



Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.e-jds.com



Original Article

Distributions of dental freshmen enrolled by northern, central, and southern dental schools in each city or county and different regions of Taiwan in 2020



Julia Yu-Fong Chang^{a,b,c†}, Feng-Chou Cheng^{d†}, Tsui-Hua Liu^d,
Tzu-Chiang Lin^e, Yung-Ta Chang^{d**}, Chun-Pin Chiang^{a,b,c,f*}

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

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

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

^d School of Life Science, National Taiwan Normal University, Taipei, Taiwan

^e Center for the Liberal Arts, National Kaohsiung University of Science and Technology, Kaohsiung, Taiwan

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

Received 13 May 2021; Final revision received 15 May 2021

Available online 2 June 2021

KEYWORDS

Uneven distribution;
Urban-rural gap;
Regional imbalance;
Dental freshmen

Abstract *Background/purpose:* In Taiwan, the uneven distribution and the urban-rural gap of dentists are long-standing problems. Thus, the regional balance of domestic dental schools and their students are very important for the further distribution of practicing dentists. The main purpose of this study was to evaluate the distributions of dental freshmen enrolled by dental schools of general universities in each city or county and different regions of Taiwan in 2020. *Materials and methods:* This study mainly collected the number of dental freshmen enrolled by the northern, central, and southern dental schools and further evaluated their distributions in each city or county and different regions of Taiwan in 2020.

Results: The distribution of dental freshmen in Taiwan in 2020 did have a regional imbalance. These dental freshmen were mainly concentrated in municipalities, cities with dental schools, and the northern region of Taiwan. The enrolled dental freshmen tended to choose a dental

* 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, National Taiwan Normal University, No. 88, Sec. 4, Ting-Chou Road, Taipei, 11677, Taiwan. *E-mail addresses:* biofv031@ntnu.edu.tw (Y.-T. Chang), cpchiang@ntu.edu.tw (C.-P. Chiang).

† These two authors contributed equally to this work.

school which was in the same location as they grew up. We also found that the dental freshmen enrolled by the northern, central, and southern dental schools mostly came from the northern, the northern, and the southern regions of Taiwan, respectively.

Conclusion: We conclude that the dental freshmen are mainly concentrated in municipalities, cities with dental schools, and the northern region of Taiwan. Moreover, the dental freshmen enrolled by the northern or central dental schools mostly come from the northern region of Taiwan and those enrolled by the southern dental schools majorly come from the southern region of Taiwan.

© 2021 Association for Dental Sciences of the Republic of China. Publishing services by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Introduction

The uneven distribution and the urban-rural gap of medical resources in Taiwan are long-standing problems, and the same problems also exist in dental resources. The dentist manpower is the most important part of dental resources. However, the locations of dental schools and the distribution of dental students have an impact on the distribution of practicing dentists.¹ There are 8 universities with dental schools or departments of dentistry in Taiwan, of which 7 are general universities and one is the military university. Furthermore, the time for the establishment of these 7 dental schools of general universities and their locations are as follows: the National Taiwan University was established in 1953, Taipei Medical University in 1960, and National Yang Ming Chiao Tung University in 1976 in Taipei City; the Chung Shan Medical University was established in 1960 and China Medical University in 1980 in Taichung City; the Kaohsiung Medical University was established in 1957 in Kaohsiung City; and the National Cheng Kung University was established in 2019 in Tainan City.²

The Taiwan's government considered the regional balance of domestic dental schools, so the government decided to establish the 8th dental department of National Cheng Kung University in the southern region of Taiwan. However, the newly-established 8th dental department and the previously-established dental schools have a difference of nearly 40 years in their establishment time. The main reason considered by the government is that the establishment of the Department of Dentistry of National Cheng Kung University can balance the difference in dental resources between the northern and southern regions and reduce the gap in dental resources between urban and rural areas. The cities or counties where medical practitioners choose to open new clinics are quite geographically related, especially the locations of their enrolled universities and training hospitals.³ However, four Taiwan's dental schools are located in Taipei City, two in the former Taichung City, one in the former Kaohsiung City, and one in the former Tainan City. Moreover, the training hospitals for dental students are also mainly in areas of a high degree of urbanization. Therefore, the relationship between the dental freshmen enrolled by dental schools of different regions and those from different geographic regions of Taiwan is worth exploring.

In Taiwan, the recruitment of dental students has undergone for 66 years and the earliest dental students were recruited in the Department of Dentistry of National Taiwan University through the university entrance examination in 1955.¹ However, there were no detailed analyses on the distributions of dental freshmen enrolled by the northern, central, and southern dental schools in each city or county and different regions of Taiwan in 2020. In addition, there were also no detailed analyses on the distributions of dental freshmen from each city or county and from different regions of Taiwan in the northern, central, and southern dental schools in Taiwan in 2020. In addition, this study also assessed whether there was a similar tendency between the distributions of dental freshmen and the distributions of practicing dentists in different cities or counties and different regions of Taiwan in 2020.

Materials and methods

This study used the secondary data analysis to collect the information about the numbers of practicing dentists and dental students enrolled by the seven dental schools or departments from 7 general universities in Taiwan in 2020. This information was open to access and could be collected from the related websites.

The information of overall practicing dentists in 22 cities and counties of Taiwan in May 2020 was available from the Newsletter of Taiwan Dental Association.⁴ Based on our previous study,¹ we also obtained the information of enrolled dental freshmen in 2020 from the website of the Joint Board of College Recruitment Commission. In addition, this information included the dental schools and examination areas of enrolled dental freshmen. According to the locations of the examination rooms in different examination areas of Taiwan, we could find the locations of the cities or counties where enrolled dental freshmen came from.

The dental schools of Taiwan could be divided into three groups according their locations: northern, central and 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 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. In addition, the whole area of Taiwan could also be divided into two groups: municipalities and non-municipalities. Moreover, the whole area of Taiwan could also be divided into two groups: cities with dental schools as well as cities and counties without dental schools. For statistical analysis, Mann–Whitney *U* test was used for comparisons of data between two subgroups, and Kruskal–Wallis test was used for comparisons of data among three or more subgroups.

Results

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

The distributions of enrolled dental freshmen in northern, central and southern dental schools and in 22 cities and counties of Taiwan in 2020 are shown in Table 1. There were a total number of 386 enrolled dental freshmen accepted by the admission system of the Joint Board of

College Recruitment Commission in 2020. Of these 386 enrolled dental freshmen, Taipei City was the city with the largest number of enrolled dental freshmen (108, 27.98%), and Nantou County, Hualien County, and Kinmen County were the counties with the smallest non-zero number of enrolled dental freshman (1, 0.26%) among all cities and counties in Taiwan (Table 1). It should be noted that there was none of enrolled dental freshman in Chiayi County and Taitung County. The mean number of enrolled dental freshmen in one city or county in Taiwan was 17.55 (386/22). Thus, there were 15 of the 22 cities and counties with 17 or fewer enrolled dental freshmen that were below the mean number of 17.55 enrolled dental freshmen nationwide (Table 1).

One hundred and fifty-four dental freshmen were enrolled by the northern dental schools. Taipei City was the city with the largest number of dental freshmen enrolled by the northern dental schools (57, 37.01%), and Hsinchu and Lienchiang Counties were the counties with the smallest non-zero number of dental freshmen enrolled by the northern dental schools (1, 0.65%) among 22 cities and counties in Taiwan (Table 1). It should be noted that there were 7 counties without any dental freshmen enrolled by the northern dental schools. The mean number of dental freshmen enrolled by the northern dental schools in one city or county of Taiwan was 7 (154/22). Thus, there were 15 of the 22 cities and counties with 6 or fewer enrolled dental freshmen that were below the mean number of 7

Table 1 Distributions of enrolled dental freshmen in northern, central and southern dental schools and in 22 cities and counties of Taiwan as well as distributions of overall practicing dentists in 22 cities and counties of Taiwan in 2020.

	Northern dental schools	Central dental schools	Southern dental schools	Total	Overall practicing dentists
Municipalities (n = 6)					
Taipei City	57	34	17	108	3373
New Taipei City	10	7	8	25	2673
Taoyuan City	7	7	4	18	1218
Taichung City	21	32	15	68	1979
Tainan City	11	14	14	39	1136
Kaohsiung City	17	8	23	48	1867
Non-municipalities (n = 16)					
Keelung City	2	1	0	3	186
Hsinchu City	6	6	3	15	342
Chiayi City	9	5	6	20	232
Hsinchu County	1	0	1	2	251
Miaoli County	0	1	1	2	183
Changhua County	5	5	7	17	587
Nantou County	0	1	0	1	167
Yunlin County	3	0	1	4	185
Chiayi County	0	0	0	0	110
Pingtung County	0	3	0	3	208
Penghu County	2	0	1	3	36
Yilan County	2	1	2	5	184
Hualien County	0	0	1	1	149
Taitung County	0	0	0	0	66
Kinmen County	0	1	0	1	19
Lienchiang County	1	2	0	3	4
Nationwide (n = 22)	154	128	104	386	15,155
Mean	7	5.82	4.73	17.55	688.86

dental freshmen enrolled by the northern dental schools (Table 1).

A total of 128 dental freshmen were enrolled by the central dental schools. Taipei City was also the city with the largest number of dental freshmen enrolled by the central dental schools (34, 26.56%). There were 5 cities or counties with the smallest non-zero number of dental freshmen enrolled by the central dental schools (1, 0.78%) among 22 cities and counties in Taiwan. It should be noted that there were 6 cities or counties without any dental freshmen enrolled by the central dental schools. The mean number of dental freshmen enrolled by the central dental schools in one city or county of Taiwan was 5.82 (128/22). Thus, there were 15 of the 22 cities and counties with 5 or fewer enrolled dental freshmen that were below the mean number of 5.82 dental freshmen enrolled by the central dental schools (Table 1).

A total of 104 dental freshmen were enrolled by the southern dental schools. Kaohsiung City was the city with the largest number of dental freshmen enrolled by the southern dental schools (23, 22.12%). There were 5 counties with the smallest non-zero number of dental freshmen enrolled by the southern dental schools (1, 0.96%) among 22 cities and counties of Taiwan. It should be noted that there were 7 cities and counties without any dental freshmen enrolled by the southern dental schools. The mean number of dental freshmen enrolled by the southern dental schools in one city or county of Taiwan was 4.73 (104/22). Thus, there were 15 of the 22 cities and counties with 4 or fewer enrolled dental freshmen that were below the mean number of 4.73 dental freshmen enrolled by the southern dental schools (Table 1).

Distribution of overall practicing dentists in 22 cities and counties of Taiwan in 2020

The number of overall practicing dentists in 22 cities and counties of Taiwan in 2020 are shown in Table 1. There were a total number of 15,155 practicing dentists in May 2020. Of the 15,155 practicing dentists, Taipei City was the city with the largest number of practicing dentists (3373, 22.26%), and Taitung County and offshore islands (Penghu County, Kinmen County and Lienchiang County) were the counties with fewer than 100 practicing dentists among 22 cities and counties in Taiwan (Table 1). It should be noted that Taitung County was the county with the smallest number of practicing dentists (66, 0.44%) among all cities and counties on the main island of Taiwan, while Lienchiang County was the county with the smallest number of practicing dentists (4, 0.03%) among 3 offshore islands of Taiwan (Table 1). The mean number of practicing dentists in one city or county in Taiwan was 688.86 (15,155/22). Thus, there were 16 (all belong to non-municipalities) of the 22 cities and counties with 587 or fewer practicing dentists that were below the mean number of 688.86 practicing dentists nationwide (Table 1).

Comparisons of enrolled dental freshmen from different regions of Taiwan in 2020

Comparisons of enrolled dental freshmen from different regions of Taiwan in 2020 are shown in Table 2. The

enrollment number or rate of dental freshmen from municipalities (306 or 79.27%) was significantly higher than that from non-municipalities (80 or 20.73%, $P < 0.001$). Moreover, 123, 102, and 81 dental freshmen from municipalities and 31, 26, and 23 dental freshmen from non-municipalities were enrolled by the northern, central and southern dental schools, respectively. Thus, the dental freshmen enrollment rates in the northern dental schools (31.87%), the central dental schools (26.42%), and the southern dental schools (20.98%) for the 306 dental freshmen from municipalities were all significantly higher than the corresponding dental freshmen enrollment rates (8.03%, 6.74%, and 5.96%, respectively) for the 80 dental freshmen from non-municipalities of Taiwan (Table 2).

We also found that the enrollment number or rate of dental freshmen from cities with dental schools (263 or 68.13%) was significantly higher than that from cities and counties without any dental schools (123 or 31.87%, $P < 0.001$) (Table 2). In addition, the dental freshmen enrollment rates in the northern dental schools (27.46%), the central dental schools (22.80%), and the southern dental schools (17.88%) for the 263 dental freshmen from cities with dental schools were all significantly higher than the corresponding dental freshmen enrollment rates (12.44%, 10.36%, and 9.07%, respectively) for the 123 dental freshmen from cities and counties without dental schools in Taiwan (Table 2).

Furthermore, the enrollment number or rate of dental freshmen from the northern region of Taiwan (171, 44.30%) was higher than that of dental freshmen from each of other 4 regions of Taiwan. In addition, the dental freshmen enrollment numbers or rates in the northern dental schools (83 or 21.50%) or in the central dental schools (55 or 14.25%) for the 171 dental freshmen from the northern region of Taiwan were both relatively higher than that of dental freshmen from each of other 4 regions of Taiwan, respectively. However, the dental freshmen who came from the southern region of Taiwan and were admitted by the southern dental schools had the higher enrollment number or rate (43 or 11.14%) than that of dental freshmen who came from each of other 4 regions of Taiwan and were admitted by the southern dental schools, respectively. Therefore, it implies that a large number and proportion of enrolled dental freshmen are from the northern region (171 and 44.30%, respectively), municipalities (306 and 79.27%, respectively; especially the Taipei City, 108 and 27.98%, respectively) or cities with dental schools (263 and 68.13%, respectively).

Comparisons of the practicing dentists in different regions of Taiwan in 2020

The number or frequency of practicing dentists in municipalities (12,246 or 80.81%) was significantly higher than that in non-municipalities (2909 or 19.19%, $P < 0.001$) (Table 2). Moreover, the number or frequency of practicing dentists in cities with dental schools (8355 or 55.13%) was significantly higher than that in cities and counties without dental schools (6800 or 44.87%, $P < 0.01$) (Table 2). In addition, the number or frequency of practicing dentists in the northern region of Taiwan (8043 or 53.07%) was also significantly

Table 2 Comparisons of dental freshmen from different regions of Taiwan and those enrolled by the northern, central, and southern dental schools as well as comparisons of overall practicing dentists in different regions of Taiwan in 2020.

	Northern dental schools	Central dental schools	Southern dental schools	Total	Overall practicing dentists
Municipalities (n = 6)					
Dental freshmen (%)	123 (31.87%)	102 (26.42%)	81 (20.98%)	306 (79.27%)	12,246 (80.81%)
Mean	20.5	17	13.5	51	2041
Non-municipalities (n = 16)					
Dental freshmen (%)	31 (8.03%)	26 (6.74%)	23 (5.96%)	80 (20.73%)	2909 (19.19%)
Mean	1.94	1.63	1.44	5	181.81
Mann–Whitney U test	1***	<0.001***	2***	1***	<0.001***
Cities with dental schools (n = 4)					
Dental freshmen (%)	106 (27.46%)	88 (22.80%)	69 (17.88%)	263 (68.13%)	8355 (55.13%)
Mean	26.5	22	17.25	65.75	2088.75
Cities and counties without dental schools (n = 18)					
Dental freshmen (%)	48 (12.44%)	40 (10.36%)	35 (9.07%)	123 (31.87%)	6800 (44.87%)
Mean	2.67	2.22	1.94	6.83	377.78
Mann–Whitney U test	<0.001***	<0.001***	<0.001***	<0.001***	4**
Northern region (n = 6)					
Dental freshmen (%)	83 (21.50%)	55 (14.25%)	33 (8.55%)	171 (44.30%)	8043 (53.07%)
Mean	13.83	9.17	5.5	28.5	1340.5
Central region (n = 5)					
Dental freshmen (%)	29 (7.51%)	39 (10.10%)	24 (6.22%)	92 (23.83%)	3101 (20.46%)
Mean	5.8	7.8	4.8	18.4	620.2
Southern region (n = 5)					
Dental freshmen (%)	37 (9.59%)	30 (7.77%)	43 (11.14%)	110 (28.50%)	3553 (23.44%)
Mean	7.4	6	8.6	22	710.6
Eastern region (n = 3)					
Dental freshmen (%)	2 (0.52%)	1 (0.26%)	3 (0.78%)	6 (1.55%)	399 (2.63%)
Mean	0.67	0.33	1	2	133
Offshore islands (n = 3)					
Dental freshmen (%)	3 (0.78%)	3 (0.78%)	1 (0.26%)	7 (1.81%)	59 (0.39%)
Mean	1	1	0.33	2.33	19.67
Kruskal–Wallis test	5.07	5.49	3.75	4.69	12.77*

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

higher than that in each of other 4 regions of Taiwan ($P < 0.05$) (Table 2). Therefore, it indicates that enrolled dental freshmen tend to choose a dental school that is in the same location as they grow up. The practicing dentists are more concentrated in the northern region (especially the northern municipalities) of Taiwan than the enrolled dental freshmen.

Comparisons of dental freshmen enrolled by northern, central and southern dental schools in 2020

We also compared the dental freshmen enrolled by northern, central and southern dental schools in 2020 (Table 2). For 154 dental freshmen enrolled by the northern dental schools, 79.87% (123/154) came from the municipalities and 20.13% (31/154) came from the non-municipalities. Regarding the 128 dental freshmen enrolled by the central dental schools, 79.69% (102/128) came from the municipalities and 20.31% (26/128) came from the non-municipalities. Moreover, for the 104 dental freshmen enrolled by the southern dental schools, 77.88% (81/104)

came from the municipalities and 22.12% (23/104) came from the non-municipalities of Taiwan (Table 2).

Furthermore, for 154 dental freshmen enrolled by the northern dental schools, 68.83% (106/154) came from the cities with dental schools and 31.17% (48/154) came from the cities and counties without dental schools. Regarding the 128 dental freshmen enrolled by the central dental schools, 68.75% (88/128) came from the cities with dental schools and 31.25% (40/128) came from the cities and counties without dental schools. Moreover, for the 104 dental freshmen enrolled by the southern dental schools, 66.35% (69/104) came from the cities with dental schools and 33.65% (35/104) came from the cities and counties without dental schools in Taiwan (Table 2).

In addition, for 154 dental freshmen enrolled by the northern dental schools, a large proportion of them (53.90%, 83/154) came from the northern region, followed by the southern region (24.03%, 37/154) and central region of Taiwan (18.83%, 29/154). Regarding the 128 dental freshmen enrolled by the central dental schools, a large proportion of them (42.97%, 55/128) came from the northern region, followed by the central region (30.47%, 39/128) and southern region of Taiwan (23.44%, 30/128).

Moreover, for the 104 dental freshmen enrolled by the southern dental schools, a large proportion of them (41.35%, 43/104) came from the southern region, followed by the northern region (31.73%, 33/104) and central region of Taiwan (23.08%, 24/104) (Table 2).

Discussion

In Taiwan, various resources, such as educational and medical resources, are unevenly distributed. In addition to the problem of the urban-rural gap, the balance among different regions is another problem. In the whole Taiwan area, there is a serious problem of the resource gap between the main island and the offshore islands. In the main island of Taiwan, the educational and medical resources of the eastern region are obviously lagging behind that of the western region. Moreover, in the western region, the educational and medical resources are mostly concentrated in the northern region. This situation makes various resources more concentrated in the northern part or cities of Taiwan, especially the Taipei City. Therefore, the Taiwan's government has long been committed to balancing regional development of educational, medical and dental resources.

In Taiwan, dental resources also have problems with the urban-rural gap and the regional imbalance. There are currently the problems of a surplus of dentists, uneven distribution of dentists, and concentration of dentists in the metropolitan areas.^{5–10} Therefore, the Taiwan's government has implemented a total number control of students enrolled by domestic dental schools for many years. Thus, under the premise that the total number of enrolled dental students does not increase, the government agrees to establish the 8th dental school in the southern region of Taiwan, and this dental school began to enroll dental freshmen since 2019.² The dentists are the most important dental resources. However, the dental schools have two pivotal roles in dental resources and educational resources. Therefore, the difference in dental resources in different regions is reflected to the differences in the distribution of dentists and dental schools. The past studies have also pointed out that the choice of practice locations for physicians or dentists is affected by the locations where they grow up, the locations of their medical or dental schools, and the locations of their training hospitals. This is because they tend to choose the same locations mentioned above as their practice locations.^{2,3}

The impact of dental schools on the geographical distribution of dentists is not only the locations of dental schools that influence their graduates' choice of practice locations, but also the regions of dental schools that may recruit students from different regions, which in turn affects the geographical distribution of dentists in the future. Therefore, the difference in the regional composition of dental students on the choice of dental schools in different regions is worth studying.

Our study found that the enrolled dental freshmen' locations where they grew up had an impact on the selection of the northern, central, and southern dental schools. Moreover, enrolled dental freshmen were uniformly concentrated in municipalities or cities with dental schools. In addition, the enrollment rates of dental freshmen

enrolled by the northern dental schools (31.87%), the central dental schools (26.42%), and the southern dental schools (20.98%) for the 306 enrolled dental freshmen from the municipalities were all significantly higher than the corresponding enrollment rates (8.03%, 6.74%, and 5.96%, respectively) for the 80 enrolled dental freshmen from non-municipalities of Taiwan. Besides, the enrollment rates of dental freshmen enrolled by the northern dental schools (27.46%), the central dental schools (22.80%), and the southern dental schools (17.88%) for the 263 enrolled dental freshmen from cities with dental schools were all significantly higher than the corresponding enrollment rates (12.44%, 10.36%, and 9.07%, respectively) for the 123 enrolled dental freshmen from cities and counties without dental schools in Taiwan (Table 2). The worrying situation is that the vast majority of dental freshmen from metropolitan areas almost continue to practice in metropolitan areas (such as the locations where they grow up) after they become dentists, while a very small number of dental freshmen from remote areas or offshore islands are also likely to continue to practice in metropolitan areas (such as the locations near their dental schools) after they become dentists. Therefore, the problems of the urban-rural gap and the uneven distribution of dentists most likely become worse. However, such inferences still need to be supported by further empirical studies.

On the other hand, we also found the interlaced relationship between dental schools in different regions and dental freshmen from different regions of Taiwan. In terms of the regions of dental schools, for the northern dental schools, their dental freshmen were mostly (more than half) from the northern region of Taiwan, followed by the southern region of Taiwan, the central region of Taiwan, and the eastern and offshore island regions of Taiwan. For the central dental schools, their dental freshmen were mainly from the northern region of Taiwan, followed by the central region of Taiwan, the southern region of Taiwan, and the eastern and offshore island regions of Taiwan. However, for the southern dental schools, their dental freshmen were mostly from the southern region of Taiwan, followed by the northern region of Taiwan, the central region of Taiwan, and the eastern and offshore island regions of Taiwan. Furthermore, in terms of the regions where dental freshmen came from, for the dental freshmen from the northern region of Taiwan, they were mainly enrolled by the northern dental schools, followed by the central dental schools, and the southern dental schools. For the dental freshmen from the central region of Taiwan, they were mainly enrolled by the central dental schools, followed by the northern dental schools, and the southern dental schools. However, for the dental freshmen from the southern region of Taiwan, they were mainly enrolled by the southern dental schools, followed by the northern dental schools, and the central dental schools. Overall, the northern dental schools enrolled the majority of dental freshmen, and the enrolled dental freshmen mostly came from the northern region of Taiwan.

For regional distributions of practicing dentists in May 2020, there were 80.81% (12,246/15,155) of the total practicing dentists in municipalities, 55.13% (8355/15,155) of the total practicing dentists in cities with dental schools, and 53.07% (8043/15,155) of the total practicing dentists in

the northern region of Taiwan. For regional distributions of dental freshmen, there were 79.27% (306/386) of the total dental freshmen in municipalities, 68.13% (263/386) of the total dental freshmen in cities with dental schools, and 44.30% (171/386) of the total dental freshmen in the northern region of Taiwan in 2020 in this study. These findings indicate that dental schools may attract more local dental students. However, when dental students graduate from dental schools and become dentists, they may be more concentrated in municipalities and the northern region of Taiwan due to the market factors and their own personal factors. If the locations where dental students grow up and the locations of their dental schools and training hospitals are metropolitan areas, they may tend to practice in metropolitan areas close to one of the same locations mentioned above. Even dental students from remote areas are likely to be affected by their dental schools and training hospitals, and tend to stay in metropolitan areas to practice after graduation. Dental students or dentists who have studied or trained in the northern dental schools or hospitals are more likely to continue practicing in the northern region of Taiwan. Therefore, in discussing the impact of dental schools on the distribution and the supply of dentists, in addition to the geographical location of the dental schools, it should also include the number and regional composition of their dental students, the difference between the number of enrolled dental freshmen through the university admission examination and the number of graduates from domestic dental schools, and the difference between the number of dental graduates who participate in the dentist national examination and the number of graduates from domestic dental schools, as well as the number of new issued dentists.

Furthermore, we further found the numbers of enrolled dental freshmen through the university admission examination in 2014 from the websites of the Joint Board of College Recruitment Commission, the domestic dental graduates from the Ministry of Education, the total dental graduates who participated in the dentist national examination from the Ministry of Examination, and new issued dentists in 2020 from the Ministry of Health and Welfare. For the enrolled dental freshmen through the university admission examination in 2014, there were 165 enrolled dental freshmen in the northern dental schools, 139 in the central dental schools, and 89 in the southern dental schools, respectively, with a total of 393. After 6 years, for domestic dental graduates in 2020, there were 186, 130, and 91 domestic dental graduates in the northern, central, and southern dental schools, respectively, with a total of 407. We unexpectedly discovered the difference between the number of dental freshmen enrolled through university admission examination in 2014 and the number of dental graduates in 2020. The number of dental students did not decrease but increase from enrollment to graduation, indicating that there are other special admission channels and department transfers for dental students that finally cause an increase in dental students. However, this situation may cause the total number control of domestic dental students to become out of control, and the supply of dentists finally exceeds the number of expected dentists in the original plan. Moreover, the increased rates of dental students from enrollment in 2014 to graduation in 2020, there

were 12.73% (21/165) dental students in the northern dental schools, -6.47% (-9/139) dental students in the central dental schools, and 2.25% (2/89) dental students in the southern dental schools, respectively, with a total increase of 3.56% (14/393) overall dental students. The rate of increase or decrease varied greatly in different regions of Taiwan, with the highest increase in the northern dental schools. For example, among them, a certain dental school in the northern region had a very high increase rate of 16.48% (15/91), which would further cause an imbalance in the distribution of dentists.

For overall dental graduates who participated in the dentist national examination in 2020, there were 33 in the northern region, 17 in the central region, and 8 in the southern region, respectively, with a total of 58 dental graduates in the first dentist national examination, of which 38 passed the examination. Moreover, there were 213, 143, and 103 dental graduates in the northern, central, and southern regions of Taiwan, respectively, with a total of 459 dental graduates in the second dentist national examination, of which 376 passed the examination. Therefore, there were 414 new issued dentists in 2020. Assuming that those who failed the first examination would take the second examination, we estimated that there were a total of 497 dental graduates who participated in the dentist national examination in 2020. In the same year, the number of dental graduates who participate in the dentist national examination is much higher than the number of domestic dental graduates, indicating that there are not only some graduates who retake the examination but also many graduates from foreign dental schools (so-called foreign dental graduates) that have caused a large increase in the overall dental graduates in Taiwan. However, foreign dental graduates have surpassed the mechanism of the total number control of domestic dental students, and further cause the oversupply of dentists in Taiwan. Moreover, we also found the difference in the number of dental graduates who participated in the dentist national examination in different regions of Taiwan. The number of dental graduates who participated in the dentist national examination in the northern region of Taiwan was indeed much higher. It can be speculated that the students who can go to foreign dental schools for studying dentistry are mostly from families with high socioeconomic status, and thus, these families may also be mostly from the northern metropolitan areas. This also causes the supply of dentists to exceed the original expectation and the uneven distribution of dentists in Taiwan in the future, because they may be large in number and their future practice locations may be more concentrated in the northern metropolitan areas. Nevertheless, the above inference needs to be supported by the long-term observations and empirical studies.

Every year, many new-entry dentists graduate from Japan's 29 dental universities and schools (dental colleges) in 19 of the 47 prefectures, and this has a particularly significant impact on the number of dentists in prefectures with dental colleges.^{11,12} Unlike Japan, in addition to dental graduates from Taiwan's 7 domestic dental schools in 4 of the 22 cities and counties (the newly-established 8th dental school still has no graduate students currently), every year, many foreign dental graduates come back to Taiwan to take the dentist national examination for the

future practice in Taiwan, and this also has a particularly significant impact on the oversupply and the uneven distribution of dentists.^{2,5,10} However, every year the new issued dentists who are concentrated in the metropolitan areas may cause the uneven distribution of dentists to become more and more serious. Thus, to obtain effective oral health care services, it is necessary to maintain a balance between the supply of new-entry dentists with balanced distribution and the population through resolution of regional differences and urban concentrations.^{11–14}

We conclude that the dental freshmen are mainly concentrated in municipalities, cities with dental schools, and the northern region of Taiwan. Moreover, the dental freshmen enrolled by the northern or central dental schools mostly come from the northern region of Taiwan and those enrolled by the southern dental schools majorly come from the southern region of Taiwan. These phenomena may be potential factors that cause an imbalance in the distribution of practicing dentists in the future. Therefore, in addition to efforts aimed in resolving regional differences in oral health care services, the policy for the balanced distribution of domestic dental schools to rectify the uneven regional distribution of dental students is required. Moreover, the policies for the total number control of domestic dental students to prohibit excessive and additional dental students (such as foreign dental students) and to normalize the number of new-entry dentists are required. Moreover, we also recommend that the policy for the postgraduate year training program for dentists (PGYD) to request oral health care services in remote areas is required.^{6,15–17}

Declaration of Competing Interest

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

References

1. Cheng FC, Liu TH, Chang JYF, et al. Distribution of students admitted to dental schools of general universities in Taiwan in 2020. *J Dent Sci* 2021;16:567–79.
2. Cheng FC. *The research of practicing PGY system in dental institutions*. PhD Thesis. Taipei: National Taiwan Normal University School of Life Science, 2019 [In Chinese, English abstract].
3. Ouyang LCL. The geographical study of health care facility distribution in Taipei City, Taiwan. *J Geogr Res* 2006;45:51–72 [In Chinese, English abstract].
4. Taiwan Dental Association. Statistics on the number of members of dental associations of counties and cities in May 2020. *Newslett Taiwan Dent Asso* 2020;39:86 [In Chinese].
5. Cheng FC, Liu TH, Chang JYF, et al. Regional distributions of overall dentists and institutional dentists in Taiwan in 2019. *J Dent Sci* 2021;16:682–90.
6. Cheng FC, Chang JYF, Lin TC, et al. Imbalance in the geographical distribution of practicing dentists in postgraduate dental training institutions in Taiwan. *J Dent Sci* 2020;15:249–56.
7. Cheng FC, Chang JYF, Lin TC, et al. The status of hospital dentistry in Taiwan in October 2019. *J Dent Sci* 2020;15:505–12.
8. Huang CS, Cher TL, Lin CP, et al. Projection of the dental workforce from 2011 to 2020, based on the actual workload of 6762 dentists in 2010 in Taiwan. *J Formos Med Assoc* 2013;112:527–36.
9. Cher TL, Lai HH, Huang CS, et al. Field survey of dental manpower in Taiwan's hospitals. *J Formos Med Assoc* 2012;111:305–14.
10. Cheng FC, Chang JYF, Lin TC, et al. Dentist manpower development and geographical distribution of dentists in Taiwan. *J Dent Sci* 2020;15:121–31.
11. Gotouda H, Kasai K, Kaneda T, et al. Associations among distributions of dental postgraduate residents, dentists and clinical training facilities in Japan. *J Oral Sci* 2009;51:635–9.
12. Okada M, Yamada Y, Okawa Y, et al. An analysis of regional differences in dental care facilities and in dental care expenditure. Part 2. According to the presence/absence of a dental college. *Nihon Shika Iryou Kanri Gakkai Zasshi* 2004;38:310–20 [in Japanese].
13. Hirata SI. The general representation of dental postgraduate clinical training program. *Nihon Shika Ishikai Zasshi* 2006;58:1067–73 [in Japanese].
14. Hirata SI, Hidaka K. Postgraduate clinical training program for dentists in Japan. *Dent Jpn* 2006;42:191–4.
15. Cheng FC, Chang JYF, Lin TC, et al. Does postgraduate year training program for dentists worsen the imbalance of geographical distribution of dentists in Taiwan? *J Dent Sci* 2020;15:542–9.
16. Cheng FC, Chiang CP, Lin TC, et al. Trends of participation of post-graduate year training program for dentists in Taiwan dental training institutions from 2010 to 2018. *J Dent Sci* 2019;14:47–53.
17. Cheng FC, Chang JYF, Lin TC, et al. The changes of the number and regional distribution of dentists and dental institutions 9 years after the implementation of postgraduate year training program for dentists in Taiwan. *J Dent Sci* 2021;16:437–44.