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The relationship between graduation school background and geographical distribution of dentists in Taiwan

Feng-Chou Cheng ^{a,b,c}, Tzu-Chiang Lin ^d, Ling-Hsia Wang ^e,
Wen-Juain Lin ^f, Ming-Chung Lee ^{b**}, Chun-Pin Chiang ^{g,h,i,j*}

^a Chia-Te Dental Clinic, New Taipei City, Taiwan

^b School of Life Science, College of Science, National Taiwan Normal University, Taipei, Taiwan

^c Science Education Center, National Taiwan Normal University, Taipei, Taiwan

^d Center for Teacher Education, National Kaohsiung University of Science and Technology, Kaohsiung, Taiwan

^e Center for the Literature and Art, Hsin Sheng Junior College of Medical Care and Management, Taoyuan, Taiwan

^f Taipei First Girls High School, Taipei, Taiwan

^g Department of Dentistry, National Taiwan University Hospital, College of Medicine, National Taiwan University, Taipei, Taiwan

^h Graduate Institute of Clinical Dentistry, School of Dentistry, National Taiwan University, Taipei, Taiwan

ⁱ Graduate Institute of Oral Biology, School of Dentistry, National Taiwan University, Taipei, Taiwan

^j Department of Dentistry, Hualien Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, Hualien, Taiwan

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Abstract *Background/purpose:* Taiwan's eight dental schools are all located in the western region. This study attempted to analyze the relationship between the geographical distribution of dentists in Taiwan and their graduation school background and to develop several statistical indicators to analyze the geographical distribution of dentists.

Materials and methods: The method of the secondary data analysis was adopted to collect the open information related to the number of the practicing dentists based on their graduation schools and practice locations by cities and counties in Taiwan in January 2023. The data were used to develop several statistical indicators to analyze the geographical distribution of dentists.

* Corresponding author. Department of Dentistry, Hualien Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, No. 707, Section 3, Chung-Yang Road, Hualien, 970, Taiwan.

** Corresponding author. School of Life Science, College of Science, National Taiwan Normal University, No. 88, Sec. 4, Ting-Chou Road, Taipei, 11677, Taiwan.

E-mail addresses: t43006@ntnu.edu.tw (M.-C. Lee), cpchiang@ntu.edu.tw (C.-P. Chiang).

Results: There were 16,533 practicing dentists in Taiwan in January 2023. Of the 16,533 dentists, 15,687 (94.88 %) graduated from domestic dental schools and 846 (5.12 %) graduated from foreign dental schools. For the school location, the coefficient of variation, Gini coefficient, population proportion index, and population density index were the largest (168.57 %, 0.47, 10.76 %, and 3927.01 people/square kilometer) in the dentists graduating from the northern dental schools. In overall, the dentists were concentrated in municipalities, cities, and the northern region of Taiwan, especially those graduating from the northern dental schools.

Conclusion: In Taiwan, the geographical distribution of dentists is highly related to their graduation school background. Promoting a balanced distribution of dental enrollment quotas and dental student sources from different geographical locations and inducing the movement of dentists to the dentist-shortage areas may be the more feasible ways to solve the uneven geographical distribution of dentists in Taiwan.

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Introduction

In Taiwan, the number of people living in cities was more than 50,000 people and accounted for 33 % of the total population in 1956. By the 2000 census, the figure of people living in cities had increased to 78 %. The urban population of the United States was 40 % in 1900 and reached 75 % in 1990. It means that in Taiwan, it took only 44 years to achieve the same degree of urbanization that required almost a century (90 years) in the United States.¹

Taiwan is a long and narrow island, divided into the east and west parts by the central mountains. Since the ancient times, based on factors such as history, industrial development, terrain barriers, and transportation construction, Taiwan's political and economic development and population have been concentrated in the west, especially in its northern region. During the Japanese colonial period (1895–1945), Taiwan's modernization was accelerated, and the Taipei City became the political and economic center of Taiwan. In addition to population, Taiwan's various resources such as medical care, education, transportation construction and public facilities are more and more concentrated in the west, especially in the Taipei City or the northern region.

Regarding the geographical distribution of dentists in Taiwan, our previous researches proved that from the Japanese colonial period to the present, the distribution of dentists has been very uneven. They are concentrated in the urban areas or in the northern region, especially the Taipei City.^{2–7} The location of the medical schools or training hospitals where the physicians attend do affect their choice of practice location, and they tend to practice close to the location where they ever studied or trained.⁸ In addition, our other previous researches on the geographical distribution of dental freshmen in Taiwan found that our high school graduates tend to choose the dental schools close to their hometowns.^{9–11} However, currently Taiwan's eight dental schools are all located in the western region. This means that the distribution of dental schools may also be one of the factors affecting the uneven geographical distribution of dentists.^{12–14}

This study attempted to analyze the relationship between the geographical distribution of dentists in Taiwan and their graduation school backgrounds, and attempted to develop several statistical indicators to analyze the uneven geographical distribution of dentists to compare the differences in these indicators among groups of dentists with different graduation school background. The research results may serve as a reference for formulating the policies of dental education and dental workforce development in the future.

Materials and methods

In this study, we adopted the method of the secondary data analysis to collect the open information related to the number of the practicing dentists based on their graduation schools and practice locations by cities and counties. The information was released by the nationwide dental professional guild (Taiwan Dental Association, TWDA) according to the data of January 2023. In addition, the population data including number and density (people/square kilometer) by cities and counties at the same time were obtained from the website of the Ministry of Interior.

All dentists were classified into two major groups based on their graduation school background: dentists graduating from the domestic dental schools and dentists graduating from the foreign dental schools. Among the dentists graduating from the domestic dental schools, based on their school attributes, they were divided into the dentists graduating from the public, private or military dental schools, while based on their school locations, they were divided into the dentists graduating from the northern, central or southern dental schools.

The whole area of Taiwan was divided into five regions: northern, central, southern, and eastern regions and offshore islands. The northern region included Keelung City, New Taipei City, Taipei 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, and Pingtung County. The eastern region included Yilan County,

Hualien County, and Taitung County. The offshore islands included Penghu County and Kinmen County. Among them, the New Taipei City, Taipei City, Taoyuan City, Taichung City, Tainan City, and Kaohsiung City are municipalities.

Among different dentist groups, the number of dentists was summed by cities and counties, and the other statistical values of each dentist group were calculated, including the proportion of each dentist group in the whole, mean, and standard deviation. We developed five indicators to assess the geographical distribution of the dentists. From the numbers of dentists of each dentist group in different cities or counties, the ratio of the maximum to minimum number (excluding offshore islands), and coefficient of variation were calculated as indicators of the maximum gap and relative dispersion, respectively. Then, the Gini coefficient was used as an indicator of equality of geographical distribution of dentists. Furthermore, the sum of the proportion of the number of dentists in each city or county to the total number of dentists multiplied by the proportion of the population in each city or county to the overall population and the sum of the proportion of the number of dentists in each city or county to the total number of dentists multiplied by the population density of each county or city were used as calculation formulas for the population proportion index and population density index, respectively.

For statistical analysis, from the numbers of dentists of each dentist group, they were further classified as the dentists practicing in municipalities or in non-municipalities, the dentists practicing in cities or in counties, and the dentists practicing in different regions of Taiwan. Then, Mann-Whitney *U* test was used for comparisons between two subgroups, and Kruskal-Wallis test was used for comparisons among three or more subgroups.

Results

In overall, there were 16,533 practicing dentists in Taiwan in January 2023. Of the 16,533 dentists, 15,687 (94.88 %) graduated from the domestic dental schools and 846 (5.12 %) graduated from the foreign dental schools. The distribution of dentists based on their graduation school background and practice place by city and county level administrative districts of Taiwan as well as the population data of the same time are shown in Table 1. Excluding offshore islands, for all dentists, the Taipei City was the city with the largest number (3618) of dentists, while the Taitung County was the county with the smallest number (70) of dentists. The maximum gap of the number of dentists among cities and counties was 51.69. For the dentists graduating from the domestic dental schools, the Taipei City was the city with the largest number (3406) of dentists, while the Taitung County was the county with the smallest number (65) of dentists. The maximum gap was 52.4. For the dentists graduating from the foreign dental schools, the Taipei City was the city with the largest number (212) of dentists, while the Chiayi County was the county with the smallest number (3) of dentists. The maximum gap was 70.67 (Table 1).

Among different dentist groups of the school attribute, there were 12,337 (74.62 %) dentists graduating from the private dental schools, followed by the public (2597,

15.71 %) and the military (753, 4.55 %) dental schools. The Taipei City was the city with the largest number of the dentists graduating from the public (884), private (2314), and military (208) dental schools, respectively. The Chiayi County, Taitung County, and Chiayi City were the counties or cities with the smallest number of the dentists graduating from the public (5), private (50), and military (2) dental schools, respectively. Their maximum gaps were 176.8, 46.28 and 104 for the dentists graduating from the public, private, and military dental schools, respectively (Table 1).

Among different dentist groups of the school location, there were 6918 (41.84 %) dentists graduating from the northern dental schools, followed by the central (5158, 31.20 %) and the southern (3611, 21.84 %) dental schools. The Taipei City, Taichung City, and Kaohsiung City were the cities with the largest number of the dentists graduating from the northern (2131), central (1313), and southern (1180) dental schools, respectively. The Chiayi County was the county with the smallest number (27) of the dentists graduating from the northern dental schools, while the Taitung County was the county with the smallest number of the dentists graduating from the central (13) and southern (20) dental schools, respectively. Their maximum gaps were 78.93, 101, and 59 for the dentists graduating from the northern, central, and southern dental schools, respectively (Table 1).

Furthermore, there were 23,288 thousand people in Taiwan in January 2023. There were 4004 thousand people in the New Taipei City with the largest number, while there were 213 thousand people in the Taitung County with the smallest number. The maximum gap was 18.80 (Table 1). It should be noted that only the calculation of the maximum gap excluded offshore islands, and the calculation of other statistical values and distribution indicators was based on all cities and counties.

For comparisons of the maximum gap and coefficient of variation between the population and all dentists, these values of all dentists (51.69 and 132.42 %) were much greater than those of the population (18.80 and 100.81 %), indicating that the gap in geographical distribution among cities and counties of dentists and its relative dispersion are much greater than those of the population. For comparisons among the various dentist groups, the maximum gap (70.67) and coefficient of variation (140.04 %) of the dentists graduating from the foreign dental schools were greater than those of the dentists graduating from the domestic dental schools (52.4 and 132.16 %). For the school attribute, these values were the largest (176.8 and 179.64 %) for the dentists graduating from public dental schools, followed in a descending order by the dentists graduating from the military (104 and 144.63 %) and the private (46.28 and 127.20 %) dental schools. For the school location, the maximum gap was the largest (101) for the dentists graduating from central dental schools, followed in a descending order by the dentists graduating from the northern (78.93) and the southern (59) dental schools. In addition, the coefficient of variation was the largest (168.57 %) for the dentists graduating from the northern dental schools, followed in a descending order by the dentists graduating from the southern (159.41 %) and the central (135.24 %) dental schools (Table 1).

Table 1 Distribution of dentists based on their graduation school background and practice place by city and county level administrative districts of Taiwan in January 2023.

Number of the dentists	Dentists graduating from the domestic dental schools						Dentists graduating from the foreign dental schools	Overall	Population (thousand people)	
	School attribute			School location						Total
	Public	Private	Military	Northern	Central	Southern				
Practice place										
New Taipei City	614	2015	95	1651	706	367	2724	147	2871	4004
Taipei City	884	2314	208	2131	787	488	3406	212	3618	2488
Taoyuan City	279	975	84	734	373	231	1338	87	1425	2287
Taichung City	143	1839	93	487	1313	275	2075	99	2174	2820
Tainan City	129	1043	33	340	432	433	1205	31	1236	1855
Kaohsiung City	117	1723	99	390	369	1180	1939	97	2036	2732
Keelung City	37	150	10	111	64	22	197	14	211	362
Hsinchu City	75	270	22	186	122	59	367	31	398	453
Chiayi City	22	219	2	68	113	62	243	6	249	263
Hsinchu County	86	179	14	151	82	46	279	9	288	582
Miaoli County	21	153	10	70	87	27	184	16	200	535
Changhua County	49	533	6	167	314	107	588	36	624	1246
Nantou County	11	141	11	43	87	33	163	4	167	480
Yunlin County	16	157	6	53	88	38	179	7	186	664
Chiayi County	5	89	5	27	43	29	99	3	102	488
Pingtung County	26	209	11	64	63	119	246	15	261	799
Yilan County	40	134	13	111	46	30	187	12	199	449
Hualien County	24	104	22	77	43	30	150	12	162	319
Taitung County	11	50	4	32	13	20	65	5	70	213
Penghu County	6	25	4	16	8	11	35	1	36	107
Kinmen County	2	15	1	9	5	4	18	2	20	142
Statistical value										
Total number	2597	12,337	753	6918	5158	3611	15,687	846	16,533	23,288
Proportion	15.71 %	74.62 %	4.55 %	41.84 %	31.20 %	21.84 %	94.88 %	5.12 %	100 %	100 %
Mean	123.67	587.48	35.86	329.43	245.62	171.95	747.00	40.29	787.29	1109
Standard deviation	222.15	747.24	51.86	555.33	332.17	274.11	987.23	56.42	1042.52	1118
Distribution indicator										
Maximum gap	176.8	46.28	104	78.93	101	59	52.4	70.67	51.69	18.80
Coefficient of variation	179.64 %	127.20 %	144.63 %	168.57 %	135.24 %	159.41 %	132.16 %	140.04 %	132.42 %	100.81 %
Gini coefficient	0.50	0.28	0.33	0.47	0.32	0.39	0.30	0.33	0.30	—
Population proportion index	10.75 %	10.25 %	10.00 %	10.76 %	9.95 %	10.01 %	10.32 %	10.29 %	10.32 %	—
Population density index*	4185.42	2860.59	3518.69	3927.01	2596.34	2285.03	3111.51	3424.75	3127.54	—

*The unit is people/square kilometer.

We adopted 3 other statistical analysis methods that required the use of population data for assessing the geographical distribution of dentists. For all dentists, the Gini coefficient, population proportion index, and population density index were 0.30, 10.32 %, and 3127.54 people/square kilometer. For comparisons among the various dentist groups, the Gini coefficient of the dentists graduating from the foreign dental schools (0.33) was greater than that of the dentists graduating from the domestic dental schools (0.30), indicating that the degree of uneven geographical distribution among cities and counties of the dentists graduating from the foreign dental schools is greater than that of the dentists graduating from the domestic dental schools. The population proportion indexes of the dentists graduating from the domestic dental schools and the dentists graduating from the foreign dental schools were 10.32 % and 10.29 %, respectively, indicating that the average population proportion of the practice places of both is roughly the same. In addition, the population density index of the dentists graduating from the foreign dental schools (3424.75 people/square kilometer) was greater than that of the dentists graduating from the domestic dental schools (3111.51 people/square kilometer), indicating that the degree of dense population of the practice place of the dentists graduating from the foreign dental schools is greater than that of the dentists graduating from the domestic dental schools (Table 1).

For the school attribute, the Gini coefficient and population density index were the largest (0.50 and 4185.42 people/square kilometer) for the dentists graduating from the public dental schools, followed in a descending order by the dentists graduating from the military (0.33 and 3518.69 people/square kilometer) and the private (0.28 and 2860.59 people/square kilometer) dental schools, while the population proportion index was the largest (10.75 %) in the dentists graduating from the public dental schools, followed in a descending order by the dentists graduating from the private (10.25 %) and the military (10.00 %) dental schools (Table 1).

For the school location, the Gini coefficient and population proportion index were the largest (0.47 and 10.76 %) in the dentists graduating from the northern dental schools, followed in a descending order by the dentists graduating from the southern (0.39 and 10.01 %) and the central (0.32 and 9.95 %) dental schools, while the population density index was the largest (3927.01 people/square kilometer) for the dentists graduating from the northern dental schools, followed in a descending order by the dentists graduating from the central (2596.34 people/square kilometer) and the southern (2285.03 people/square kilometer) dental schools (Table 1).

The comparisons of distribution among the various dentist groups in municipalities or non-municipalities, in cities or counties, and in different regions of Taiwan are exhibited in Tables 2–4. In overall, the number of the dentists practicing in municipalities (13,360, 80.81 %) was higher than that (3173, 19.19 %) in non-municipalities of Taiwan ($P < 0.001$) (Table 2). Among different dentist groups based on their graduation school background, the number of the dentists of each group practicing in municipalities was higher than that in non-municipalities of Taiwan (all P values < 0.001) (Table 2). In proportion, the

dentists graduating from the domestic dental schools (12,687, 80.88 %) and the dentists graduating from the foreign dental schools (673, 79.55 %) were concentrated in municipalities to a similar extent. For the school attribute, the dentists graduating from the public dental schools (2166, 83.40 %) were most concentrated in municipalities, followed by the dentists graduating from the private (9909, 80.32 %) and the military (612, 81.27 %) dental schools. For the school location, the dentists graduating from northern (5733, 82.87 %) and the southern dental schools (2974, 82.36 %) were more concentrated in municipalities, followed by the dentists graduating from the central dental schools (3980, 77.16 %) (Table 2).

In overall, the number of the dentists practicing in cities (14,218, 86.00 %) was higher than that (2315, 14.00 %) in counties of Taiwan ($P < 0.001$) (Table 3). Among different dentist groups based on their graduation school background, the number of the dentists of each group practicing in cities was higher than that in counties of Taiwan (all P values < 0.01 or 0.001) (Table 3). For comparisons among different dentist groups, their concentration in cities was the same as their concentration in municipalities.

Furthermore, in overall, the number of the dentists practicing in the northern region (8811, 53.29 %) was the largest, followed in a descending order by the southern (3884, 23.49 %), the central (3351, 20.27 %), and the eastern (431, 2.61 %) regions and offshore islands (56, 0.12 %) of Taiwan ($P < 0.05$) (Table 4). Among the dentists graduating from the domestic and the foreign dental schools as well as the dentists graduating from the public, private, military and the northern dental schools, the number of the dentists of each group practicing in the northern region was the largest, followed in a descending order by the southern, central, eastern regions and the offshore islands of Taiwan (all P values < 0.05 except the dentists graduating from the foreign and the military dental schools) (Table 4). For the dentists graduating from the central schools, the number of the dentists practicing in the northern region was the largest, followed in a descending order by the central, southern, and eastern regions and the offshore islands of Taiwan ($P < 0.05$) (Table 4). For the dentists graduating from the southern schools, the number of the dentists practicing in the southern region was the largest, followed in a descending order by the northern, central, and eastern regions and the offshore islands of Taiwan ($P < 0.05$) (Table 4).

Discussion

In Taiwan, there are three major problems of the dentist occupation: a surplus of dentists, an uneven regional distribution of dentists, and a concentration of dentists in the metropolitan regions.^{3,5} The indicator to evaluate whether the dental manpower meets the demand is relatively simple, and a ratio of the number of dentists to the population is usually used as the evaluation indicator. In 2010, the National Health Research Institutes had proposed the issue on 2020 dentist manpower planning, and suggested that the ideal value of the number of people served by each dentist was 2000, equivalent to 50 dentists per 100,000 people.¹⁵ In fact, Taiwan had reached this standard as early as in year 2010 with the value of 1987 people served by a dentist,

Table 2 Distribution of the dentists based on their graduation school background and practice place by municipalities or non-municipalities in Taiwan in January 2023.

School background	Dentists practicing in municipalities (n = 6)			Dentists practicing in non-municipalities (n = 15)			Mann-Whitney <i>U</i> test
	Number	Proportion	Mean $\pm$ SD	Number	Proportion	Mean $\pm$ SD	
Public schools	2166	83.40 %	361.00 $\pm$ 317.85	431	16.60 %	28.73 $\pm$ 25.00	120.00***
Private schools	9909	80.32 %	1651.50 $\pm$ 536.51	2428	19.68 %	161.87 $\pm$ 124.83	120.00***
Military school	612	81.27 %	102.00 $\pm$ 57.38	141	18.73 %	9.40 $\pm$ 6.46	120.00***
Northern schools	5733	82.87 %	955.50 $\pm$ 752.69	1185	17.13 %	79.00 $\pm$ 55.17	120.00***
Central schools	3980	77.16 %	663.33 $\pm$ 364.31	1178	22.84 %	78.53 $\pm$ 74.39	120.00***
Southern schools	2974	82.36 %	495.67 $\pm$ 348.60	637	17.64 %	42.47 $\pm$ 32.65	120.00***
Domestic schools	12,687	80.88 %	2114.50 $\pm$ 836.89	3000	19.12 %	200.00 $\pm$ 141.97	120.00***
Foreign schools	673	79.55 %	112.17 $\pm$ 61.33	173	20.45 %	11.53 $\pm$ 10.17	121.50***
Overall	13,360	80.81 %	2226.67 $\pm$ 896.01	3173	19.19 %	211.53 $\pm$ 151.07	120.00***

SD: Standard deviation; ****P* < 0.001.**Table 3** Distribution of the dentists based on their graduation school background and practice place by cities or counties in Taiwan in January 2023.

School background	Dentists practicing in cities (n = 9)			Dentists practicing in counties (n = 12)			Mann-Whitney <i>U</i> test
	Number	Proportion	Mean $\pm$ SD	Number	Proportion	Mean $\pm$ SD	
Public schools	2300	88.56 %	255.56 $\pm$ 297.23	297	11.44 %	24.75 $\pm$ 23.94	87.00**
Private schools	10,548	85.50 %	1172.00 $\pm$ 835.54	1789	14.50 %	149.08 $\pm$ 135.20	85.00***
Military school	646	85.79 %	71.78 $\pm$ 64.33	107	14.21 %	8.92 $\pm$ 5.78	95.00**
Northern schools	6098	88.15 %	677.56 $\pm$ 727.19	820	11.85 %	68.33 $\pm$ 51.04	85.50***
Central schools	4279	82.96 %	475.44 $\pm$ 403.27	879	17.04 %	73.25 $\pm$ 81.94	85.00***
Southern schools	3117	86.32 %	346.33 $\pm$ 355.32	494	13.68 %	41.17 $\pm$ 35.46	91.00**
Domestic schools	13,494	86.02 %	1499.33 $\pm$ 1136.29	2193	13.98 %	182.75 $\pm$ 150.41	85.00***
Foreign schools	724	85.58 %	80.44 $\pm$ 68.23	122	14.42 %	10.17 $\pm$ 9.58	90.00**
Overall	14,218	86.00 %	1579.78 $\pm$ 1202.40	2315	14.00 %	192.92 $\pm$ 159.31	85.00***

SD: Standard deviation; ****P* < 0.001; ***P* < 0.01.

equivalent to 50.3 dentists per 100,000 people.¹² In this study, however, according to the data of January 2023, this value reached 1409 people served by a dentist, equivalent to 71.0 dentists per 100,000 people, which was much higher than that of 2010. Although whether there is a surplus of dentist manpower can be assessed using a simple dentist-to-population ratio, the distribution of dentists cannot be analyzed by this simple ratio. For example, Taiwan still has the remote areas, offshore islands, and other areas where there is a shortage of dentists. Although the dentist-to-population ratio was 71.0 in this study, using each city or county as the calculation unit, there were 10 counties (including offshore islands) with a dentist-to-population ratio of less than 50. The population in these areas where the dentist-to-population ratio did not meet the standard accounted for 19.15 % of the total population. Therefore, it is necessary to develop indicators to assess the distribution of dentists.

However, it is difficult to evaluate the distribution of dentists using only a single indicator. In this study, the calculation of the maximum gap and coefficient of variation did not include the population data. These two indicators can only analyze the gap between the cities and counties

with the largest number of dentists and the least number of dentists, and the relative dispersion among the number of dentists in each county and city with its mean value. Moreover, the Gini coefficient, population proportion index, and population density index were calculated including the population data. The Gini coefficient is first developed as an economic indicator used to evaluate the resource distribution (such as national income). The Gini coefficient is between 0 and 1. The higher the Gini coefficient indicates the more uneven the distribution of resource. In the past, some studies in the field of medical and public health used the Gini coefficient as an indicator to evaluate the geographical distribution of medical resources (such as the number of medical personnel by administrative districts). The higher the Gini coefficient indicates the more uneven the geographical distribution of medical resources. Such as, there are more medical personnel concentrated in the places where medical personnel are sufficient, or medical personnel are more concentrated in the places with a higher ratio of medical personnel to population.¹⁶ In our previous study, the Gini coefficient by cities and counties in January 2018 was 0.21,¹⁶ while in this study, the Gini coefficient by cities and

Table 4 Distribution of the dentists based on their graduation school background and practice place by regions of Taiwan in January 2023.

School background	Northern region (n = 6)		Central region (n = 5)		Southern region (n = 5)		Eastern region (n = 3)		Offshore islands (n = 2)		Kruskal-Wallis test
	Number	Proportion	Number	Proportion	Number	Proportion	Number	Proportion	Number	Proportion	
	Mean ± SD		Mean ± SD		Mean ± SD		Mean ± SD		Mean ± SD		
Public schools	1975	76.05 %	240	9.24 %	299	11.51 %	75	2.89 %	8	0.08 %	9.95*
	329.17 ± 346.58		48.00 ± 55.11		59.80 ± 58.38		25.00 ± 14.53		4.00 ± 2.83		
Private schools	5903	47.85 %	2823	22.88 %	3283	26.61 %	288	2.33 %	40	0.12 %	10.86*
	983.83 ± 968.02		564.60 ± 731.45		656.60 ± 707.20		96.00 ± 42.57		20.00 ± 7.07		
Military school	433	57.50 %	126	16.73 %	150	19.92 %	39	5.18 %	5	0.13 %	7.38
	72.17 ± 76.00		25.20 ± 37.97		30.00 ± 40.44		13.00 ± 9.00		2.50 ± 2.12		
Northern schools	4964	71.75 %	820	11.85 %	889	12.85 %	220	3.18 %	25	0.13 %	10.17*
	827.33 ± 868.17		164.00 ± 187.17		177.80 ± 172.54		73.33 ± 39.63		12.50 ± 4.95		
Central schools	2134	41.37 %	1889	36.62 %	1020	19.78 %	102	1.98 %	13	0.10 %	10.99*
	355.67 ± 323.62		377.80 ± 531.93		204.00 ± 182.55		34.00 ± 18.25		6.50 ± 2.12		
Southern schools	1213	33.59 %	480	13.29 %	1823	50.48 %	80	2.22 %	15	0.11 %	9.49*
	202.17 ± 193.42		96.00 ± 105.19		364.60 ± 483.24		26.67 ± 5.77		7.50 ± 4.95		
Domestic schools	8311	52.98 %	3189	20.33 %	3732	23.79 %	402	2.56 %	53	0.11 %	10.73*
	1385.17 ± 1382.06		637.80 ± 823.09		746.40 ± 799.30		134.00 ± 62.55		26.50 ± 12.02		
Foreign schools	500	59.10 %	162	19.15 %	152	17.97 %	29	3.43 %	3	0.24 %	8.31
	83.33 ± 82.09		32.40 ± 39.27		30.40 ± 38.79		9.67 ± 4.04		1.50 ± 0.71		
Overall	8811	53.29 %	3351	20.27 %	3884	23.49 %	431	2.61 %	56	0.12 %	11.02*
	1468.50 ± 1463.56		670.20 ± 862.02		776.80 ± 836.13		143.67 ± 66.43		28.00 ± 11.31		

SD: Standard deviation; * $P < 0.05$.

counties in January 2023 was 0.30, indicating that the geographical distribution of dentists in Taiwan is developing toward the worse direction from 2018 to 2023.

In addition, the population proportion index or population density index were calculated by the sum of the proportion of the number of dentists in each city or county to the total number of dentists multiplied by the proportion of the population in each city or county to the overall population or multiplied by the population density of each county or city, respectively. These two indicators indicated the weighted average population proportion and population density of the practice places of dentists. The higher the population proportion index and population density index means that dentists are concentrated to practice in places with higher population proportion and higher population density. These two indicators can be used to evaluate whether the geographical distribution of dentists has changed toward to be concentrated in densely populated areas within a time period.

From the evaluation of five indicators for the distribution of dentists, the results showed that in terms of the maximum gap and coefficient of variation indicators, compared with the population, each dentist group had a large gap and relative dispersion in the distribution of dentists. Compared among various dentist groups, four indicators of the maximum gap, coefficient of variation, Gini coefficient, and population density index of the dentists graduating from the foreign dental schools were higher than those of the dentists graduating from the domestic dental schools. This indicates that the dentists graduating from the foreign dental schools are more unevenly distributed and concentrated to practice in densely populated areas. This may be related to the fact that most of them come from families with a high socioeconomic status and most of them grew up in the urban areas.⁹ For the school attributes, the dentists graduating from the public dental schools had the highest values in all five indicators. For the school location, the dentists graduating from the northern dental schools had the highest values in the four indicators except the maximum gap. This may be related to the fact that the public dental schools are concentrated in the northern region, while Taiwan's regional development is centered in the northern region.

In this study, the calculation of the Gini coefficient was based on the distribution of dentists by cities and counties. However, this was only a rough analysis. The calculation based on the distribution of dentists by townships may be closer to the real situation, because the result of the Gini coefficient by townships may show more unevenly distributed than that by cities and counties. In our previous study, the Gini coefficient by cities and counties in January 2018 was 0.21, while the Gini coefficient by townships was 0.36. Therefore, when comparing the Gini coefficients, the difference in their calculation method should be noted.¹⁶ Taking the six municipalities as an example, the urbanization level of each section in the Taipei City is relatively average. However, there is an obvious urban-rural gap among each section of other municipalities. This means that there may also be areas with insufficient medical resources in these municipalities.

Each dentist group was concentrated in the municipalities and cities. In addition to the dentists graduating from

the southern dental schools to be concentrated in the southern region of Taiwan, various dentist groups all were concentrated in the northern region of Taiwan. This indicates that there are indeed the serious urban-rural gap and the imbalanced regional distribution of dentists in Taiwan. However, the dentists graduating from the public dental schools were very concentrated in the northern region of Taiwan. This may be due to the fact that the public dental schools in Taiwan are all in the northern part of Taiwan in addition to a new public dental school in the southern part (Tainan) of Taiwan still without its graduates currently.

Due to the factors of historical background, geography, and economic development, Taiwan's regional development has long been based on the northern region or the Taipei City as its political and economic center. The population and various resources are concentrated in the northern region, especially the Taipei City. This study found that the location of a dentist's graduation school has a high degree of relationship with the place where he or she practices. This finding was consistent with that in another study on the geographic distribution of physicians.⁸ Although the New Taipei City was the most populous city, the Taipei City had the largest number of dentists. However, for the dentist groups of different school locations, the dentists graduating from the northern dental schools were most concentrated in the Taipei City, accounting for 30.80 % of their total dentist number (2131/6918). The dentists graduating from the central dental schools were most concentrated in the Taichung City, accounting for 25.46 % of their total dentist number (1313/5158). The dentists graduating from the southern dental schools were most concentrated in the Kaohsiung City, accounting for 33.68 % of their total (1180/3611). Obviously, this is related to the fact that the dental schools in the north, central, and south regions of Taiwan were located in these three municipalities (the Taipei, Taichung, and Kaohsiung Cities, respectively).

Furthermore, the dentists graduating from the northern dental schools were most concentrated in the northern region of Taiwan, accounting for 76.05 % of their total dentist number. The dentists graduating from the central dental schools were concentrated in the northern and central regions of Taiwan, accounting for 41.37 % and 36.62 % of their total dentist number, respectively. The dentists graduating from the southern dental schools were concentrated in the northern and southern regions, accounting for 33.59 % and 50.48 % of their total dentist number, respectively. We previously found that the high school graduates tend to choose dental schools in the same area as their families located. The students from the northern region of Taiwan tend to choose the dental schools in the northern region. The students from the central region of Taiwan tend to choose the dental schools in the central region. The students from the southern region of Taiwan tend to choose the dental schools in the southern region.⁹ This means that there may be complex interactions among the area where a dentist grew up, the location of his or her graduation school, and the place where he or she practices.

According to our previous studies about the distribution of dental freshmen in Taiwan in 2020, the students from the

northern region accounted for 53.90 % of the dental freshmen admitted by the northern dental schools. The students from the northern and central regions accounted for 42.97 % and 30.47 % of the dental freshmen admitted by the central dental schools, respectively. The students from the northern and southern regions accounted for 31.73 % and 41.35 % of the dental freshmen admitted by the southern dental schools. In addition, the students from the northern region accounted for 44.30 % of the dental freshmen admitted by all dental schools.^{10,11}

Past research found that physicians tend to practice closer to the hospitals or medical schools where they were trained or attended and the areas where they grew up.⁸ Due to the interactions of these factors, as well as Taiwan's regional development factors, population and medical resources (including dental schools and teaching hospitals with dental intern or resident training) are also concentrated in the northern region to influence the distribution of dentists in Taiwan. Comparing to our previous results with those of this study, we infer that a very high proportion of the dentists from the northern region and graduating from the northern dental schools tend to stay and practice in the northern region of Taiwan. However, a significant proportion of the dentists from the northern region but graduated from the central or southern dental schools may return to practice in the northern region, while a significant proportion of the dentists from the central or southern regions but graduated from the northern dental schools may also remain to practice in the northern region of Taiwan. This further forms the phenomenon of the dentists continuing to be concentrated in the northern region of Taiwan.

The factors that cause Taiwan's dentists to be concentrated in the municipalities, cities, and the northern region of Taiwan or the Taipei City as well as their geographical distribution to be uneven are long-term and rigid. Therefore, blindly increasing the number of additional dentists (such as opening up a large number of graduates from foreign dental schools to become dentists) and requiring them to serve in the remote areas of Taiwan is not a suitable solution. It may worsen the problems of the surplus and uneven geographical distribution of dentists and their concentration in the metropolitan areas. Because once the contract ends, the background factors of these additional dentists will inevitably drive them to serve in places other than the remote areas of Taiwan.

Therefore, facing the problem of uneven geographical distribution of dentists, it is necessary to balance the enrollment quotas of dental schools among different regions of Taiwan under the premise of total quantity control (whether the dentists graduating from the domestic or foreign dental schools), to increase the dental enrollment quotas for the students from disadvantaged groups or from the remote areas, and to use policy incentives to induce the existing dentists to serve in the remote areas of Taiwan. These seem to be the more feasible ways. We conclude that the geographical distribution of dentists is highly related to their graduation school background. Promoting a balanced distribution of dental enrollment quotas and dental student sources (their geographical background) and inducing the movement of the existing dentists to serve in the dentist-shortage areas of Taiwan may be more feasible ways to

solve the uneven geographical distribution of dentists in Taiwan.

Declaration of competing interest

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

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