	0.22	—	0.26	—	0.37	0.33	0.31

Table 3 Numbers of institutions and their practicing dentists in different levels of hospitals, dentists in clinics, and overall dentists in different regions of Taiwan by city and county in October 2019.

Region of Taiwan	City or county[a]	Medical center		Regional hospital		District hospital		Total hospitals		Clinic dentists	Overall dentists
		Institutions	Dentists	Institutions	Dentists	Institutions	Dentists	Institutions	Dentists		
Northern											
	Taipei City	9	550	11	159	10	19	30	728	2576	3304
	New Taipei City	2	51	7	132	4	15	13	198	2399	2597
	Keeling City	0	0	2	18	3	4	5	22	162	184
	Taoyuan City	1	80	7	39	5	43	13	162	1016	1178
	Hsinchu City	0	0	2	32	4	14	6	46	276	322
	Hsinchu County	0	0	1	2	3	4	4	6	238	244
Central											
	Miaoli County	0	0	2	7	1	5	3	12	163	175
	Taichung City	4	142	9	57	6	10	19	209	1738	1947
	Changhua County	2	54	3	48	6	20	11	122	452	574
	Nantou County	0	0	1	3	4	24	5	27	134	161
	Yunlin County	0	0	4	13	2	3	6	16	159	175
Southern											
	Chiayi City	0	0	3	40	1	1	4	41	188	229
	Chiayi County	0	0	2	19	1	3	3	22	82	104
	Tainan City	2	123	6	66	3	12	11	201	926	1127
	Kaohsiung City	3	191	7	74	11	36	21	301	1535	1836
	Pingtung County	0	0	4	15	3	4	7	19	193	212
	Penghu County	0	0	0	0	1	1	1	1	35	36
Eastern											
	Yilan County	0	0	3	32	1	1	4	33	150	183
	Hualien County	1	22	2	11	5	5	8	38	109	147
	Taitung County	0	0	1	3	3	3	4	6	59	65
Offshore islands											
	Kinmen County	0	0	0	0	1	0	1	0	19	19
	Lienchiang County	0	0	0	0	1	3	1	3	3	6

[a] There are six municipalities in Taiwan: Taipei City, New Taipei City, Taoyuan City, Taichung City, Tainan City, and Kaohsiung City.

indicating an increase of 3.74 physicians per 100,000 people per year (Table 1). In other words, the number of people served by each physician decreased from 1228 in 1986 to 497 in 2018.

Therefore, it implied that for the same number of people there were more and more dentists and physicians in Taiwan in the recent 32 years. Thus, the people obtained higher quantity and quality of dental and medical services in the recent 32 years.

The changes of the total numbers of dentists in hospitals and in dental clinics from 1986 to 2018

The total number of hospital dentists increased from 809 in 1986 to 2121 in 2018 with a total increase of 1312 dentists by 162.18%. However, the proportion of hospital dentists in the total number of dentists decreased from 21.64% in 1986 to 14.41% in 2018 (Table 1). On the other hand, the total number of dental clinic dentists increased from 2930 in 1986 to 12,596 in 2018 with a total increase of 9666 dentists by 329.90%. The proportion of dental clinic dentists in the total number of dentists increased from 78.36% in 1986 to 85.59% in 2018 (Table 1). Thus, our results indicate a 3.3-fold increase of dentists and a shift of dentists from the hospitals to the dental clinics from 1986 to 2018 (Table 1).

The changes of the total numbers of physicians in hospitals and clinics from 1986 to 2018

The total number of hospital physicians increased from 8483 in 1986 to 30,098 in 2018 with a total increase of 21,615 physicians by 254.80%. However, the proportion of hospital physicians in the total number of physicians increased from 53.80% in 1986 to 63.46% in 2018 (Table 1). On the contrary, the total number of clinic physicians increased from 7284 in 1986 to 17,328 in 2018 with a total increase of 10,044 physicians by 137.89%. The proportion of clinic physicians in the total number of physicians decreased from 46.20% in 1986 to 36.54% in 2018. Therefore, our results show a 2.5-fold increase of physicians and a shift of physicians from the clinics to the hospitals from 1986 to 2018 (Table 1).

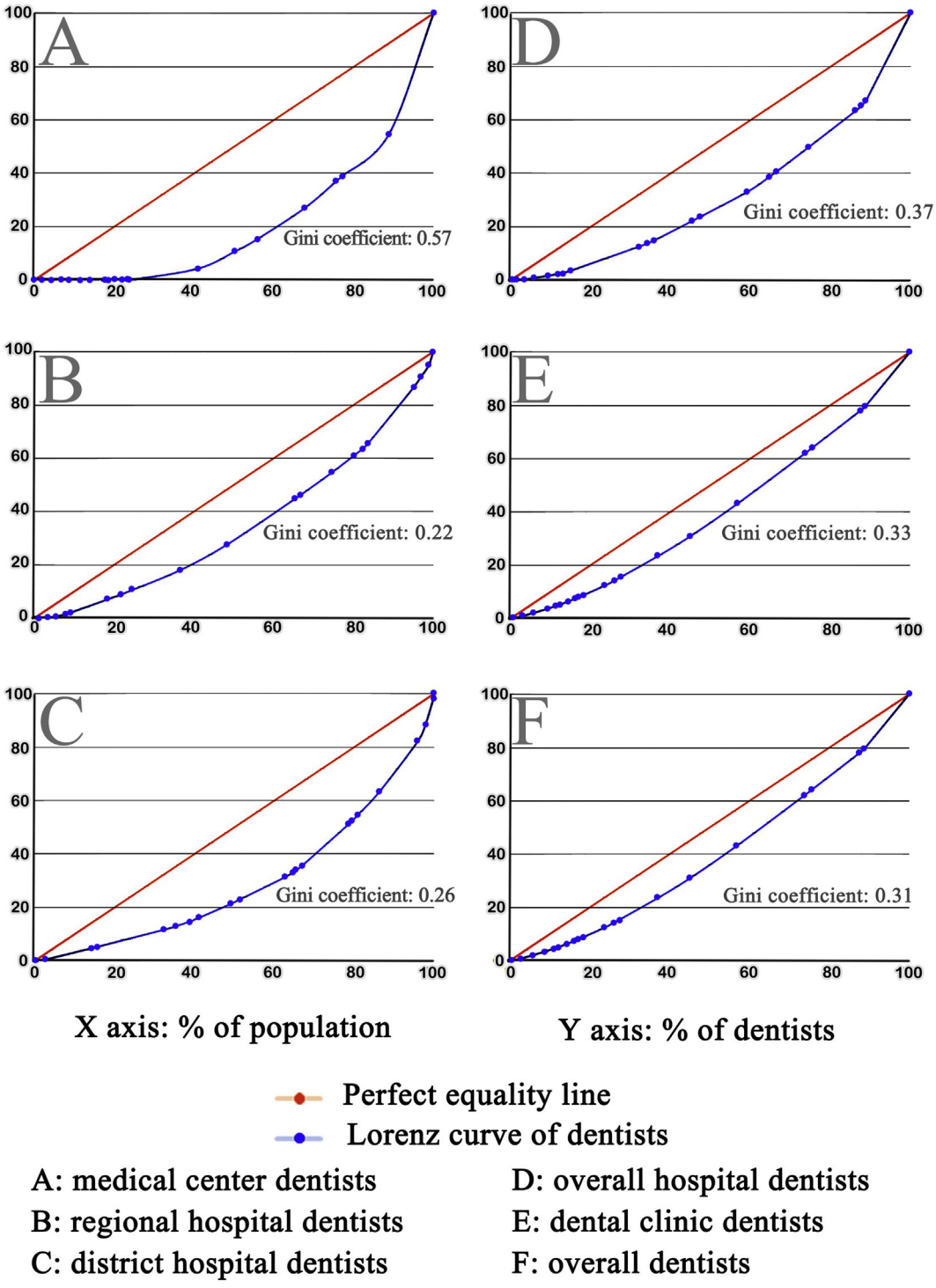

Figure 1 The Lorenz curves of different-typed dentists and overall dentists by city and county.

The changes of the ratios of the number of dentists to that of physicians from 1986 to 2018

The ratio of the number of dentists to the number of physicians increased from 0.237 in 1986 to 0.310 in 2018 (Table 1). However, the ratio of the number of dentists to the number of physicians in hospitals decreased from 0.095 in 1986 to 0.070 in 2018 (Table 1). The ratio of the number of dentists to the number of physicians in clinics increased from 0.402 in 1986 to 0.727 in 2018 (Table 1). These results indicate that the increased proportion of dentists is higher than that of physicians. However, there is a gradual shift of dentists from the hospitals to the dental clinics. On the contrary, there is a gradual shift of physicians from the clinics to the hospitals.

The number of hospitals with dental departments in 2019

In Taiwan, the total number of hospitals of all three different levels was 474, including 25 medical centers, 89 regional hospitals, and 360 district hospitals. In these 474 hospitals, 180 established dental departments, so-called the hospital dentistry. Of these 180 hospitals with dental departments, 24 were medical centers, 77 were regional hospitals, and 79 were district hospitals (Table 2). Thus, 96% (24/25) medical centers, 86.52% (77/89) regional hospitals, and 21.94% (79/360) district hospitals had dental departments. There were 4 children's hospitals belonging to medical centers, of which 3 had dental departments. Moreover, the mean numbers of dentists per hospital were 50.54 for the medical center, 10.00 for the regional hospital, and 2.91 for the district hospital (Table 2).

The geographical distribution of medical center dentists in 2019

There were 20 cities or counties in Taiwan and 2 counties in the offshore islands (Table 3). The total number of medical center dentists was 1213 (Table 2). Taipei City had the largest number of medical center dentists (550, 45.34%), and Hualien County had the smallest number of medical center dentists (22, 1.81%). Moreover, there were 14 cities or counties without any medical center (Table 3). The mean number of medical center dentists in 22 cities and counties was 55.14 (Table 2). There were 17 out of the 22 cities and counties with the medical center dentists being below the average number of 55.14 (with 54 or fewer medical center dentists) (Table 3). Therefore, the maximum gap was >25-fold, the coefficient of variation was 2.24, and the Gini coefficient was 0.57 (Table 2).

The geographical distribution of regional hospital dentists in 2019

The total number of regional hospital dentists was 770 (Table 2). Taipei City had the largest number of regional hospital dentists (159, 20.65%), and Hsinchu County had the smallest number of regional hospital dentists (2, 0.26%). There were 3 counties (Penghu, Kinmen and Lienchiang Counties) without any regional hospital (Table 3). The mean number of regional hospital dentists in 22 cities and counties was 35 (Table 2). There were 14 out of the 22 cities and counties with the regional hospital dentists being below the average number of 35 (with 32 or fewer regional hospital dentists) (Table 3). Thus, the maximum gap was >79.5-fold, the coefficient of variation was 1.21, and the Gini coefficient was 0.22 (Table 2).

The geographical distribution of district hospital dentists in 2019

The total number of district hospital dentists was 230 (Table 2). Taoyuan City had the largest number of district hospital dentists (43, 18.70%), and Chiayi City, Penghu County, and Yilan County had the smallest number of district hospital dentists (1, 0.43%). There was no city or county without any district hospital with dental department (Table 3). Although there was a district hospital with dental department in Kinmen County, there was no dentist in that district hospital at the time of enquiry. The mean number of district hospital dentists in 22 cities and counties was 10.45 (Table 2). There were 14 out of the 22 cities and counties with the district hospital dentists being below the average number of 10.45 (with 10 or fewer district hospital dentists) (Table 3). Thus, the maximum gap was >43-fold, the coefficient of variation was 1.12, and the Gini coefficient was 0.26 (Table 2).

The geographical distribution of hospital dentists in 2019

In Taiwan, hospital accreditation is divided into three levels: medical center, regional hospital, and district hospital. Therefore, the total number of hospital dentists was 2213 (Table 2). Taipei City had the largest number of hospital dentists (728, 32.90%), and Penghu County had the smallest number of hospital dentist (1, 0.05%) (Table 3). There was none of hospital dentist in Kinmen County. The mean number of hospital dentists in 22 cities and counties was 100.59 (Table 2). There were 15 out of the 22 cities and counties with the hospital dentists being below the average number of 100.59 (with 46 or fewer hospital dentists) (Table 3). Thus, the maximum gap was >728-fold, the coefficient of variation was 1.64, and the Gini coefficient was 0.37 (Table 2).

The geographical distribution of dental clinic dentists in 2019

The total number of dental clinic dentists was 12,612 (Table 2). Taipei City had the largest number of dental clinic dentists (2,576, 20.42%), and Lienchiang County had the smallest number of dental clinic dentists (3, 0.02%) (Table 3). The mean number of dental clinic dentists in 22 cities and counties was 573.27 (Table 2). There were 16 out of the 22 cities and counties with the dental clinic dentists being below the average number of 573.27 (with 452 or fewer dental clinic dentists) (Table 3). Thus, the maximum gap was 858.67-fold, the coefficient of variation was 1.37, and the Gini coefficient was 0.33 (Table 2).

The geographical distribution of overall dentists in 2019

The number of overall dentists was 14,825 (Table 2). Taipei City had the largest number of overall dentists (3,304, 22.29%), and Lienchiang County had the smallest number of overall dentists (6, 0.04%). The mean number of overall dentists in 22 cities and counties was 673.86 (Table 2). There were 16 out of the 22 cities and counties with the overall dentists being below the average number of 673.86 (with 574 or fewer overall dentists) (Table 3). The maximum gap was 550.67-fold, the coefficient of variation was 1.38, and the Gini coefficient was 0.31 (Table 2).

Comparisons among regional distribution of different-typed dentists in 2019

The overall number of dentists was 14,825, including 1213 dentists in medical centers, 770 in regional hospitals, 230 in district hospitals, and 12,612 in dental clinics (Table 2). Comparisons among the numbers of those dentists by regions revealed that the maximum numbers of different types of dentists were all in the northern region of Taiwan, including 681 dentists in medical centers, 382 dentists in regional hospitals, 99 dentists in district hospitals, 6667 in dental clinics, and 7829 for the overall dentists (Table 2). Approximately half of the dentists, including 56.14% of medical center dentists, 49.61% of regional hospital dentists, 43.04% of district hospital dentists, 52.86% dental clinic dentists, and 52.81% of overall dentists, populated in the northern region of Taiwan (Table 2). Predictably, very few dentists (25 dentists, 0.17%) served in offshore islands. Of these 25 dentists, 3 (1.30%) served in district hospitals and 22 (0.17%) served in dental clinics (Table 2).

Comparisons among geographical distribution of different-typed dentists

Comparisons among the numbers of hospital dentists revealed that the maximum numbers of hospital dentists were 550 for the medical center, 159 for the regional hospital in Taipei City, and 43 for the district hospital in Taoyuan City. The minimum numbers (non-zero) of hospital dentists were 22 for the medical center in Hualien County, 2 for the regional hospital in Hsinchu County, and 1 for the district hospital in Chiayi City, Penghu County, and Yilan County (Table 3). Thus, the maximum gap in the number of hospital dentists was >728-fold, which remained larger than the maximum gap in the number of overall dentists (550.67-fold). However, the maximum gap in the number of dental clinic dentists (858.67-fold) was also larger than that of overall dentists (550.67-fold) (Table 2).

The coefficient of variation for the number of overall dentists was 1.38, which was smaller than that of medical center dentists (2.24) but was larger than that of regional hospital dentists (1.21) and that of district hospital dentists (1.12), indicating that the geographical distribution of dentists in medical centers was more widely dispersed than that of overall dentists. However, the coefficient of variation for the number of dental clinic dentists (1.37) was close to that of overall dentists (1.38) (Table 2).

The Lorenz curves for the numbers of dental clinic dentists and overall dentists were also closer to the perfect equality line than that for the number of medical center dentists (Fig. 1). The Gini coefficient for the dental clinic dentists and overall dentists were 0.33 and 0.31, respectively, which were both lower than the Gini coefficient of 0.57 for the medical center dentists. For the numbers of dental clinic dentists and overall dentists, however, the Lorenz curves were not closer to the perfect equality line than those of regional hospital dentists and district hospital dentists, which had the Gini coefficients of 0.22 and 0.26, respectively (Fig. 1). These findings indicate that the disparities in the number of hospital dentists among cities and counties were compensated by regional hospitals and district hospitals with a more diffuse distribution in Taiwan. However, the practicing dentists were dominated by dental clinic dentists, accounting for 85.07% of the overall dentists (Table 2). Thus, our results indicate that the disparities in the number of overall dentists among cities and counties were predominantly determined by a large proportion of dental clinic dentists in overall dentists.

Discussion

The number of dentists in Taiwan increased gradually from 1986 to 2018. According to the statistics of the Ministry of Health and Welfare,[2] the total population of the country was about 19.36 million, the number of dentists was 3,739, and the number of people served by each dentist was 5,177, equivalent to 19.3 dentists per 100,000 people in 1986. By the end of year 2000, the total population exceeded 22.27 million, the number of dentists increased to 8,597, and the number of people served by each dentist became 2,591, equivalent to 38.6 dentists per 100,000 people, twice as much as that in 1986. It is obvious that the dentist manpower growth and the population growth are very stable. However, after year 2000, Taiwan's population growth rate turned close to zero growth. In 2018, the population increased to about 23.59 million. The number of people served by each dentist was 1,603, equivalent to 62.4 dentists per 100,000 people. Compared to year 2000, the increase rate of dentists was 71.2%, far exceeding the population growth rate of 5.9%.

Because the Ministry of Education did not restrict the growth of dentists, the National Health Insurance was implemented in 1995, and the relative increase in the income of the dentist, the department of dentistry in each university became a popular department, which also led to an increase in the number of dental students (including those studying dentistry in developed foreign countries), a decline in the number of dental students who re-took the university entrance examination for leave from department of dentistry, and a surge in the number of practicing dentists. Therefore, some scholars suggested that "the manpower of dentists needs to maintain a certain number".[9]

The number of dentists increased significantly after the implementation of National Health Insurance. Although the increase in the number of dentists has a positive effect on the overall national oral health care, there are still some needs of dental services by dentists due to the elevation of aged people in Taiwan. Therefore, it is necessary to assess whether the manpower of dentists is sufficient to meet the demand or oversupplied at this stage.

In 2010, the National Health Research Institutes had proposed the issue on 2020 dentist manpower planning, and suggested that a mechanism to control the total dentist manpower should be established as soon as possible to control the number of people serviced by each dentist between 1900 and 2000. Besides, the total number of enrolled dental students in the eight departments of dentistry of domestic universities should be limited to 350 each year. The Ministry of Education should avoid increasing the enrollment quota of dental students through the informal admission channels.[10]

According to an American standard, the ideal value of the number of people served by each dentist was 2,000, equivalent to 50 dentists per 100,000 people.[11] In fact, Taiwan had reached this standard as early as in year 2010. At that time, the total population of Taiwan was about 23.16 million, the number of dentists was 11,656, and the number of people served by each dentist was 1,987, equivalent to 50.3 dentists per 100,000 people. The National Health Research Institutes used different methods to estimate Taiwan's dentist manpower demand in 2020. The results showed that the demand of the number of dentists were between 12,222 and 15,421, and the number of people served by each dentist was 1520 to 1,918, equivalent to 52.1 to 65.8 dentists per 100,000 people.[10] Based on the data of this study in October 2019, the total population of Taiwan was about 23.59 million, the number of dentists was 14,825, and the number of people served by each dentist was 1,592, equivalent to 62.8 dentists per 100,000 people. Thus, the current dentist manpower in Taiwan exactly meets the demand estimates of the National Health Research Institutes, and it is even oversupplied.

In 2018, the number of people served by each physician was 497, equivalent to 201.1 physicians per 100,000 people. If it was estimated by the ideal ratio of dentists to physicians of 1:3,[10] the demand of the number of people served by each dentist was 1,491, equivalent to 67.0 dentists per 100,000 people. In the superficial viewpoint, it seems that the current dentist supply is less than this estimate, but in fact the current oversupply of physicians is more serious than that of dentists in Taiwan.

Besides, according to a press release issued by the Ministry of Health and Welfare on June 24, 2019, the results surveyed by Association for Dental Sciences of the Republic of China (ADS-ROC) in 2018 showed that there were 6.05 dentists per 10,000 people (i.e., the number of people served by each dentist was 1677) in Taiwan, this datum was similar to that in the developed countries such as the United States, Australia, Canada, and France. About 420 graduates from dental schools each year have entered the dental service market. The dentist manpower cultivated by the eight dental departments of domestic universities alone is sufficient to meet the current demand for the dental service market. The statistics from the Ministry of Examination showed that the numbers of dental graduates who passed the national license examination in the graduation years from 2011 to 2015 were 407, 429, 450, 465, and 467, respectively. The number of dental graduates who passed the national license examination increased year by year. However, the enrollment of dental students did not increase in the years mentioned above. Thus, the increase in the qualified dentists per year should be derived from foreign dental graduates. To consider the problem that the number of foreign dental graduates returning to Taiwan increased year by year, the domestic dentist manpower was actually oversupplied. Unfortunately, this problem has already happened.

From 1986 to 2018, the number of dentists in hospitals increased slowly from 809 to 2121. After 32 years, a total of 1312 hospital dentists have been added, with a mean annual increase of 41 dentists per year. Interestingly, during the period from 1986 to 2018, the number of hospital dentists decreased twice and increased significantly once. Since the National Health Insurance implemented in year 1995, the income of dental clinic dentists increased and the life quality of dental clinic dentists improved, while the number of hospital dentists decreased by 180 from 1316 in year 1994 to 1136 in year 1996. Afterwards, the number of hospital dentists increased slowly.[12] However, when the disease of severe acute respiratory syndrome (SARS) suddenly happened in year 2003, the number of hospital dentists decreased by 34 from 1326 in year 2002 to 1292 in year 2003. Moreover, the number of hospital dentists (1316 hospital dentists) in 1994 remained the same as that (1316 hospital dentists) in 2005. The National Health Insurance and SARS actually had a great impact on the number of hospital dentists, and the effect lasted for more than ten years.[4] From 2005 until now, the number of hospital dentists increased by 62 per year. The postgraduate year training program for dentists (PGYD) implemented in year 2010. Although this system was not mandatory, the number of hospital dentists still increased gradually in the first three years from 1509 in 2010 to 1647 in 2012. It showed that the PGYD system was implemented hurriedly and thus many dental graduates were on the sidelines. However, in the next two years, the number of hospital dentists suddenly increased more than one hundred from 1764 in 2013 to 1870 in 2014, suggesting that the PGYD system matured gradually and accepted by the majority of dental graduates. The training period of the PGYD system was two years. Because the hospitals provide better resources for dentistry,[13] an average of 60% of the dental trainees received their PGYD training in the hospitals.[1] Therefore, after a significant increase in the number of hospital dentists for two consecutive years in 2013 and 2014, the increment returned back to a stable level afterwards.

The number of hospital dentists was 21.64% of the overall dentists in 1986, and this value decreased to 14.41% in 2018. On the contrary, the ratio of dentists in dental clinics to overall dentists increased from 78.36% in 1986 to 85.59% in 2018. In fact, after going through SARS event, the ratio of hospital dentists continued to decrease to a lowest point of 12.74% in 2007. Then, the ratio increased gradually to 14.93% based on the data of this study in October 2019. Predictably, due to the implementation of PGYD in 2010 and of comprehensive dental specialist system in 2018, the ratio of hospital dentists may continuously increase to another stable level in the future.

In comparison to the overseas data, other studies have reported that there were 10% dentists working in hospitals and schools, and 90% dentists working in dental clinics in Sweden in 2008. Moreover, 23% dentists work in the public institutions and 77% work as private practitioners in the United Kingdom in 2008; 15% dentists work in the public institutions and schools, and 85% work as private practitioners in Japan in 2004; 18% dentists work in the public institutions and schools, and 82% work as private practitioners in Singapore in 2000.[4] Moreover, there were 5% dentists working in the public institutions or in training, 15% working as part-time dentists, and 80% working as private practitioners in Netherlands in 2004. Furthermore, 22% dentists work in non-private institutions, 6% work in other institutions, and 72% work in private institutions in the United States in 2008.[10] These results indicate that the

practice of dentists in various countries all over the world is mainly working in either the dental clinics or private institutions.

In Taiwan, the Taipei City had the largest numbers of hospitals (including 9 medical centers, 11 regional hospitals, and 10 district hospitals) with dental department and a total of 3304 dentists. However, only one district hospital (none of medical center and regional hospital) was located in Penghu and offshore islands, and there were 36 dentists in Penghu County, 19 dentists in Kinmen County, and 6 dentists in Lienchiang County. Besides, there were 14 out of the 22 cities and counties without any medical center. Thus, the maximum gaps were greater than 728-fold for the hospital dentists, 858.67-fold for the dental clinic dentists and 550.67-fold for the overall dentists. More than half (52.8%) of overall dentists practiced in the northern region of Taiwan. There were 16 out of the 22 cities and counties with the number of dentists below the average (574 dentists). This finding indicates that there is a serious urban-rural disparity in dentist manpower resources in Taiwan. Based on the data reported in October 2019, this study also found a big difference in the number of people served by each dentist in different regions of Taiwan; i.e., the number of people served by each dentist was 801 for the Taipei City, approximately 1100—1400 for the Hsinchu City and Chiayi City, 4841 for the Chiayi County, 3896 for the Yunlin County, and 3867 for the Pingtung County. When compared with the data published 10 years ago in 2009, the number of people served by each dentist was 1036 for the Taipei City, 5765 for the Chiayi County, 4663 for the Yunlin County, and 4550 for the Pingtung County. According to the standard recognized by the Taiwan Dental Association, the lack of dentist manpower means that one dentist should serve more than 4000 people. As time goes by, in Taiwan there is a decrease in regions with insufficient dentist manpower. Moreover, an increased number of dentists have moved to non-urban areas because the implementation of the total budget system for dentists in the national health insurance since 1998. In addition, the increase in dentist manpower in urban areas is relatively low due to the approaching to the saturation point of dentist manpower in the urban areas. Although the health care policies are indeed an important factor influencing the growth of dentists, the phenomenon of oversupply of dentists in the urban areas and the urban-rural imbalance of dentists still exist in Taiwan up to date.[10]

In this study, the Gini coefficient for the hospital dentists was 0.37. However, the Gini coefficients were 0.57 for the medical center, 0.22 for the regional hospital, 0.26 for the district hospital, 0.33 for the dental clinic dentists and 0.31 for the overall dentists. These findings indicate that geographical disparities caused by the increased number of medical center dentists in cities and counties can be partly corrected by the more equal distribution of the number of dentists in regional and district hospitals. However, only 14.93% of the total dentists were hospital dentists. Thus, the disparities in the number of overall dentists were similar to those in the number of dental clinic dentists.

The Lorenz curve and Gini coefficient, expressing the equality level of distribution, are mainly utilized to analyze the imbalance of income. They are also reasonable indicators to be used for analysis of geographical distribution of practicing dentists, because they have already been used as indicators for analyzing the imbalance of geographical distribution of dentists or physicians in other studies.[8,14,15] Moreover, the Gini coefficient has been reported to be 0.340 for the distribution of physicians by municipality in Japan in 1990,[14] and 0.129 for the distribution of overall physicians by state in the United States in 1992.[15]

In fact, it is difficult to directly compare the Gini coefficient values in our study. However, the Gini coefficient is still useful for relative comparisons in the geographical distribution of dentists. For example, in a Japanese study the Gini coefficient has been reported to be 0.405 and 0.335 for the distributions of dental trainees belonging to either a program or a facility, respectively. The same study also demonstrated that the disparities in the number of dental trainees in prefectures can be partly corrected by the redistribution of these dental trainees in the facilities-group system.[8] According to the Gini coefficient values, we found that the geographical disparities caused by medical center dentists could be partly corrected by regional and district hospital dentists. Meanwhile, both the maximum gap and the coefficient of variation for the numbers of dental clinic dentists and overall dentists were similar, indicating that the current distribution of overall dentists is mainly determined by the dentists in the dental clinics that have several characteristics such as smaller organization, wider distribution, and higher proportion.

In conclusion, this study found that the supply of dentists has already exceeded the originally estimated demand. Moreover, the geographical distribution of overall dentists showed a significantly greater imbalance in Taiwan, especially that of medical center dentists. This finding indicates that the problem of dentist oversupply and geographical imbalance of dentists may continue to deteriorate. Therefore, in order to prevent these untoward outcomes, we suggest that a mechanism for absolute control of the total dentist manpower should be implemented. For example, the number of enrolled domestic dental students should not be increased. Moreover, to enroll dental students by informal channels such as department transfer and dual majors should be forbidden. Furthermore, we also have to set a mechanism to control the sudden growth of a large number of dentists graduated from foreign dental schools. In addition, none of the dental department should be allowed to establish in Taiwan in the near future. With regard to the distribution of dentists, the hospital accreditation should include the item that a teaching hospital must have the responsibility to train the dentists for the remote areas of Taiwan. The government should grant subsidies to encourage dentists to serve in the remote areas, and combine the resources of the society into a joint plan to continuously promote the oral health care programs for people living in the remote areas.

Declaration of Competing Interest

The authors have no conflicts of interest relevant to this article.

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