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Original Article

Correlation between dental professionally topical fluoride application and children's dental use for dental caries under the National Health Insurance system in Taiwan from 2008 to 2021

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Abstract *Background/purpose:* Dental caries is one of the most common oral diseases in children worldwide, especially in Taiwan. This study investigated dental professionally topical fluoride application (PTFA) and children's dental use for dental caries under the National Health Insurance (NHI) system in Taiwan from 2008 to 2021.

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application;
Children;
Dental caries;
Dental use indicator

Materials and methods: The population data and medical records of the NHI system were obtained from the websites of the Ministry of the Interior and the Ministry of Health and Welfare, respectively. The dental PTFA services and dental use indicators for dental caries were analyzed from 2008 to 2021.

Results: The number of out-patient visits for dental PTFA services increased from 221,675 in 2008 to 1,078,099 in 2021. The total increase of the out-patient visits was 856,424 with a total increase rate of 386.34%. The one-year increase was 65,879 with a one-year increase rate of 29.72%. Among the 3 age groups of children, their dental use indicators almost presented decreasing trends from 2008 to 2021. Moreover, in general, the dental use indicators showed a negative correlation with the number of the overall out-patient visits for dental PTFA services from 2008 to 2021.

Conclusion: In Taiwan, there is a negative correlation between the dental use indicators in NHI system and the number of the overall out-patient visits for dental PTFA services from 2008 to 2021. However, the problem of dental caries in children is still serious and there is still a space for improvement in the oral health education for child caregivers and children.

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Introduction

Dental caries is one of the most common chronic diseases in children worldwide.¹ The occurrence of dental caries deeply affects the oral health status, and oral health is a part of the whole body health. The oral health of school children is related to their learning, quality of life, and physical and mental development. Therefore, the advanced countries in the world often pay great attention to the prevention of dental caries for school children.²

Dental fluoride research began in 1901.³ The use of fluoride has been shown to be an effective public health measure for the prevention of dental caries.⁴ In 1942, Bibby discovered that the topical application of sodium or potassium fluoride on the tooth surface can be used for reduction of dental caries in children.⁵ The systemic and topical (local) applications of fluorides have been widely used in the strategies of dental caries prevention in countries all over the world.⁴ Although it is generally believed that the dental professional fluoride use as an anti-caries method is not suitable as a comprehensive public health measure, it is feasible in a low fluoride content area with a high prevalence of dental caries and sufficient dental manpower.² Since the implementation of the National Health Insurance (NHI) system in Taiwan in 1995, the insurance coverage rate has reached 99.9%.⁶ In addition, Taiwan's hospital dentistry and dental clinics are top-rated. The convenience of dental treatment is high for our people. Therefore, in Taiwan, where both the accessibility of dental care and the prevalence of dental caries among children are high, and the measure such as a comprehensive drinking water fluoridation has not been implemented, the dental professionally topical fluoride application (PTFA) service is a feasible and appropriate public health measure for dental caries prevention in Taiwan.²

In 2004, the Ministry of Health and Welfare began to implement the preventive health care subsidy plan of dental PTFA services for preschool children.² Since 2007, the Health Promotion Administration subsidized children

under the age of 5 years to have dental PTFA services by dentists in dental institutions twice per year.⁷ In the world, Taiwan is one of the few countries that provide a long-term nationwide and organized dental PTFA services for all children and high-risk individuals of dental caries (vulnerable children). However, there are few analytical reports on the epidemiology of dental caries among children and the effectiveness of dental PTFA services in Taiwan. Therefore, we provided a comprehensive overview of the changes in all children's dental use indicators for dental cares under the NHI system and the dental PTFA services in Taiwan over the past decade.

Materials and methods

This study adopted the secondary data analysis. The mid-year population of Taiwan from 2008 to 2021 were obtained from the website of the Ministry of the Interior. The records of out-patient visits for dental PTFA services, including the numbers of out-patient visits for dental PTFA services in hospitals of different levels (medical centers, regional hospitals, or district hospitals) and dental clinics were obtained from the website of the Ministry of Health and Welfare. The number of dentists registered in hospitals and dental clinics was also obtained to calculate the number of dental PTFA services provided by each dentist. In addition, the dental treatment records for dental caries, including the numbers of patients, the out-patient visits, and the associated medical expenses were obtained from the website of the NHI Administration. This study only investigated and analyzed the dental PTFA services and dental treatment records for dental caries claimed in Taiwan from 2008 to 2021.

In this study, the dental patient data were divided into 3 age groups (0–4, 5–9, and 10–14 years) in order to match the 3 age groups published by the Ministry of the Interior and represent the 3 different age groups of children. For children's dental use indicators, according to the dental patients who received dental services for dental caries

under the NHI system, the dental use rate, the mean number of out-patient visits per 1000 people, and the mean medical expense NHI points per person were analyzed among the 3 age groups. The dental use rate of patients in each age group was calculated by dividing the number of patients in each age group to the total population of the same age group. This study further compared the mean number of out-patient visits per patient, the mean medical expense NHI points per patient, and the mean medical expenses per out-patient visit in each age group of patients. Furthermore, it should be noted that the value of one NHI point is settled quarterly, and one NHI point fluctuates around TWD 0.8–1.2. In addition, the out-patient statistics of the Ministry of Health and Welfare were the total numbers of out-patient clinics of dentistry, western medicine, and traditional Chinese medicine before 2015. For example, the number of patients with a disease code of dental caries included patients with dental caries diagnosed by dentists, western medicine doctors, and traditional Chinese medicine doctors. After 2016, the statistics of out-patient clinics of dentistry, western medicine, and traditional Chinese medicine were separated.

All secondary data were public information that could be accessed and collected from the respective websites. The research data were stored in excel files and used for the descriptive statistics used to compare the changes in the aforementioned indicators related to the dental PTFA services and the dental use for dental caries among the 3 different age groups of children under the NHI system in Taiwan from 2008 to 2021. In addition, the coefficient of correlation was calculated and used for comparisons between the number of the overall out-patient visits for dental PTFA services and the dental use indicators of the 3 different age groups of children in Taiwan.

Results

The numbers and changing trends of the dentists, the out-patient visits for dental PTFA services, and the dental PTFA services provided by each dentist in Taiwan from 2008 to 2021 are shown in [Table 1](#) and [Fig. 1](#). In overall, the number of practicing dentists of Taiwan increased from 11,093 in 2008 to 15,741 in 2021. To take the data of 2008 as the baseline, the total increase of the dentists was 4648 with a total increase rate of 41.90%. The one-year increase was 358 with a one-year increase rate of 3.22%. Except the decreased trend of hospital dentists from 2019 to 2021, the changes in the numbers of hospital and clinic dentists both showed an increased trend from 2008 to 2019 and from 2008 to 2021, respectively ([Table 1](#)).

In overall, the number of the out-patient visits for dental PTFA services increased from 221,675 in 2008 to 1,078,099 in 2021. The total increase of the out-patient visits was 856,424 with a total increase rate of 386.34%. The one-year increase was 65,879 with a one-year increase rate of 29.72%. The number of the out-patient visits suddenly increased in 2013 (about double that of 2012), and then gradually increased from 2013 to 2019, and then decreased from 2019 to 2021. Except the decreased trend of the out-patient visits in medical centers and regional hospitals from 2018 to 2021, the changes in the numbers of the out-patient

visits for dental PTFA services among district hospitals and dental clinics showed an increased trend from 2008 to 2019, respectively ([Table 1](#) and [Fig. 1A](#) and [B](#)).

Furthermore, the number of the dental PTFA services provided by each dentist increased from 19.98 in 2008 to 68.49 in 2021. The total increase of the visits was 48.51 with a total increase rate of 242.74%. The one-year increase was 3.73 with a one-year increase rate of 18.67%. The changes in the numbers of the dental PTFA services provided by each hospital or clinic dentist showed an increased trend from 2008 to 2018, respectively, which were similar to those for the out-patient visits for dental PTFA services ([Table 1](#), [Fig. 1C](#)).

The numbers of the population, the patients, the out-patient visits, and the medical expenses for dental caries in the 3 age groups of children under the NHI system in Taiwan from 2008 to 2021 are shown in [Table 2](#) and [Fig. 2](#). Among the 3 age groups of children, their population and the dental use indicators all presented decreasing trends from 2008 to 2021 in general ([Table 2](#) and [Fig. 2](#)). Moreover, the above dental use indicators showed the highest values in the 5-9-year age group of children, followed in a descending order by the 10-14-year age group and the 0-4-year age group ([Table 2](#)).

In the 5-9-year age group, the number of patients with dental caries decreased from 749,819 in 2008 to 541,778 in 2021. The total decrease was 208,041 with a total decrease rate of 27.75%. The one-year decrease was 16,003 with a one-year decrease rate of 2.13%. The number of the out-patient visits for dental caries decreased from 1,736,259 in 2008 to 1,208,039 in 2021. The total decrease was 528,220 with a total decrease rate of 30.42%. The one-year decrease was 40,632 with a one-year decrease rate of 2.34%. In addition, the medical expenses for dental caries decreased from 2086.47 million NHI points in 2008 to 1340.96 million NHI points in 2021. The total decrease was 745.51 million NHI points with a total decrease rate of 35.73%. The one-year decrease was 57.35 million NHI points with a one-year decrease rate of 2.75% ([Table 2](#) and [Fig. 2](#)). However, among the 3 age groups of children, the above dental use indicators all showed a negative correlation with the number of the overall out-patient visits for dental PTFA services. Especially in the 5-9-year age group and the 10-14-year age group, their correlation coefficients were between -0.699 and -0.842 , suggesting a highly negative correlation ([Table 2](#)).

The dental use rate, the number of out-patient visits per 1000 people, and the medical expenses per person for dental caries in the 3 age groups of children under the NHI system in Taiwan from 2008 to 2021 are shown in [Table 3](#) and [Fig. 3](#). Except an increasing trend of the dental use rate in the 10-14-year age group, among the 3 age groups of children, the above dental use indicators all presented decreasing trends from 2008 to 2021 ([Table 3](#) and [Fig. 3](#)). Moreover, the above dental use indicators also showed the highest values in the 5-9-year age group of children, followed in a descending order by the 10-14-year age group and the 0-4-year age group ([Table 3](#)).

In the 5-9-year age group, the dental use rate for dental caries decreased from 55.96% in 2008 to 50.90% in 2021. The total decrease was 5.06% with a total decrease rate of 9.04%. The one-year decrease was 0.39% with a one-year

Table 1 The numbers of the dentists, the out-patient visits for dental professionally topical fluoride application (PTFA) services, and the dental PTFA services provided by each dentist in Taiwan from 2008 to 2021.

Year	Dentists			Out-patient visits for dental PTFA services						Dental PTFA services provided by each dentist		
	Hospital	Dental clinic	Overall	Hospital				Dental clinic	Overall	Hospital	Dental clinic	Overall
				Medical center	Regional hospital	District hospital	Total					
2008	1421	9672	11,093	13,336	5825	3917	23,078	198,597	221,675	16.24	20.53	19.98
2009	1458	9893	11,351	13,351	5989	5927	25,267	226,313	251,580	17.33	22.88	22.16
2010	1509	10,147	11,656	13,418	7401	6151	26,970	250,469	277,439	17.87	24.68	23.80
2011	1568	10,424	11,992	14,570	8596	6413	29,579	279,539	309,118	18.86	26.82	25.78
2012	1647	10,744	12,391	15,743	10,382	6712	32,837	339,520	372,357	19.94	31.60	30.05
2013	1764	11,030	12,794	23,829	28,879	22,714	75,422	669,093	744,515	42.76	60.66	58.19
2014	1870	11,308	13,178	30,257	38,985	26,048	95,290	906,345	1,001,635	50.96	80.15	76.01
2015	1918	11,584	13,502	29,325	34,068	21,413	84,806	986,553	1,071,359	44.22	85.17	79.35
2016	1982	11,930	13,912	30,236	35,393	21,749	87,378	1,080,076	1,167,454	44.09	90.53	83.92
2017	2115	12,264	14,379	30,985	28,535	21,561	81,081	993,601	1,074,682	38.34	81.02	74.74
2018	2121	12,596	14,717	32,787	34,232	29,958	96,977	1,145,924	1,242,901	45.72	90.98	84.45
2019	2186	12,941	15,127	31,467	30,261	32,381	94,109	1,165,336	1,259,445	43.05	90.05	83.26
2020	2183	13,246	15,429	22,789	26,426	29,955	79,170	1,129,389	1,208,559	36.27	85.26	78.33
2021	2174	13,567	15,741	17,983	23,986	25,032	67,001	1,011,098	1,078,099	30.82	74.53	68.49
Total change	753	3895	4648	4647	18,161	21,115	43,923	812,501	856,424	14.58	53.99	48.51
Total change rate (%)	52.99	40.27	41.90	34.85	311.78	539.06	190.32	409.12	386.34	89.77	262.96	242.74
One-year change	58	299.62	358	357	1397	1624	3379	62,500	65,879	1.12	4.15	3.73
One-year change rate (%)	4.08	3.10	3.22	2.68	23.98	41.47	14.64	31.47	29.72	6.91	20.23	18.67

decrease rate of 0.70% (Table 3). The number of the out-patient visits per 1000 people for dental caries decreased from 1295.88 in 2008 to 1135.05 in 2021. The total decrease was 160.83 with a total decrease rate of 12.41%. The one-year decrease was 12.37 with a one-year decrease rate of 0.95% (Table 3). In addition, the medical expenses per person for dental caries decreased from 1557.27 NHI points in 2008 to 1259.94 NHI points in 2021. The total decrease was 297.32 NHI points with a total decrease rate of 19.09%. The one-year decrease was 22.87 NHI points with a one-year decrease rate of 1.47% (Table 3 and Fig. 3). The dental use rate and the number of the out-patient visits per 1000 people in the 10-14-year age group showed a highly positive correlation with the number of the overall out-patient visits for dental PTFA services with the correlation coefficients being 0.836 and 0.708, respectively. The medical expenses per person in the 0-4-year age group showed a highly negative correlation with the number of the overall out-patient visits for dental PTFA services with the correlation coefficient being -0.714 (Table 3).

The number of out-patient visits per patient, the medical expenses per patient, and the medical expenses per out-patient visit for dental caries in the 3 age groups of children under the NHI system in Taiwan from 2008 to 2021 are shown in Table 4 and Fig. 4. Among the 3 age groups of children, the above dental use indicators all presented decreasing trends from 2008 to 2021 (Table 4 and Fig. 4).

Moreover, the above dental use indicators showed the highest decrease rates in the 0-4-year age group of children, followed in a descending order by the 10-14-year age group and the 5-9-year age group.

In the 0-4-year age group, the number of the out-patient visits per patient for dental caries decreased from 2.66 in 2008 to 1.90 in 2021. The total decrease was 0.75 with a total decrease rate of 28.42%. The one-year decrease was 0.06 with a one-year decrease rate of 2.19% (Table 4). The medical expenses per patient for dental caries decreased from 3683.26 NHI points in 2008–2052.16 NHI points in 2021. The total decrease was 1631.10 NHI points with a total decrease rate of 44.28%. The one-year decrease was 125.47 NHI points with a one-year decrease rate of 3.41%. In addition, the medical expenses per out-patient visit for dental caries decreased from 1386.50 NHI points in 2008 to 1079.21 NHI points in 2021. The total decrease was 307.30 NHI points with a total decrease rate of 22.16%. The one-year decrease was 23.64 NHI points with a one-year decrease rate of 1.70% (Table 4 and Fig. 4). The number of the out-patient visits per patient and the medical expenses per patient in the 0-4-year age group, and the medical expenses per out-patient visit in the 5-9-year age group showed a highly negative correlation with the number of the overall out-patient visits for dental PTFA services with the correlation coefficients being -0.866 , -0.802 and -0.808 , respectively (Table 4).

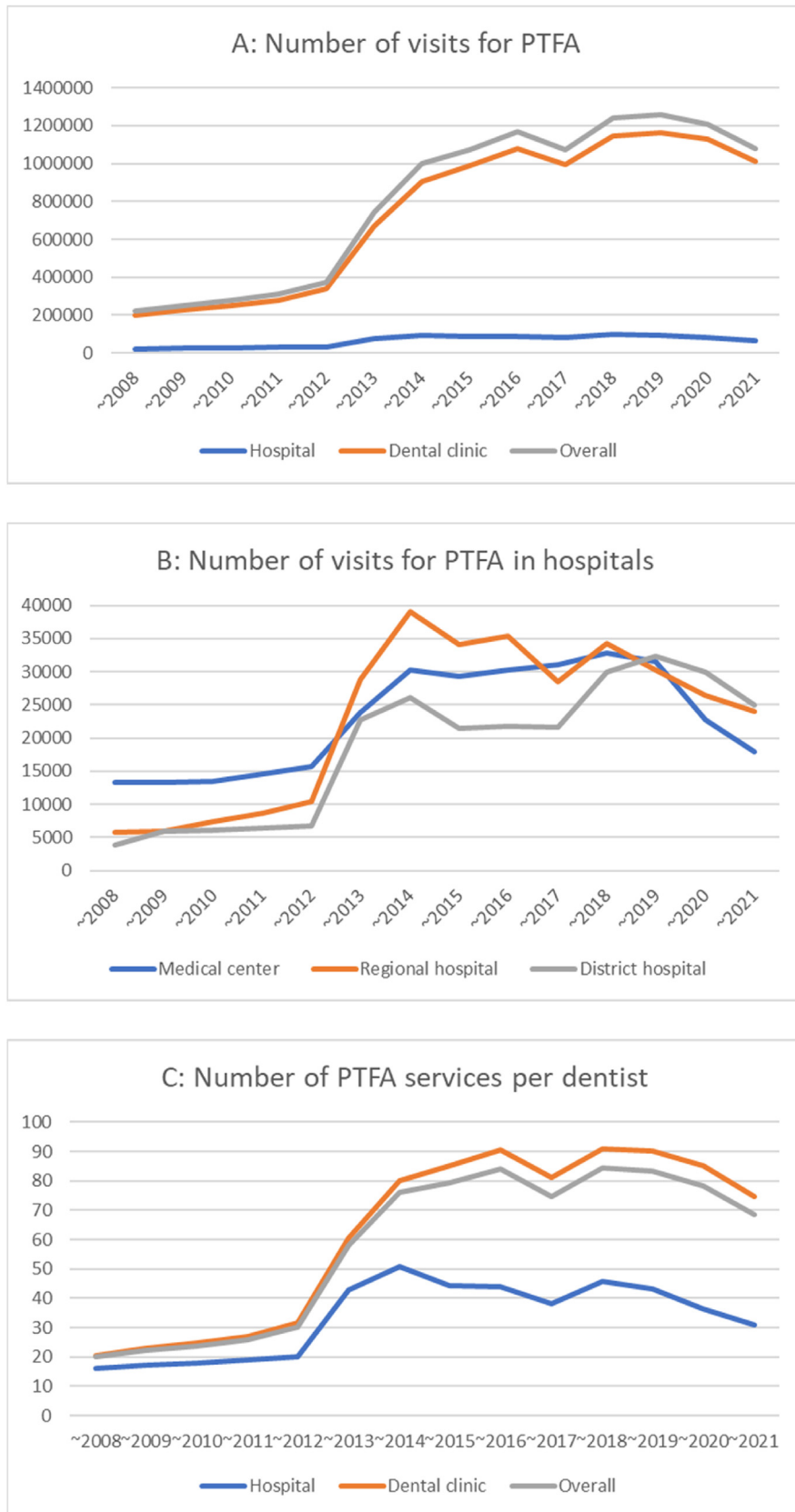


Figure 1 The changing trends of the number of out-patient visits for dental PTFA services (A), the number of out-patient visits for dental PTFA services in hospitals of different levels (B), and the number of dental PTFA services provided by each dentist (C) in Taiwan from 2008 to 2021.

Table 2 The numbers of the population, the patients, the out-patient visits, and the medical expenses for dental caries in the 3 age groups of children under the National Health Insurance (NHI) system in Taiwan from 2008 to 2021.

Year	Population (million people)			Number of patients			Number of out-patient visits			Medical expenses (million NHI points)		
	0–4	5–9	10–14	0–4	5–9	10–14	0–4	5–9	10–14	0–4	5–9	10–14
2008	1.04	1.34	1.59	217,812	749,819	481,733	578,620	1,736,259	890,359	802.26	2086.47	1155.74
2009	1.01	1.29	1.54	219,438	728,475	476,245	562,903	1,663,645	872,040	776.54	2010.57	1147.39
2010	0.98	1.21	1.51	231,092	694,080	482,835	574,254	1,565,476	874,340	775.95	1900.31	1152.55
2011	0.96	1.13	1.47	275,857	650,896	469,606	650,177	1,479,999	842,532	808.77	1816.08	1116.36
2012	0.97	1.09	1.40	273,755	648,416	467,877	675,118	1,468,392	821,153	819.68	1817.44	1101.02
2013	0.99	1.05	1.34	336,194	656,967	459,685	753,937	1,525,867	821,662	840.26	1843.93	1109.35
2014	1.00	1.03	1.29	350,125	667,543	470,098	754,431	1,594,024	838,710	815.12	1868.85	1123.20
2015	1.03	1.00	1.21	373,400	636,632	438,846	793,836	1,490,014	773,310	844.78	1729.53	1032.30
2016	1.06	0.97	1.13	197,465	576,773	403,797	454,876	1,393,069	725,949	584.37	1648.75	932.35
2017	1.04	0.99	1.09	180,580	579,486	389,405	395,075	1,402,064	697,932	496.57	1657.05	883.27
2018	1.02	1.00	1.05	183,552	579,160	381,445	395,938	1,402,083	675,176	478.11	1625.92	843.60
2019	0.99	1.01	1.03	176,454	581,160	372,160	369,267	1,394,570	655,439	423.88	1581.62	800.83
2020	0.95	1.04	0.99	160,043	580,149	341,026	321,253	1,353,812	596,434	360.49	1524.74	730.86
2021	0.90	1.06	0.97	146,351	541,778	313,244	278,293	1,208,039	533,528	300.34	1340.96	641.81
Total change	−0.14	−0.28	−0.62	−71,461	−208,041	−168,489	−300,327	−528,220	−356,831	−501.92	−745.51	−513.94
Total change rate (%)	−13.84	−20.56	−39.14	−32.81	−27.75	−34.98	−51.90	−30.42	−40.08	−62.56	−35.73	−44.47
One-year change	−0.01	−0.02	−0.05	−5497	−16,003	−12,961	−23,102	−40,632	−27,449	−38.61	−57.35	−39.53
One-year change rate (%)	−1.06	−1.58	−3.01	−2.52	−2.13	−2.69	−3.99	−2.34	−3.08	−4.81	−2.75	−3.42
Correlation coefficient ^a	—	—	—	−0.235	−0.842	−0.789	−0.467	−0.699	−0.798	−0.690	−0.791	−0.779

^a Correlation coefficient with the number of the overall out-patient visits for dental professionally topical fluoride application (PTFA) services.

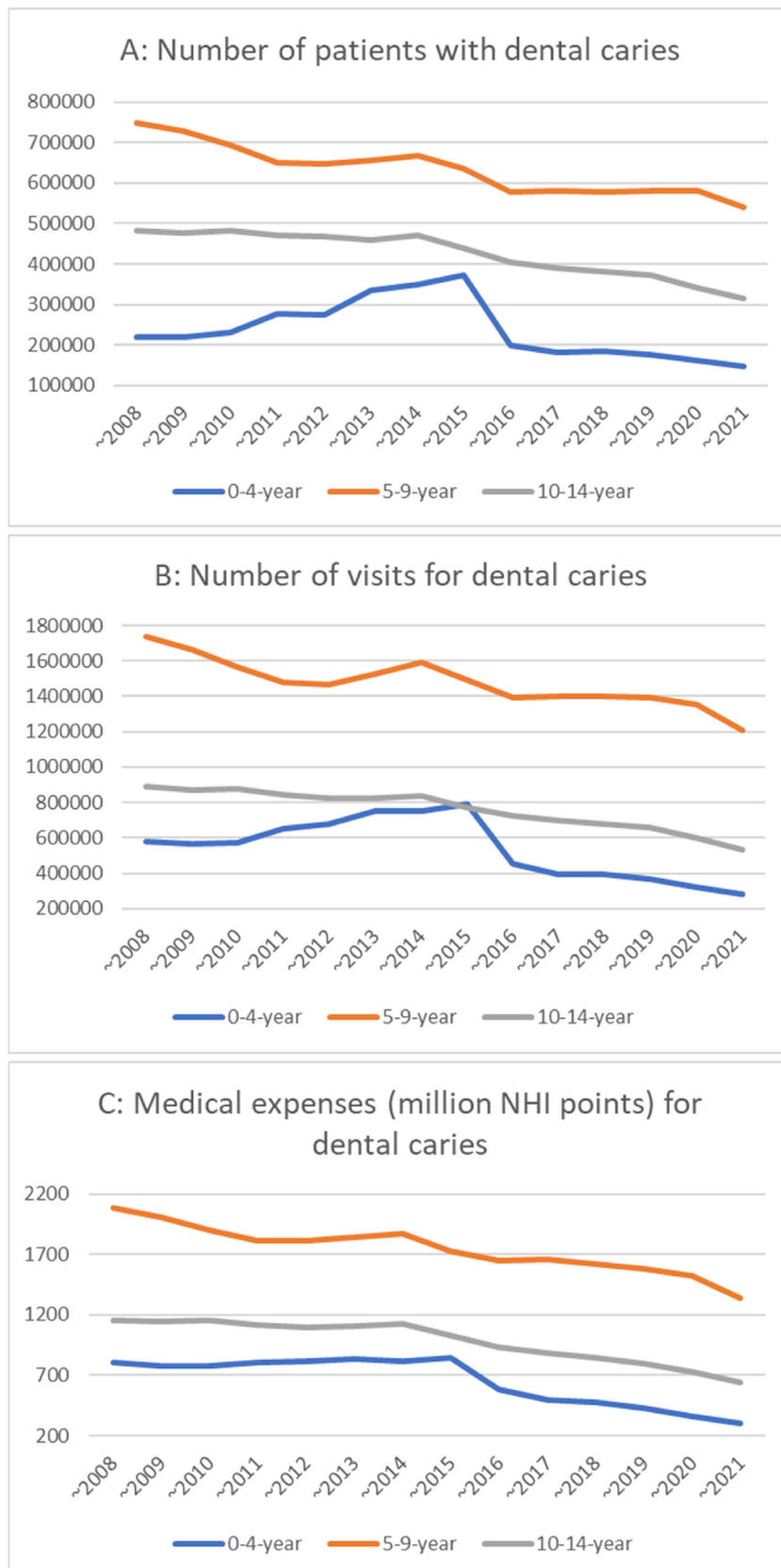


Figure 2 The changing trends of the number of patients with dental caries (A), the number of out-patient visits for dental caries (B), and the medical expenses for dental caries (C) in the 0-4-year, 5-9-year, and 10-14-year age groups under the NHI system in Taiwan from 2008 to 2021.

Table 3 The dental use rate, the number of out-patient visits per 1000 people, and the medical expenses per person for dental caries in the 3 age groups of children under the National Health Insurance (NHI) system in Taiwan from 2008 to 2021.

Year	Dental use rate (%)			Number of out-patient visits per 1000 people			Medical expenses per person (NHI points)		
	0–4	5–9	10–14	0–4	5–9	10–14	0–4	5–9	10–14
2008	20.96	55.96	30.32	556.69	1295.88	560.43	771.85	1557.27	727.47
2009	21.64	56.56	30.93	555.03	1291.75	566.43	765.68	1561.13	745.29
2010	23.51	57.50	31.96	584.11	1296.87	578.68	789.27	1574.25	762.81
2011	28.72	57.43	31.96	676.89	1305.87	573.48	842.00	1602.41	759.86
2012	28.21	59.58	33.47	695.76	1349.22	587.35	844.74	1669.93	787.53
2013	34.12	62.32	34.31	765.17	1447.52	613.32	852.78	1749.25	828.06
2014	35.15	64.91	36.51	757.43	1550.02	651.42	818.36	1817.25	872.38
2015	36.30	63.84	36.37	771.62	1494.25	640.91	821.14	1734.45	855.55
2016	18.67	59.19	35.65	430.04	1429.68	640.91	552.46	1692.09	823.14
2017	17.32	58.72	35.81	378.88	1420.75	641.90	476.22	1679.13	812.35
2018	18.07	57.83	36.23	389.82	1399.97	641.28	470.73	1623.48	801.25
2019	17.78	57.54	36.24	372.10	1380.83	638.24	427.13	1566.03	779.82
2020	16.84	55.69	34.29	337.96	1299.55	599.69	379.25	1463.63	734.85
2021	16.34	50.90	32.40	310.76	1135.05	551.83	335.38	1259.94	663.83
Total change	−4.61	−5.06	2.08	−245.93	−160.83	−8.60	−436.48	−297.32	−63.65
Total change rate (%)	−22.01	−9.04	6.85	−44.18	−12.41	−1.53	−56.55	−19.09	−8.75
One-year change	−0.35	−0.39	0.16	−18.92	−12.37	−0.66	−33.58	−22.87	−4.90
One-year change rate (%)	−1.69	−0.70	0.53	−3.40	−0.95	−0.12	−4.35	−1.47	−0.67
Correlation coefficient ^a	−0.253	0.101	0.836	−0.486	0.332	0.708	−0.714	−0.001	0.278

^a Correlation coefficient with the number of the overall out-patient visits for dental professionally topical fluoride application (PTFA) services.

Discussion

The World Health Organization (WHO) pointed out that oral health not only affects chewing, nutrition, speaking, and social interaction, but also is an important cornerstone of overall health and quality of life. The dental caries is one of the most common oral diseases in children. The prevention and treatment of oral diseases, especially the dental caries, can improve the quality of personal health and quality of life.⁸ Therefore, Taiwan government has long been committed to the health policies on the prevention and treatment of dental caries in children. As early as 2004, the Ministry of Health and Welfare began to implement the health policy of dental PTFA services for preschool children. This policy has been implemented for nearly 20 years.² To the best of our knowledge, this study was the first to analyze the changing trends of children's dental PTFA visits and compared the children's dental PTFA visits with the children's dental use indicators for dental caries under the NHI system in Taiwan from 2008 to 2021.

Our results showed that in 2013, the number of children's dental PTFA visits began to grow significantly, and continued to grow until 2019. The reason for the growth of the number of children's dental PTFA visits may be that in the second half year of 2012, the policy of "delivery of fluorides to kindergartens" was further promoted. Especially, dentists were allowed to provide free dental PTFA services directly in the kindergartens, while originally the dental PTFA services must be performed within dental

institutions. In addition, in the second half year of 2013, the subsidy targets for children's dental fluoride health care services have been expanded from children under the age of 5 years to those under the age of 6 years, and the subsidy can be given twice per year. For children under the age of 12 years from the low-income families, those with disabilities, and those in aboriginal, remote, and outlying island areas, the subsidy can be given four times per year.² As long as the government implements policy promotion methods, the number of children's dental PTFA visits will increase significantly. The main reason is that Taiwan has sufficient manpower of dentists and is suitable for implementing dental PTFA services as a comprehensive public health measure. In 2021, there were 15,741 dentists and 23.37 million people in Taiwan, indicating that there are 67.34 dentists per 100,000 people. Therefore, Taiwan currently has sufficient manpower of dentists for implementing dental PTFA services. However, the decline in the number of children's dental PTFA visits for two consecutive years after 2019 is related to the COVID-19 pandemic.

There is a problem of uneven distribution of dental resources in Taiwan.^{9–12} However, over 85% of dentists work in the dental clinics. The dental clinics are characterized by small scale and high management flexibility, and their geographical distribution is wider and deeper into the communities, and even easier to locate in relatively remote areas. Therefore, clinic dentists become the main human resources for the execution of dental PTFA services in Taiwan. The proportion of dental PTFA services performed

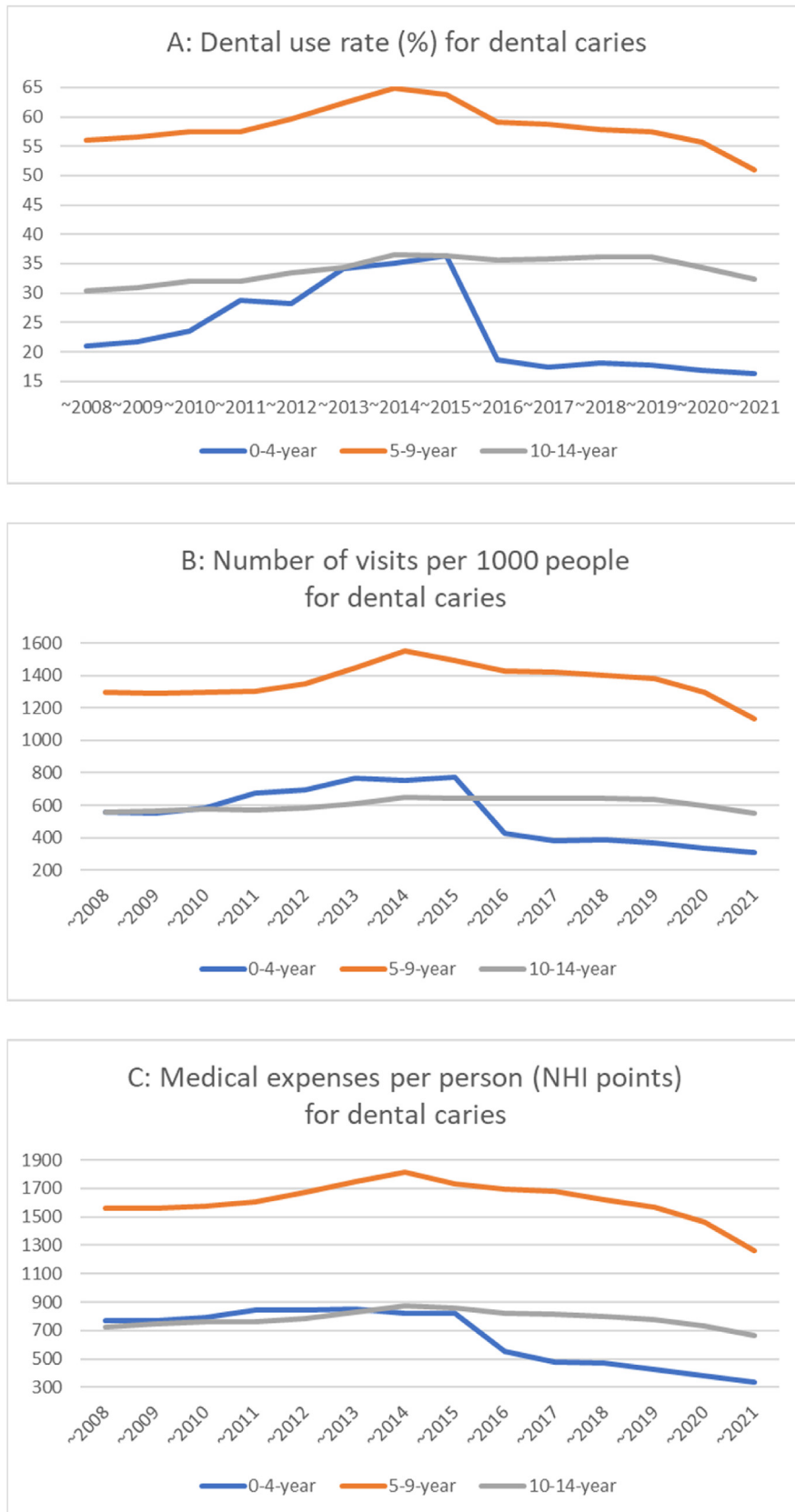


Figure 3 The changing trends of the dental use rate for dental caries (A), the number of out-patient visits per 1000 people for dental caries (B), and the medical expenses per person for dental caries (C) in the 0-4-year, 5-9-year, and 10-14-year age groups under the NHI system in Taiwan from 2008 to 2021.

Table 4 The number of the out-patient visits per patient, the medical expenses per patient, and the medical expenses per out-patient visit for dental caries in the 3 age groups of children under the National Health Insurance (NHI) system in Taiwan from 2008 to 2021.

Year	Number of out-patient visits per patient			Medical expenses per patient (NHI points)			Medical expenses per out-patient visit (NHI points)		
	0–4	5–9	10–14	0–4	5–9	10–14	0–4	5–9	10–14
2008	2.66	2.32	1.85	3683.26	2782.63	2399.13	1386.50	1201.70	1298.06
2009	2.57	2.28	1.83	3538.75	2759.97	2409.24	1379.52	1208.53	1315.75
2010	2.48	2.26	1.81	3357.74	2737.88	2387.04	1351.23	1213.88	1318.19
2011	2.36	2.27	1.79	2931.85	2790.13	2377.23	1243.93	1227.09	1325.01
2012	2.47	2.26	1.76	2994.21	2802.89	2353.23	1214.13	1237.71	1340.83
2013	2.24	2.32	1.79	2499.34	2806.73	2413.29	1114.50	1208.45	1350.13
2014	2.15	2.39	1.78	2328.09	2799.60	2389.29	1080.44	1172.41	1339.20
2015	2.13	2.34	1.76	2262.41	2716.69	2352.30	1064.18	1160.75	1334.91
2016	2.30	2.42	1.80	2959.35	2858.59	2308.96	1284.67	1183.54	1284.32
2017	2.19	2.42	1.79	2749.88	2859.51	2268.24	1256.91	1181.86	1265.55
2018	2.16	2.42	1.77	2604.79	2807.38	2211.58	1207.55	1159.65	1249.45
2019	2.09	2.40	1.76	2402.23	2721.48	2151.85	1147.90	1134.12	1221.82
2020	2.01	2.33	1.75	2252.47	2628.19	2143.12	1122.14	1126.26	1225.38
2021	1.90	2.23	1.70	2052.16	2475.11	2048.90	1079.21	1110.03	1202.95
Total change	−0.75	−0.09	−0.15	−1631.10	−307.52	−350.23	−307.30	−91.67	−95.12
Total change rate (%)	−28.42	−3.71	−7.85	−44.28	−11.05	−14.60	−22.16	−7.63	−7.33
One-year change	−0.06	−0.01	−0.01	−125.47	−23.66	−26.94	−23.64	−7.05	−7.32
One-year change rate (%)	−2.19	−0.29	−0.60	−3.41	−0.85	−1.12	−1.70	−0.59	−0.56
Correlation coefficient ^a	−0.866	0.673	−0.611	−0.802	−0.194	−0.688	−0.663	−0.808	−0.597

^a Correlation coefficient with the number of the overall out-patient visits for dental professionally topical fluoride application (PTFA) services.

by the clinic dentists increased from 89.59% (198,597/221,675) in 2008 to 93.79% (1,011,098/1,078,099) in 2021, which was higher than the proportion of clinic dentists (86.19%, 13,567/15,741) in 2021. In addition, our previous study also confirmed that remote and outlying island counties or the eastern region of Taiwan did have a better dental PTFA use rate (the number of dental PTFA visits per child population) in 2021.⁷

On the other hand, the number of dental PTFA services performed by hospital dentists, including medical centers, regional hospitals, and district hospitals, also increased significantly after 2012. This may be due to the policy promotion of government in 2012. Perhaps some hospitals also assign dentists to kindergartens to provide dental PTFA services, and hospital dentists are more willing to take the initiative to perform dental PTFA to children who come to the hospital for dental treatment. Moreover, there are also parents who choose to take their children to the hospitals for the dental PTFA. From 2019 to 2021, the decrease rate of children's dental PTFA visits was only 14.40% in overall, and those of hospitals and dental clinics were 28.80% and 13.24%, respectively. Among hospitals, these decrease rates were 42.85% in medical centers, 20.74% in regional hospitals, and 22.70% in district hospitals, respectively. This indicates that Taiwan can still maintain the capacity of children's oral health services during the COVID-19 pandemic. However, due to the burden of COVID-19

medical responsibilities and personnel control during the pandemic, the medical centers' dental PTFA services were reduced the most in proportion.

In this study, among the 3 age groups of children, the numbers of the patients, the out-patient visits, and the medical expenses for dental caries under the NHI system in Taiwan from 2008 to 2021 all showed the highest values in the 5-9-year age group of children, followed in a descending order by the 10-14-year age group and the 0-4-year age group. This is consistent with our previous research results.^{13–16} The main reason is that the 5-9-year-old children are still in the stage of mixed dentition with difficulty to clean and insufficient self-care ability, so they have more oral problems. However, the younger children are still in the early stage of deciduous teeth eruption, so they have not yet begun to suffer from oral problems in large numbers.

Over the past ten years, the above dental use indicators of children and adolescents have indeed shown a trend of decreasing in overall. In addition to the significant reduction in 2020 and 2021 due to the impact of the COVID-19 pandemic, and the statistics before 2015 including the out-patient clinics of dentistry, western medicine, and traditional Chinese medicine, showing that the 0-4-year-old children are more likely to seek help from western medicine first because they are not sure about their oral problems, the main reason of the reduction of children's dental

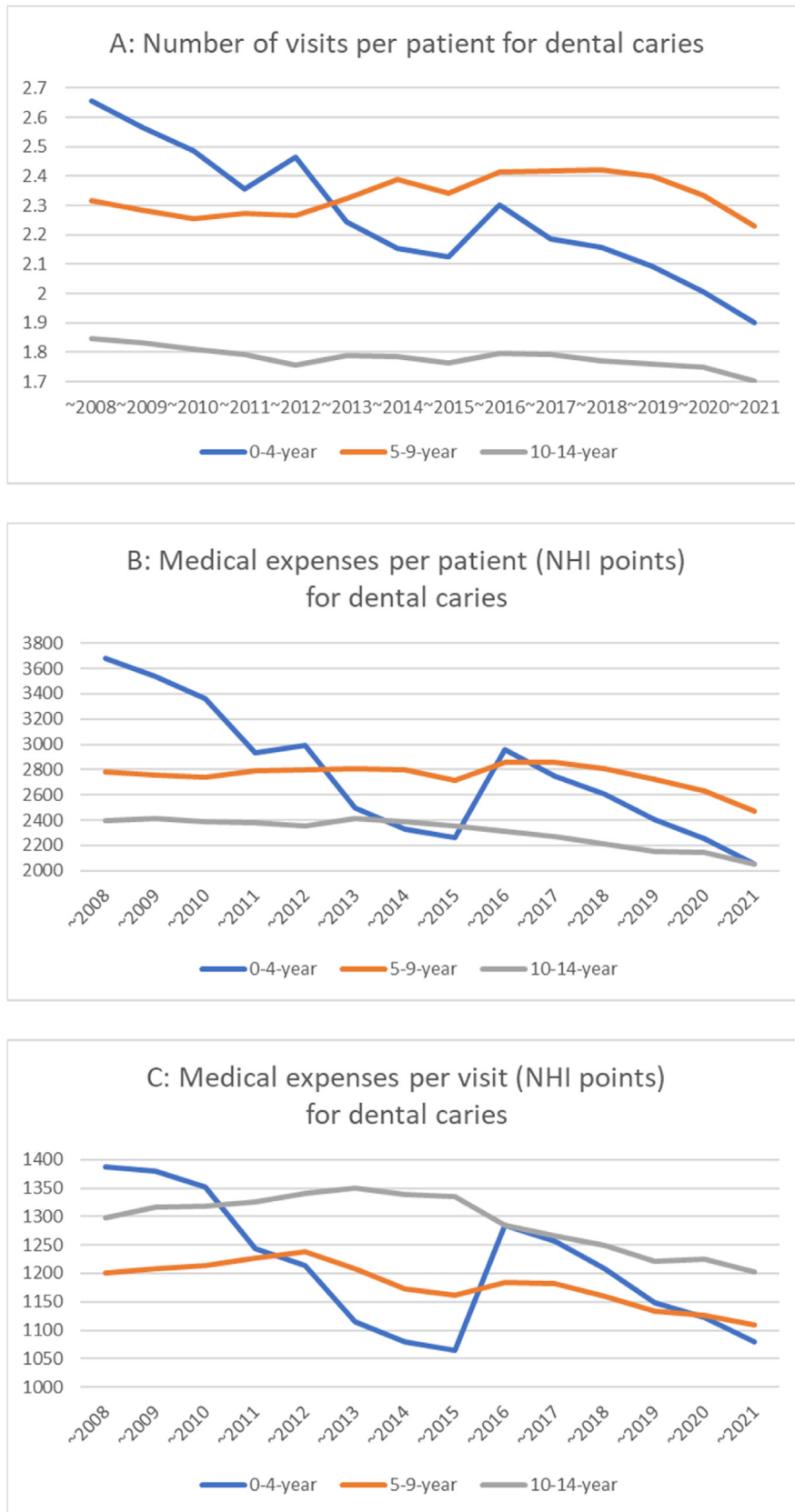


Figure 4 The changing trends of the number of out-patient visits per patient for dental caries (A), the medical expenses per patient for dental caries (B), and the medical expenses per out-patient visit for dental caries (C) in the 0-4-year, 5-9-year and 10-14-year age groups under the NHI system in Taiwan from 2008 to 2021.

use indicators in numbers is the low birthrate problem in Taiwan. From 2008 to 2021, the population of children and adolescents aged 0–14 has decreased by more than 1 million people, so it is not surprising that these groups have decreased in the numbers of the patients, the out-patient visits, and the medical expenses for dental caries. However, among the 3 age groups of children, the total decrease rates of the above dental use indicators were greater than that of their population. This means that the dental caries problem of children and adolescents has been improved for a long time in Taiwan.

In order to exclude the influence of population size, this study calculated the dental use rate, the number of out-patient visits per 1000 people, and the medical expenses per person for dental caries in the 3 age groups of children with population as the denominator. The results showed that only the dental use rate in the 10-14-year age group showed an increasing trend, and among the 3 age groups, the above dental use indicators all presented decreasing trends. However, the dental use rate for dental caries refers to the ratio of the number of people who seek medical attention for dental caries to the total population. It is different from the definition of the prevalence rate of dental caries. The change trends of the two were similar, but the value of the dental use rate was lower. For example, a report pointed out that the dental caries rate of 5-year-old children in Taiwan decreased from 79.32% in 2011 to 65.43% in 2018.² In this study, however, the dental use rate for dental caries of 5-9-year-old children was 57.83% in 2018. Therefore, it means that some people or children who had dental caries or tooth decay did not seek medical management. It is inferred that these people or children may be from disadvantaged families or rural areas. However, the increasing trend of the dental use rate for dental caries in the 10-14-year age group means that older children or adolescents are becoming more aware of their own oral health.

On the other hand, the number of the out-patient visits per patient, the medical expenses per patient, and the medical expenses per out-patient visit for dental caries can be used as indicators to check the severity of dental caries in patients. The results showed that among the 3 age groups, the above dental use indicators all presented decreasing trends. This means that over the past ten years, the severity of dental caries in patients of children and adolescents was improving. Because the out-patient visits and medical expenses for dental caries and the medical expenses per visit have been reduced. Among them, those in the 0-4-year age group had the largest reduction, indicating that the dental caries problems of younger children improve more than those of relatively older children.

In terms of the correlation between the number of the overall out-patient visits for dental PTFA services and various dental use indicators for dental caries, the numbers of the patients, the out-patient visits, and the medical expenses in the 5-9-year age group (with the correlation coefficients being -0.842 , -0.699 and -0.791 , respectively) and the 10-14-year age group (with the correlation coefficients being -0.789 , -0.798 and -0.779 , respectively), and the medical expenses per person in the 0-4-year age group (with the correlation coefficient being -0.714), as well as the number of out-patient visits per

patient and the medical expenses per patient in the 0-4-year age group (with the correlation coefficients being -0.866 and -0.802 , respectively), and the medical expenses per out-patient visit in the 5-9-year age group (with the correlation coefficient being -0.808) all presented a highly negative correlation with the out-patient visits for dental PTFA services. However, the dental use rate and the number of out-patient visits per 1000 people in the 10-14-year age group (with the correlation coefficients being 0.836 and 0.708 , respectively) showed a highly positive correlation with the number of the out-patient visits for dental PTFA services. This also means that the increase in the number of dental PTFA services is related to the reduction of dental caries in the 5-14-year-old children and adolescents, and the improvement in the severity of dental caries in younger children. It is also associated with the increased awareness of oral health in the 10-14-year-old adolescents, because their use of NHI resources for dental caries increases.

This study was not designed to directly demonstrate a causal relationship between increased children's dental PTFA visits and decreased dental use indicators for dental caries. We understand the relationship between the two from the correlation analysis. We consider that the dental PTFA service plays two roles to improve children's dental caries. First, at the microscopic and molecular levels, fluoride directly produces an anti-caries effect on children's teeth. Second, at the macroscopic and social levels, the dental PTFA policy enhances the enthusiasm of dental teams for oral care of children, and promotes the oral health awareness of child caregivers and children themselves.

In Taiwan, the problem of dental caries in children is still serious. Obviously, there is still a space for improvement in the oral health education for child caregivers and children. In fact, the number of dentists in Taiwan has doubled over the past 20 years, and hospital dentistry has also made remarkable progress.^{11,17} We believe that dentists in Taiwan should be able to play a more active role in the dental PTFA policy. Based on the results of this study, we conclude that children's dental caries prevention strategy has three directions to be further worked on. First, children's dental caries prevention policies must effectively promote oral health education and resources for child caregivers and children, so as to reduce the incidence of dental caries from the beginning. Second, Taiwan's dental clinics are top-rated. Thus, the convenience of dental treatment is high. Since the implementation of the NHI system in 1995, the insurance coverage rate has reached 99.9%, but the dental use rate has not yet reached 50%.^{13–16} The NHI system must encourage the public to use NHI resources through various oral health education and publicity, so as to cultivate children's habits for regular oral health checkups and dental cleanings. The general dentists' participation of the dental caries prevention also needs to be improved, so that they can prevent and early treat children's dental caries during daily dental practice procedures. Third, the dental PTFA services provided by each dentist still have a space to increase in the future, and the increase in the number of dentists can also increase the number of overall dental PTFA services. The dental PTFA policy should continue to be strengthened, in order to

continue to improve the effects on dental caries prevention in children.

Declaration of competing interest

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

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None.

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