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Original Article

Distributions of dental freshmen and practicing dentists and their correlations in different regions of Taiwan in 2020

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Background/purpose: Taiwan is facing the problems of the surplus, the uneven distribution, and the urban-rural gap of dental students and practicing dentists. The main purpose of this study was to evaluate the distributions of dental freshmen and practicing dentists in different regions of Taiwan in 2020.

Materials and methods: We collected the numbers of dental freshmen and practicing dentists in different regions of Taiwan in 2020 for evaluation of their regional distributions in Taiwan and their relationship by the regression analysis.

Results: The numbers of dental freshmen and of practicing dentists per 100,000 people in municipalities were higher than those in non-municipalities ($P < 0.01$ for practicing dentists only). These corresponding numbers in cities with dental schools were significantly higher than those in cities and counties without dental schools, respectively (all P -values < 0.05). In addition, the coefficients of correlation between the dentist index and the dental student index were $R^2 = 0.7521$ ($P < 0.05$) for municipalities ($n = 6$), $R^2 = 0.6332$ ($P < 0.001$) for non-

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municipalities ($n = 15$), $R^2 = 0.9334$ ($P < 0.05$) for cities with dental schools ($n = 4$), $R^2 = 0.4925$ ($P < 0.01$) for cities and counties without dental schools ($n = 17$), and $R^2 = 0.5025$ ($P < 0.001$) for nationwide ($n = 21$).

Conclusion: The dental freshmen and practicing dentists are still more concentrated in municipalities than in non-municipalities and in cities with dental schools than in cities and counties without dental schools in Taiwan in 2020.

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Introduction

There has always been a gap in educational resources between urban and rural areas in Taiwan. For the schools of medical personnel, the vast majority of their students come from the cities. Successively, these students after they graduate from the schools also target to practice in urban areas, leading to a chronic shortage of medical personnel in rural areas and creating a vicious circle for the urban-rural gap. According to the statistics from National Taiwan University, in the past 20 years, 83%–88% of their students come from municipalities, and those come from Taipei City account for 30%–38%, which is the highest in Taiwan. Although the population is originally concentrated in the cities, but in fact the population of Taipei City account for only 11% of the total population of Taiwan. Moreover, the rate of students from Taipei City enrolled in National Taiwan University is three times the rate of students from the whole Taiwan area, which shows that the problem of the urban-rural gap in educational resources is very serious.¹ Students who grow up in the cities almost choose to stay in the cities for their life and career, because the life experience and working environment in the cities are more familiar to them. Moreover, they usually cannot adapt to the life of working in rural or remote areas. Therefore, the urban-rural gap between various resources will become more and more serious and fall into a vicious circle.

Due to the regional difference in the resource distribution, in addition to the urban-rural gap, Taiwan's population and medical personnel (including dentists) are increasingly concentrated in the municipalities of the western region, especially the northern cities, such as Taipei City. Our previous studies found that the practicing dentists in the training institutions of postgraduate year training program for dentists (PGYD) (so-called institutional dentists) were unevenly distributed, and the degree of unevenness was more serious than that of the overall practicing dentists.^{2,3} By the regression analysis, cities or counties with more dentists would have more institutional dentists. This situation was more obvious in municipalities than in non-municipalities.² After the PGYD trainees have completed their training, they are likely to continue to practice in the locations near their training institutions. Therefore, the problem of the uneven distribution of dentists becomes more serious.⁴ Furthermore, we also want to explore whether there is a similar phenomenon between dental students and practicing dentists. For instance, such problems may occur at an earlier stage. In fact, Taiwan's

dental schools all are concentrated in the metropolitan areas of the municipalities, and most of their dental students also come from the metropolitan areas of the municipalities.⁵ Therefore, after they graduate from the dental schools and become dentists in the future, their practice locations are likely to be concentrated in the metropolitan area of the municipalities.

However, there was still no detailed analysis on the relations between distributions of dental students and practicing dentists in each city or county of Taiwan and in different regions of Taiwan in 2020. Therefore, in this study, we examined the distributions of dental freshmen and practicing dentists in each city or county of Taiwan and in different regions of Taiwan in 2020 and evaluated the relationship between dental freshmen and practicing dentists in Taiwan in 2020.

Materials and methods

This study used the secondary data analysis to collect the information about the population and the numbers of practicing dentists and dental freshmen enrolled in dental schools in Taiwan in 2020. This information was open to access and could be collected from the related websites.

We obtained the population data including the total population in cities and counties for May 2020 from the website of the Ministry of the Interior. In addition, the information of overall practicing dentists in cities and counties of Taiwan for May 2020 was available from the Newsletter of Taiwan Dental Association.⁶ Based on our previous study,⁵ we also obtained the information of dental freshmen enrolled in the northern, central, and southern dental schools in Taiwan in 2020 from the website of the Joint Board of College Recruitment Commission. This information included the dental schools, and examination areas of enrolled dental freshmen. According to the locations of the examination rooms in the examination areas, we could find the locations of the cities or counties where enrolled dental freshmen came from.

All dental schools in Taiwan were divided into three groups according to their locations: northern, central, and southern dental schools. The whole area of Taiwan was also divided into two groups: municipalities and non-municipalities or cities with dental schools and cities and counties without dental schools. In addition, the whole area of Taiwan was further divided into five different regions: northern, central, southern, and eastern regions, and offshore islands. The northern region included Taipei

City, New Taipei City, Keelung 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. Moreover, the offshore islands included Penghu County, Kinmen County, and Lienchiang County.

For statistical analysis, coefficient of variation (CV) was determined for comparisons of variability. Mann–Whitney U test was used for comparisons between two subgroups, and Kruskal–Wallis test was used for comparisons among three or more subgroups. Furthermore, we defined the dentist index or the dental student index as the ratio of dentists per 100,000 people or the ratio of enrolled dental freshmen per 100,000 people to their corresponding values in the whole area of Taiwan, respectively. Then, the coefficients of correlation were used for comparisons between the dentist index and the dental student index.

Results

Distributions of enrolled dental freshmen per 100,000 people in northern, central, and southern dental schools and in 22 cities and counties in Taiwan in 2020

There were 386 enrolled dental freshmen accepted by the admission system of the Joint Board of College Recruitment Commission in 2020. We calculated enrolled dental freshmen per 100,000 people based on the population of May 2020 for further comparisons. The distributions of enrolled dental freshmen per 100,000 people in 22 cities and counties of Taiwan in 2020 are shown in [Table 1](#). We found that there were 1.64 dental freshmen per 100,000 people nationwide in Taiwan in 2020. Of the 1.64 dental freshmen per 100,000 people, 0.65 was enrolled by the northern dental schools, 0.54 by the central dental schools, and 0.44 by the southern dental schools ([Table 1](#)). Chiayi City was the city with the largest corresponding number (7.48), and Nantou County was the county with the smallest non-zero corresponding number (0.20) among 20 cities and counties with non-zero dental freshmen in Taiwan. Chiayi County and Taitung County had no enrolled dental freshmen. However, Lienchiang County had a very sparse population, so its number of dental freshmen per 100,000 people was very high (23.01) and thus was not included in the subsequent statistics for comparisons. There were 14 of the 22 cities and counties with 1.34 or fewer corresponding numbers that were below the number of 1.64 dental freshmen per 100,000 people nationwide ([Table 1](#)).

For the northern dental schools, Chiayi City was the city with the largest number (3.37) of dental freshmen enrolled by the northern dental schools per 100,000 people, and Hsinchu County was the county with the smallest non-zero corresponding number (0.18) among 15 cities and counties with non-zero dental freshmen in Taiwan. However, this corresponding number of Lienchiang County was very high (7.67). There were 16 of the 22 cities and counties with 0.61 or fewer corresponding numbers that were below the

number of 0.65 dental freshmen enrolled by the northern dental schools per 100,000 people nationwide ([Table 1](#)).

For the central dental schools, Chiayi City was the city with the largest number (1.87) of dental freshmen enrolled by the central dental schools per 100,000 people, and New Taipei City was the city with the smallest non-zero corresponding number (0.17) among 16 cities and counties with non-zero dental freshmen in Taiwan. However, the corresponding number of Lienchiang County was very high (15.34). There were 15 of the 22 cities and counties with 0.39 or fewer corresponding numbers that were below the number of 0.54 dental freshmen enrolled by the central dental schools per 100,000 people nationwide ([Table 1](#)).

For the southern dental schools, Chiayi City was the city with the largest number (2.25) of dental freshmen enrolled by the southern dental schools per 100,000 people, and Yunlin County was the county with the smallest non-zero corresponding number (0.15) among 15 cities and counties with non-zero dental freshmen in Taiwan. There were 13 of the 22 cities and counties with 0.31 or fewer corresponding numbers that were below the number of 0.44 dental freshmen enrolled by the southern dental schools per 100,000 people nationwide ([Table 1](#)).

Distribution of overall practicing dentists per 100,000 people in each city or county in Taiwan in 2020

According to the statistics of Taiwan Dental Association of May 2020, there were 15,155 practicing dentists in Taiwan in 2020. The distribution of overall practicing dentists per 100,000 people in 22 cities and counties of Taiwan in 2020 are shown in [Table 1](#). We found that there were 64.25 practicing dentists per 100,000 people nationwide in Taiwan in 2020. Taipei City was the city with the largest corresponding number (128.43), and Miaoli County, Nantou County, Yunlin County, Chiayi County, Pingtung County and Taitung County, as well as offshore islands (Penghu County, Kinmen County and Lienchiang County) were the counties with less than 35 practicing dentists per 100,000 people among all cities and counties in Taiwan ([Table 1](#)). It should be noted that Chiayi County was the county with the smallest corresponding number (21.94) among all cities and counties in the main island of Taiwan, while Kinmen County was the county with the smallest corresponding number (13.60) among all offshore islands of Taiwan ([Table 1](#)). There were 16 of the 22 cities and counties with 60.48 or fewer corresponding numbers that were below the number of 64.25 practicing dentists per 100,000 people nationwide ([Table 1](#)).

Comparisons of enrolled dental freshmen and of practicing dentists per 100,000 people in different regions of Taiwan in 2020

The comparisons of enrolled dental freshmen per 100,000 people in different regions of Taiwan are exhibited in [Table 2](#). We found that the mean number of enrolled dental freshmen per 100,000 people (1.96) in municipalities was higher than that (1.32) in non-municipalities of Taiwan. Moreover, the mean numbers of dental freshmen enrolled by the northern dental schools (0.78), the central dental

Table 1 Distributions of enrolled dental freshmen by northern, central, and southern dental schools or practicing dentists per 100,000 people in 22 cities and counties of Taiwan in 2020.

	Northern dental schools	Central dental schools	Southern dental schools	Total	Dental student index (%)	Overall practicing dentists	Dentist index (%)
Taipei City	2.17	1.29	0.65	4.11	251.27	128.43	199.88
New Taipei City	0.25	0.17	0.20	0.62	37.94	66.39	103.32
Taoyuan City	0.31	0.31	0.18	0.80	48.74	53.97	84.00
Taichung City	0.75	1.14	0.53	2.41	147.53	70.26	109.36
Tainan City	0.59	0.75	0.75	2.08	126.88	60.48	94.13
Kaohsiung City	0.61	0.29	0.83	1.73	105.78	67.33	104.79
Keelung City	0.54	0.27	0	0.81	49.72	50.45	78.52
Hsinchu City	1.33	1.33	0.67	3.33	203.77	76.03	118.33
Chiayi City	3.37	1.87	2.25	7.48	457.37	86.83	135.13
Hsinchu County	0.18	0	0.18	0.35	21.58	44.31	68.97
Miaoli County	0	0.18	0.18	0.37	22.45	33.62	52.32
Changhua County	0.39	0.39	0.55	1.34	81.80	46.22	71.94
Nantou County	0	0.20	0	0.20	12.40	33.88	52.73
Yunlin County	0.44	0	0.15	0.59	35.97	27.23	42.38
Chiayi County	0	0	0	0	0	21.94	34.15
Pingtung County	0	0.37	0	0.37	22.46	25.48	39.66
Penghu County	1.90	0	0.95	2.86	174.55	34.28	53.35
Yilan County	0.44	0.22	0.44	1.10	67.30	40.53	63.08
Hualien County	0	0	0.31	0.31	18.78	45.78	71.25
Taitung County	0	0	0	0	0	30.55	47.55
Kinmen County	0	0.72	0	0.72	43.75	13.60	21.17
Lienchiang County	7.67	15.34	0	23.01	1406.22	30.68	47.76
Nationwide (n = 22)	0.65	0.54	0.44	1.64	100	64.25	100
Mean ± SD	0.63 ± 0.88	0.45 ± 0.53	0.42 ± 0.52	1.50 ± 1.79	—	50.36 ± 26.29	—
CV	1.39	1.18	1.24	1.19	—	0.52	—

The item of Lienchiang County was excluded from the statistics of mean, SD and CV.
Mean ± SD = Mean ± Standard deviation; CV = Coefficient of variation.

schools (0.66), and the southern dental schools (0.52) per 100,000 people in municipalities were higher than the corresponding mean numbers of dental freshmen enrolled by the northern dental schools (0.57), the central dental schools (0.37), and the southern dental schools (0.38), respectively, in non-municipalities of Taiwan. In addition, the mean number of practicing dentists per 100,000 people (74.48) in municipalities was significantly higher than that (29.08) in non-municipalities of Taiwan ($P < 0.01$, Table 2).

We also discovered that the mean number of enrolled dental freshmen per 100,000 people (2.58) in cities with dental schools was significantly higher than that (1.25, $P < 0.05$) in cities and counties without dental schools. Moreover, the mean numbers of dental freshmen enrolled by the northern dental schools (1.03) and the southern dental schools (0.69) per 100,000 people in cities with dental schools were significantly higher than the corresponding mean numbers of dental freshmen enrolled by the northern dental schools (0.54, $P < 0.05$) and the southern dental schools (0.36, $P < 0.05$) in cities and counties without dental schools, respectively. Although the mean numbers of dental freshmen enrolled by the central dental schools (0.87) per 100,000 people in cities with dental schools was also higher than the corresponding mean number of dental freshmen enrolled by the central dental

schools (0.36) in cities and counties without dental schools, the difference was not significant (Table 2). In addition, the mean number of practicing dentists per 100,000 people (81.63) in cities with dental schools was significantly higher than that (34.81) in cities and counties without dental schools of Taiwan ($P < 0.05$, Table 2).

Furthermore, the largest mean number of enrolled dental freshmen per 100,000 people was 2.33 in the southern region of Taiwan. Moreover, the largest mean number of dental freshmen enrolled by the northern, central, and southern dental schools per 100,000 people was 0.95 in the offshore island region, 0.65 in the southern region, and 0.76 in the southern region of Taiwan, respectively (Table 2). However, the largest mean number of practicing dentists per 100,000 people was 69.93 in the northern region of Taiwan (Table 2).

Therefore, our results indicate that the numbers of enrolled dental freshmen per 100,000 people are higher in municipalities than in non-municipalities and in cities with dental schools than in cities and counties without dental schools. However, the numbers of enrolled dental freshmen per 100,000 people were slightly different among the northern, central, southern, eastern, and offshore island regions of Taiwan. Moreover, the corresponding numbers were still low in the eastern region of Taiwan. On the other

Table 2 Comparisons of enrolled dental freshmen or practicing dentists per 100,000 people in different regions of Taiwan in 2020.

	Northern dental schools	Central dental schools	Southern dental schools	Total	Overall practicing dentists
Municipalities (n = 6)					
Mean ± SD	0.78 ± 0.71	0.66 ± 0.48	0.52 ± 0.28	1.96 ± 1.27	74.48 ± 27.06
CV	0.91	0.72	0.53	0.65	0.36
Non-municipalities (n = 15)					
Mean ± SD	0.57 ± 0.95	0.37 ± 0.55	0.38 ± 0.59	1.32 ± 1.97	29.08 ± 19.42
CV	1.66	1.48	1.57	1.49	0.67
Mann–Whitney U test	24	25	24	23	10**
Cities with dental schools (n = 4)					
Mean ± SD	1.03 ± 0.76	0.87 ± 0.45	0.69 ± 0.13	2.58 ± 1.06	81.63 ± 31.47
CV	0.74	0.52	0.19	0.41	0.39
Cities and counties without dental schools (n = 17)					
Mean ± SD	0.54 ± 0.90	0.36 ± 0.52	0.36 ± 0.56	1.25 ± 1.85	34.81 ± 19.41
CV	1.66	1.45	1.57	1.48	0.56
Mann–Whitney U test	10*	12	11*	10*	7*
Northern region (n = 6)					
Mean ± SD	0.80 ± 0.80	0.56 ± 0.59	0.31 ± 0.28	1.67 ± 1.62	69.93 ± 30.86
CV	1.00	1.05	0.89	0.97	0.44
Central region (n = 5)					
Mean ± SD	0.32 ± 0.32	0.38 ± 0.44	0.28 ± 0.25	0.98 ± 0.91	42.24 ± 17.11
CV	1.01	1.16	0.87	0.93	0.40
Southern region (n = 5)					
Mean ± SD	0.91 ± 1.40	0.65 ± 0.73	0.76 ± 0.92	2.33 ± 3.01	52.41 ± 27.95
CV	1.54	1.12	1.20	1.29	0.53
Eastern region (n = 3)					
Mean ± SD	0.15 ± 0.25	0.07 ± 0.13	0.25 ± 0.23	0.47 ± 0.57	38.95 ± 7.74
CV	1.73	1.73	0.91	1.21	0.20
Offshore islands (n = 2)					
Mean ± SD	0.95 ± 1.35	0.36 ± 0.51	0.48 ± 0.67	1.79 ± 1.51	23.94 ± 14.62
CV	1.41	1.41	1.41	0.85	0.61
Kruskal–Wallis test	2.54	3.44	0.97	3.07	6.26

* $P < 0.05$; ** $P < 0.01$; The item of Lienchiang County was excluded from the statistics of mean, SD and CV. Mean ± SD = Mean ± standard deviation; CV = Coefficient of variation.

hand, the numbers of practicing dentists per 100,000 people were also higher in municipalities than in non-municipalities and in cities with dental schools than in cities and counties without dental schools. However, the number of practicing dentists per 100,000 people was highest in the northern of Taiwan (69.93), and these corresponding numbers were still low in the eastern (38.95) and offshore island regions (23.94) of Taiwan. Considering the population factor and the regional differences, the practicing dentists were obviously more concentrated in the northern region than the enrolled dental freshmen, especially the northern municipalities.

Coefficients of variation (CV) of the number of enrolled dental freshmen per 100,000 people in different regions of Taiwan in 2020

The coefficients of variation (CV) of the number of enrolled dental freshmen per 100,000 people were 1.39 for the

northern dental schools, 1.18 for the central dental schools, 1.24 for the southern dental schools, and 1.19 for the overall (Table 1). It indicates that the number of enrolled dental freshmen per 100,000 people is not more dispersed nationwide. However, the corresponding CV values for municipalities were 0.91, 0.72, 0.53, and 0.65 for the northern, central, and southern dental schools and the overall, respectively (Table 2). The corresponding CV values were greatest for non-municipalities, which were 1.66, 1.48, 1.57, and 1.49 for the northern, central, and southern dental schools and the overall, respectively. Furthermore, similar results of CV values were discovered for cities with dental schools as well as for cities and counties without dental schools (Table 2). It indicates that the numbers of enrolled dental freshmen per 100,000 people are all more dispersed in non-municipalities than in municipalities and in cities and counties without dental schools than in cities with dental schools (Table 2). In terms of practicing dentists, similar results were found (Table 2).

Coefficients of correlation between the dentist index and the dental student index in 21 cities and counties of Taiwan in 2020

The number of enrolled dental freshmen per 100,000 people in Lienchiang County was very extreme and thus was not included in some of the subsequent statistical analyses. Lienchiang County was still included in the analyses of the numbers of practicing dentists per 100,000 people and the numbers of enrolled dental freshmen per 100,000 people, as well as in the analyses of the dentist index and the dental student index. However, it was excluded in the regression analysis between the dentist index and the dental student index. Each value of practicing dentists per 100,000 people or each value of enrolled dental freshmen per 100,000 people was calculated with an index of 100. The coefficient of correlation between the dentist index and the dental student index was $R^2 = 0.5025$ ($R = 0.71$, $P < 0.001$) with a slope of 1.8924 for nationwide ($n = 21$, Fig. 1). Moreover, the coefficients of correlation between the dentist index and the dental student index were $R^2 = 0.7521$ ($R = 0.87$, $P < 0.05$) with a slope of 1.5964 for municipalities ($n = 6$) and $R^2 = 0.6332$ ($R = 0.80$, $P < 0.001$) with a slope of 3.1635 for non-municipalities ($n = 15$), as well as $R^2 = 0.9334$ ($R = 0.97$, $P < 0.05$) with a slope of 1.2736 for cities with dental schools ($n = 4$) and $R^2 = 0.4925$ ($R = 0.70$, $P < 0.01$) with a slope of 2.6278 for cities and counties without dental schools ($n = 17$) (Fig. 1).

Discussion

The system of the Joint College Entrance Examination began in Taiwan in 1954. The Department of Dentistry of National Taiwan University enrolled its dental students through this joint examination process in 1955 for the first time, creating a new era in Taiwan's dental education.⁵ The domestic dental schools of general universities have the opportunities to enroll their dental students once a year and the joint examination process have gone through 66 times until 2020. In 1955, there was only one dental school of the general university that enrolled 9 dental students. Up to now, there are 7 dental schools of the general universities with more than 2000 dental students from year 1 to year 6. Moreover, in each year there are about 380 or more dental students enrolled by the joint college entrance system. Furthermore, Taiwan's total population increases from 7.87 million in 1951 to 23.60 million in 2019. Meanwhile, the total number of dentists increases from 538 in 1951 to 15,127 in 2019.⁷ In the same period, Taiwan's total population has grown by 3 times, but the total number of dentists has grown by as much as 28 times. The number of people served by each dentist has changed from 14,627 to 1,560, indicating that the structure of Taiwan's dentist manpower has undergone a tremendous change. In the early days, the major dentist occupation problem is the extreme lack of dentists in Taiwan. However, the situation has changed to today's three major dentist occupation problems: a surplus of dentists, an uneven distribution of dentists, and a concentration of dentists in the metropolitan areas.^{2,3,8–11} Therefore, in this study we started with

the analyses of the distributions of dental freshmen and practicing dentists in each city or county in Taiwan in 2020.

In Taiwan, in addition to the military university channel, the formal way to become a dentist is that the students enter domestic dental schools through the college entrance system to become dental students after they graduate from senior high schools. After graduating from dental schools, the dental graduates participate and pass the dentist national examination to obtain a dentist license and become a qualified dentist. However, a large number of foreign dental graduates return to Taiwan to participate in the dentist national examination, obtain a dentist license, and engage in dentist practice. These extra-increased dentists have indeed caused a change in the quality and quantity of dentists.¹¹

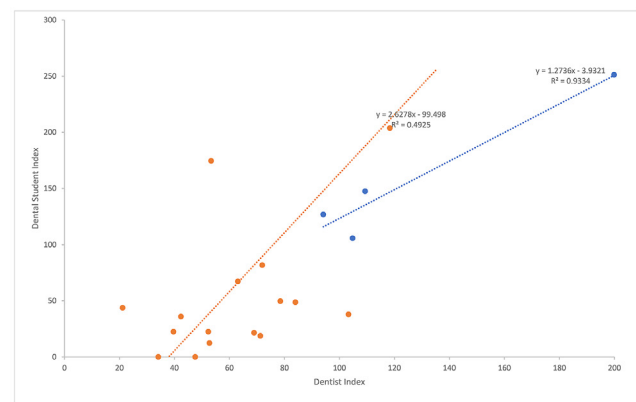
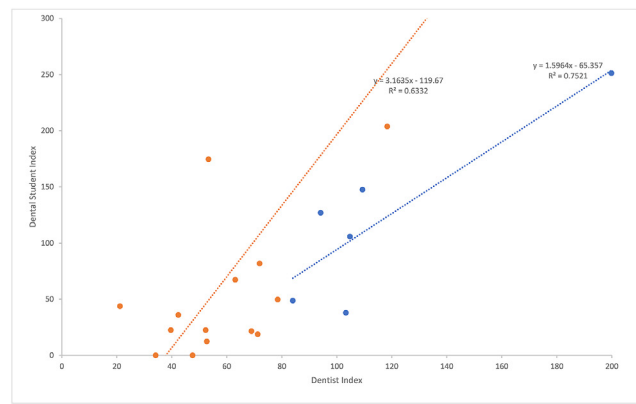


Figure 1 Correlation of dentist index and dental student index according to municipalities and non-municipalities as well as cities with dental schools and cities and counties without dental schools in Taiwan in 2020. Upper: ●: The regression of municipalities ($n = 6$): $y = 1.5964x - 65.357$, $R^2 = 0.7521$ ($R = 0.87$, $P < 0.05$). ●: The regression of non-municipalities ($n = 15$): $y = 3.1635x - 119.67$, $R^2 = 0.6332$ ($R = 0.80$, $P < 0.001$). Lower: ●: The regression of cities with dental schools ($n = 4$): $y = 1.2736x - 3.9321$, $R^2 = 0.9334$ ($R = 0.97$, $P < 0.05$). ●: The regression of cities and counties without dental schools ($n = 17$): $y = 2.6278x - 99.498$, $R^2 = 0.4925$ ($R = 0.70$, $P < 0.01$). The regression for nationwide ($n = 21$): $y = 1.8924x - 56.424$, $R^2 = 0.5025$ ($R = 0.71$, $P < 0.001$).

The postgraduate year training program for dentists (PGYD) was implemented in Taiwan in 2010, and thus the increase in the numbers of practicing dentists in the period from 2010 to 2019 had an improvement over the period from 2001 to 2010. However, the growth of the total population was gradually slowing down on the contrary. The dual changes of the practicing dentists and the total population thus increased in the numbers of practicing dentists per 100,000 people from the period of 2001–2010 to the period of 2010–2019, of which the numbers of practicing dentists per 100,000 people were 39.92 in 2001, 50.32 in 2010, and 64.09 in 2019.⁷ In fact, the practicing dentists have increased with a clear difference in absolute numbers, resulting in a surplus of dentists. However, the regional differences due to the presence or absence of dental schools have not improved. We found that the dentist index and the dental student index were highly positively correlated among all cities and counties of Taiwan, indicating that cities or counties with more practicing dentists often have more dental freshmen. The practicing dentists and dental freshmen both were obviously concentrated in municipalities and cities with dental schools, resulting in the obvious regional differences. However, both indeed had somewhat differences in geographical distribution. Although they both were concentrated in the western region of Taiwan, practicing dentists were more concentrated in the northern region than dental freshmen, especially the northern municipalities. In contrast, dental freshmen were more concentrated in Taipei City than practicing dentists. Although the government has already implemented a policy to ensure that students from remote or offshore areas can be enrolled in dental schools, there is still a lack of practicing dentists in the remote, eastern, and offshore island regions.^{5,12} Therefore, the problems of an uneven distribution of dentists and a concentration of dentists in the metropolitan areas have not been improved.

Our previous study found that there was a spreading out phenomenon about the distribution of dentists in Taiwan. Due to the concentration of resources to a certain extent as well as the competition and market-driven forces, practicing dentists would spread out from concentrated areas to other areas with fewer dentists and competition. Therefore, using Gini coefficient as an indicator, we found that the uneven geographical distribution of dentists in Taiwan did not become worse.¹³ However, the actual situation is that practicing dentists (or dental students who become dentists after graduation) may move between municipalities and cities only, such as moving from Taipei City to New Taipei City or Taoyuan City. Therefore, the urban-rural gap of dentists is still serious, and the regional imbalance of dentists still exists. Nevertheless, the above inference needs to be supported by the long-term observations and further empirical studies.

The quality and quantity of required oral health care vary as the demand according to the changes of the population of a city or a country, but any regional gap and imbalance are likely to worsen further, depending on differences in the numbers of new-entry dentists.^{14–17} The long-term accumulation of dental students and their entry into the dental service market as dentists after graduation, as well as the slow growth of population has caused the supply of dentists to exceed demand, resulting in a surplus

of dentists. In addition, practicing dentists often choose to practice in metropolitan areas with more resources and opportunities as driven by the market forces, which further leads to an uneven distribution of dentists and a concentration of dentists in the metropolitan areas. In addition to the market factors, the self-factors of dentists or dental students also affect their choices of practice locations. They tend to choose the locations where they grow up and the locations of their dental schools or training hospitals as their final practice locations.^{4,18} However, in addition to the regional factors, the self-factors of dentists or dental students also include their background factors, e.g. the dental students with certain special background are enrolled to the dental schools.

In Taiwan, due to the good income and high life quality of dentists, the enrollment to dental schools becomes more and more competitive, which is not conducive to the enrollment of disadvantaged students or students from the remote areas to the dental schools.⁵ In the past 25 years since the implementation of national health insurance in 1995, our dental students have not only increased in number, but also undergone qualitative changes. Therefore, current dental students mostly come from metropolitan areas, families with high social and economic status, and even families with dentists as their family members. They choose dental schools mostly because of financial incentives or parents' expectations. However, these students often occupy the quota and reduce the chances of disadvantaged students to enter the dental schools. Moreover, after they become dentists, they usually practice in the metropolitan areas and offer the high-charge dental services, which may subsequently lead to another vicious circle in the future. The paying of high cost to enroll in the dental schools has shaped the self-factor of dentists or dental students. For example, the difficulty in obtaining the enrollment in domestic dental schools or going abroad to study in foreign dental schools greatly increases the total cost of becoming a dentist. Therefore, after these dental students become dentists, they usually have to consider how to quickly earn the investment cost back and practice in the metropolitan areas, and offer the high-charge dental services as the main practice items.

The dental schools have become a popular choice for senior high school graduates, and the advantage of this change is that the dental schools can select more excellent dental students, which in turn help improve the overall quality of dentists in Taiwan and promote the advancement of basic dental researches and clinical oral medicine. However, the disadvantage of this change may be the lack of dentist manpower in the remote areas, the insufficient dental services for disadvantaged groups, and the low willingness of dentists to invest in unpopular dental subjects such as oral pathology and oral health care for patients with special needs. To achieve the effectiveness of required oral health care nationwide, the problems of supply and demand as well as the regional and urban-rural imbalances of dentists must be resolved through the total number control of dental students, the even regional composition of dental students, and the reasonable allocation of dental education resources to obtain the regional balance between the numbers of dental schools and their dental students.

How the dentists' self-factors affect their choices of practice locations is worthy of further studies. If the locations where dentists or dental students grow up, the locations of their dental schools, and the locations of their training hospitals are in the metropolitan areas, these factors may affect them to also practice in the metropolitan areas. However, the locations where dentists or dental students grow up and the locations of their dental schools are inherent. Therefore, we suggest that through the internship system and the PGYD system, dental students and new-entry dentists have the opportunities to learn and to be trained in the remote dental institutions to increase the experience of performing dental services in the remote areas and to improve their self-factors.^{3,7,13,19} In addition, through a reasonable screening mechanism, we hope that the dental schools may not only select excellent dental students, but also dental students who are willing to engage in dental care in the remote areas and dental care for the disadvantaged groups, as well as dental students who are willing to invest their careers in unpopular dental subjects, such as oral histology or oral pathology.

Declaration of competing interest

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

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