Original Article

Tooth life expectancy and burden of tooth loss: Two cross-sectional studies in Taiwan

Ling-Yu Liang [a], Ming-Che Tsai [b], Kuang-Chung Shih [c,d],
Shiu-Ming Huang [e], Donald E. Morisky [f], Earl Fu [g*]

[a] Jian-An Private Practice, New Taipei City, Taiwan
[b] Institute of Health and Welfare Policy, School of Medicine, National Yang Ming Chiao Tung University, Taipei, Taiwan
[c] Division of Endocrinology & Metabolism, Cheng Hsin General Hospital, Taipei, Taiwan
[d] Division of Endocrinology & Metabolism, Tri-Service General Hospital, National Defense Medical Center, Taipei, Taiwan
[e] Senior Health & Long-Term Care Research Project, National Health Research Institutes Forum, Taiwan
[f] UCLA School of Public Health, Department of Community Health Sciences, Los Angeles, CA, USA
[g] Department of Dentistry, Taipei Tzu Chi Hospital, New Taipei City, Taiwan

Abstract *Background/purpose:* Life expectancy (LE) is a hypothetical measure to predict life longevity and the indicator of society's overall health. Tooth loss is a worldwide enigma; however, the LE for tooth (LET) are obscure. LET and the burden of tooth loss in Taiwan were estimated using the scheme of National Health Insurance (NHI).
Materials and methods: Using NHI data, mortality rate, age-specific mortality rate, tooth-extraction rate, and age-specific tooth-extraction rate (ASTER) of Taiwanese in 2004 and 2013 were estimated. ASTER for the individual tooth (ASTER-T) was analyzed for each of 28 permanent teeth according to ID code and tooth location. LET and years lived with disability for tooth loss (YLDs-T) of each permanent tooth were estimated following Global Burden Disease study.
Results: In 2004, 1,741,228 teeth extracted from 1,078,254 patients among 22,646,835 Taiwanese, whereas 2,012,907 teeth extracted from 1,254,746 patients among 23,344,670 in 2013. In both years, the ASTERs presented an increasing trend as age increased. However, the ASTER-Ts presented varied according to tooth types. The LET and YLDs-T were also varied. The maximum values of YLDs-T were noticed for the first molars.

* Corresponding author. Section of Periodontology, Department of Dentistry, Taipei Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, No. 289, Jianguo Rd., Xindian Dist., New Taipei City 23142, Taiwan. Fax: +886 2 66292702.
E-mail address: fuearl@gmail.com (E. Fu).

Conclusion: Our findings of this national survey highlight the need for public health policy, particular the early loss of first molars, aiming to increase awareness regarding oral health.

Introduction

Teeth play essential roles in food mastication, speech, socio-communication, and cosmetics.[1] Tooth loss reflects the endpoint of lifetime of dental disease(s) and the individual's history of dental treatment.[2] Tooth loss may cause mild or moderate disability for tooth functions.[3] A strong association exists between the quality of life and teeth loss.[4,5]

Studies have shown that tooth loss is an enigma noted worldwide.[6] The global prevalence of total tooth loss has been estimated, with the prevalence peaks observed at 75−80 years old.[3,7] The global the years lived with disability (YLDs) for total tooth loss, with the definition of "having fewer than 9 remaining permanent teeth", in 2015 was 113 per 100,000 person-years.[7] In this definition, the burden of tooth loss is collecting the information described in edentulous or a severe condition of tooth loss. However, the mouth contains 28 teeth with different anatomical, physiological, and occlusion functions.[8] The loss of teeth over time might further complicate the estimation of oral disability. It has been suggested that a more detail appraisal of oral conditions would be ideal to help inform quantification of the burden of these health states.[3]

To estimate the disability and the duration of disability, it must be considering with the life longevity. The longevity of life can be predicted as the life expectancy (LE), which is a hypothetical statistical measure and an indicator of the overall health of a society.[9] Study also showed that, using the same principles for LE, the tooth life expectancy (LET) were predicted for each individual tooth.[10] Up to date, nevertheless, the exact LET and the burden of tooth loss are remaining obscure.

In Taiwan, a compulsory social health insurance scheme has been implemented since 1995. The Health Insurance Claim Database contains all the medical claims data of 22.6 million beneficiaries, including dental care service utilization.[11] This study therefore aimed to estimate the LET, and YLDs for the tooth loss (YLDs-T) for 28 permanent teeth of Taiwanese in 2004 and 2013.

Materials and methods

Data collection and study population

In this study, the analysis was performed based on the electronic vital registration data, and NHI claims data obtained from the Ministry of Health and Welfare in Taiwan in 2004 and 2013. The registry file contains the codes for ID number, gender, dates of birth and death, and cause of death. The NHI program, a Taiwanese health care system established in March 1995, covers 98% of the entire population of the country, that is, 22.6 million beneficiaries.[12] The Health Insurance Electronic Database contains all the dental care service claims data, including the ID number, gender, date of birth, date of service and ICD-9-CM diagnosis, procedures in tooth position, and medical care expenditure. The claims data also included the number and location of tooth extractions.

Analysis method

In the present study, the mortality and the age-specific mortality rate (ASMR) were assembled, whereas the tooth-extraction rate and age-specific tooth-extraction rate (ASTER) were obtained accordingly. In consideration of the 28 permanent teeth (excluding the wisdom teeth) per person, the ASTER for tooth (ASTER-T) at the tooth-level were further calculated. Given the life table data,[13] the LE and LET for the Taiwanese was measured.[10,14]

Based on the principle of YLDs in the published GBD studies by age and gender,[13,15] the YLDs-T could be measured at the tooth-level. The simple YLDs-T formula follows: YLDs-T $(a) = N(a) \times D(a) \times DW$, where $N(a)$ is the number of tooth-extraction cases for a given age a; $D(a)$ is the duration for the extracted tooth and uses the LET at age a; DW is the disability weight, with the value of 0.00429 modified following the previous studies.[3,7,16] The YLDs-T per capita was subsequently calculated.[17] This research was ethically approved by Taipei Tzu Chi Hospital, Tzu Chi Medical Foundation Institutional Review Board (Protocol No. 08-W-122).

Results

Age-specific mortality rate and age-specific tooth-extraction rate

The total population in Taiwan in 2004 was 22,646,835 (Table 1, Fig. 1A), and a 590 per 100,000 population mortality rate was obtained based on the 133,680 decedents recorded (Table 1), whereas a 661 per 100,000 population mortality rate was achieved in 2013 (154,374/23,344,670). The assembled ASMRs in 2004 and 2013 increased as age increased until the highest values of 23.4% and 26.1% were observed for 2004 and 2013, respectively, at the age of 98 years old (Fig. 1B).

Because 1,741,228 teeth, in 1,078,354 beneficiaries, were extracted in 2004, the tooth-extraction rate was 7689 per 100,000 population (Table 1), whereas the rate of 8623 per 100,000 population was record in 2013. Similar to ASMRs (Fig. 1B), the assembled ASTERs in 2004 and 2013 showed

Table 1 Demographics and the tooth-extraction profiles for the Taiwanese population in 2004 and 2013.

|	2004	2013
Total population	22,646,835	23,344,670
Number deceased	133,680	154,374
Mortality rate (per 100,000 population)	590	661
Patients who had the tooth extraction		
1. Number of dental patients who had extraction(s)	1,078,354	1,254,746
2. % of patients who received extraction for those dental visits	20.0%	18.6%
3. Number of teeth extracted per patient	1.61	1.60
Total teeth extracted in the population	1,741,228	2,012,907
Tooth-extraction rate (per 100,000 population)	7689	8623

A.

B.
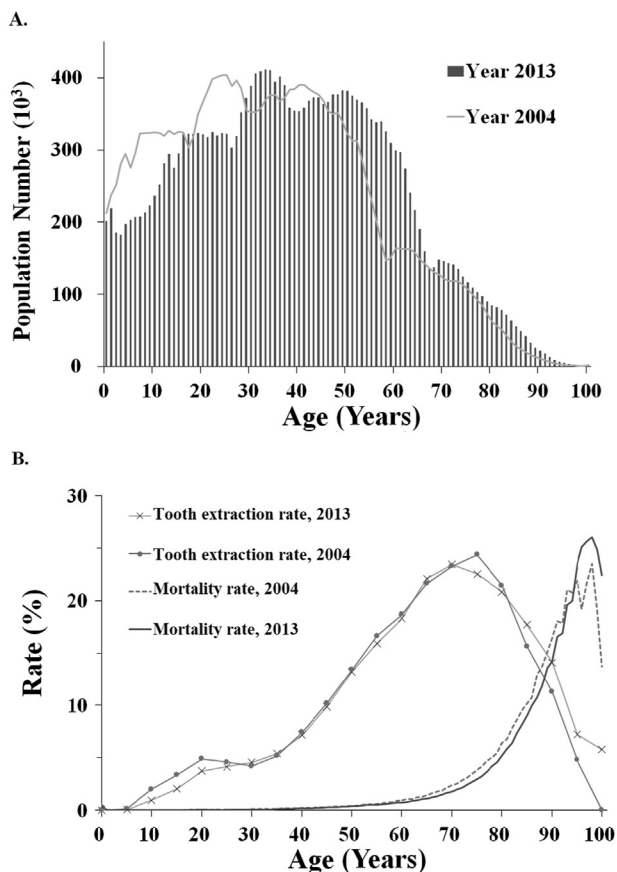
Figure 1 ASMR and ASTER of the Taiwanese population in 2004 and 2013. Profiles of the Taiwanese populations based on age in 2004 and 2013 (A). ASMR and ASTER in each of 2004 and 2013 were obtained (B), and the gaps between the mortality and the tooth extraction rates were clearly observed (ASMR = age-specific mortality rate, and ASTER = age-specific tooth-extraction rate).

an increasing trend as age increased until the highest value. However, the highest values of ASTERs, despite 2004 and 2013, were younger than that of ASMRs (24.5%, 75 years old, and 25.1%, 74 years old, for 2004 and 2013, respectively). Distributions of ASMRs (peaks at 98 years old) and ASTERs (peaks around 75 years old) were different despite of in years of 2004 and 2013, and the gaps were noticed between them.

According to the tooth individuality, the ASTER-T for every single tooth could be yielded; however, the ASTER-Ts among teeth showed varied (Fig. 2A—B), despite the years in 2004 and 2013. By tooth types (e.g., incisor, canine, premolar, or molar), however, the ASTER-Ts in both years were presented similar (Fig. 2C—F). Besides, the ASTER-Ts for incisors/canines presented one peak (located around ages of over 75 years old) (Fig. 2C—D), whereas those for molars/premolars exhibited two peaks (before 25 and around ages over 65 years old), particularly for the first molars (Fig. 2E—F). In Fig. 2F, the high peaks in the year of 2004 were noted at ages of 21 and 65 years old (with the rates of 0.78 and 0.84%), whereas that of 30 and 70 years old (with the rate 0.51 and 0.79%) in the year of 2013. It could be clearly found that the fist peaks were much different in the years of 2004 and 2013: the rate reduced (0.78 vs 0.51%) and the age delayed (21 vs 30 years old) in 2013 compared to that in 2004.

Life expectancy and life expectancy for tooth

According to life tables in 2004 and 2013, the LE in every single age for the Taiwan population could be recorded (Table 2). Compare to the LEs in 2004, the LEs in 2013 increased in each period. By the same principle, the LETs in 2004 and 2013 could also be measured for every single tooth (Table 2). Similar LETs were found in 2004 and 2013 for teeth 33 and 34. For tooth 36, in contrast, longer LFTs were noticed in 2013 than that in 2004. Among teeth, therefore, the discrepancies of LE to LETs, based on the tooth individuality or the observation year, were observed.

Years lived with disability for tooth loss

The YLDs-T in the Taiwan population was 1380 and 1445 per 100,000 population for 2004 and 2013, respectively. In each of 2004 and 2013, a total of 28 age-specific YLDs-Ts were obtained based on tooth individuality (Fig. 3A—B). As those ASTER-Ts (Fig. 2A—B), the age-specific YLDs-Ts (Fig. 3A—B) presented different among the teeth despite 2004 and 2103, but the YLDsTs presented similar if they were selected within the same toot type (Fig. 3C—F). Although the values of ASTER-Ts and age-specific YLDs-Ts from 2004 to 2013 changed un-considerable for canines, the YLDs-Ts for the first molar showed remarkable changes, particularly in young ages (Fig. 2A vs. 3A, and 2B vs. 3B). In Fig. 3F about the tooth of 36, a high first peak was noted in the year of 2004 (214, 20 years old) although two peaks were still observed in the year of 2013. For the first peak, the YLDs-T reduced and the age delayed in 2013 (135, 26 years old) compared to that in 2004 (214, 20 years old). In Fig. 4, the 28 age-specific YLDs-Ts in 2004 and 2013 were presented. Compared to that observed in 2004, the
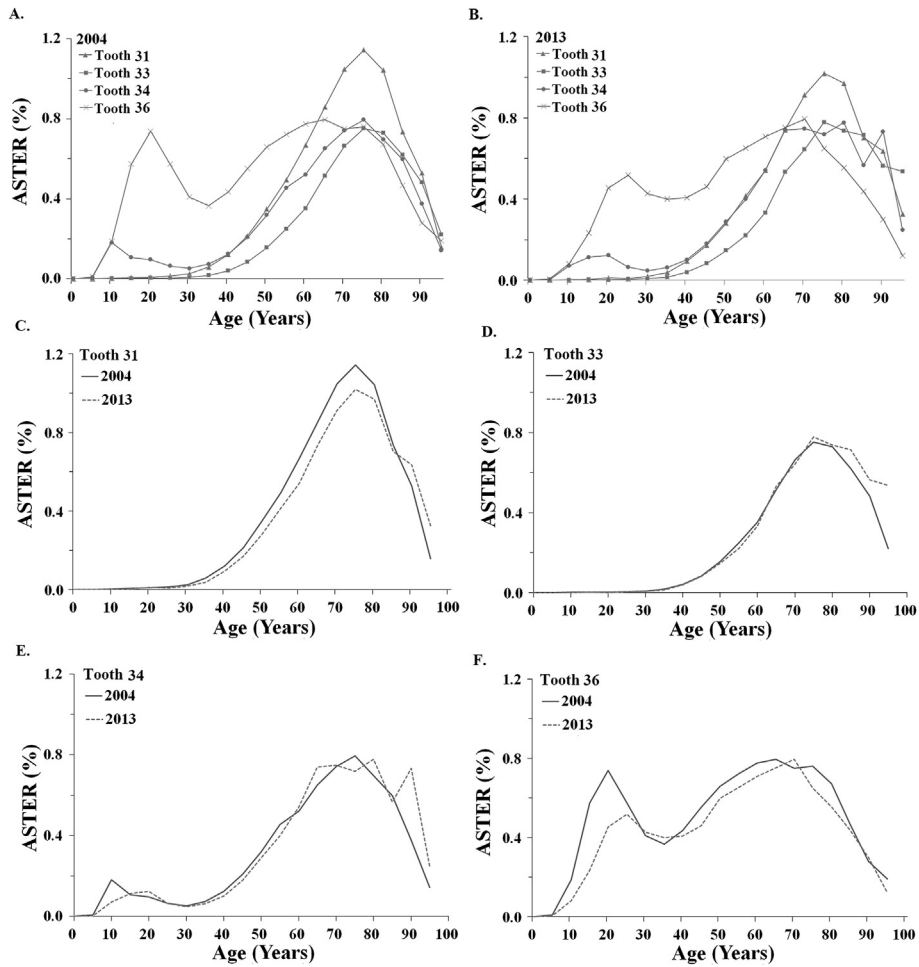
Figure 2 ASTER-Ts for teeth 36, 34, 33, and 31 in 2004 and 2013. ASTER-Ts for the four teeth in 2004 (A) and 2013 (B) were assessed, and the rates presented varied among teeth. However, the ASTER-Ts obtained in 2004 and 2013 were similar if they were analyzed by tooth 31, 33, 34, or 36 (C to F) (ASTER-T = age-specific tooth-extraction rate for tooth).

Table 2 Life expectancy (LE) for Taiwanese and the LE for tooth (LET) for the tooth 31, 33, 34, or 36 in 2004 and 2013.

| Age | LE | | LE for the individual tooth | | | | | | | |
| | | | Tooth 31 | | Tooth 33 | | Tooth 34 | | Tooth 36 | |
	2004	2013	2004	2013	2004	2013	2004	2013	2004	2013
0	77.4	79.8								
10	68.0	70.2	81.4	82.6	85.0	85.0	81.4	81.8	71.6	74.7
20	58.2	60.3	71.5	72.6	75.0	75.0	72.5	72.5	64.1	65.8
30	48.6	50.6	61.5	62.7	65.1	65.0	63.0	63.1	58.2	58.8
40	39.2	41.8	51.8	52.8	55.1	55.1	53.4	53.4	50.3	51.5
50	30.3	32.0	42.6	43.5	45.4	45.4	44.2	44.1	42.6	43.1
60	21.9	23.5	34.2	34.8	36.3	36.1	35.7	35.5	35.2	35.6
70	14.4	15.6	26.5	27.8	27.6	27.5	27.6	27.5	27.7	27.9
80	8.4	9.1	18.9	19.0	19.3	19.1	19.4	19.2	19.5	19.6
90	4.6	4.7	10.3	10.2	10.3	10.2	10.3	10.2	10.4	10.4

YLDs-Ts for each tooth increased in 2013, except that for four first molars (especially for mandibular molars). The YLDs-Ts were 79 vs 77, 80 vs 78, 100 vs 85, and 101 vs 87 in 2004 and 1013 for the tooth of 16, 26, 36, and 46, respectively.

Discussion

In the present study, the national-based LET and burden of tooth loss were estimated based on the NHI claims data in Taiwan, which cover almost all residents.[12] In this study,
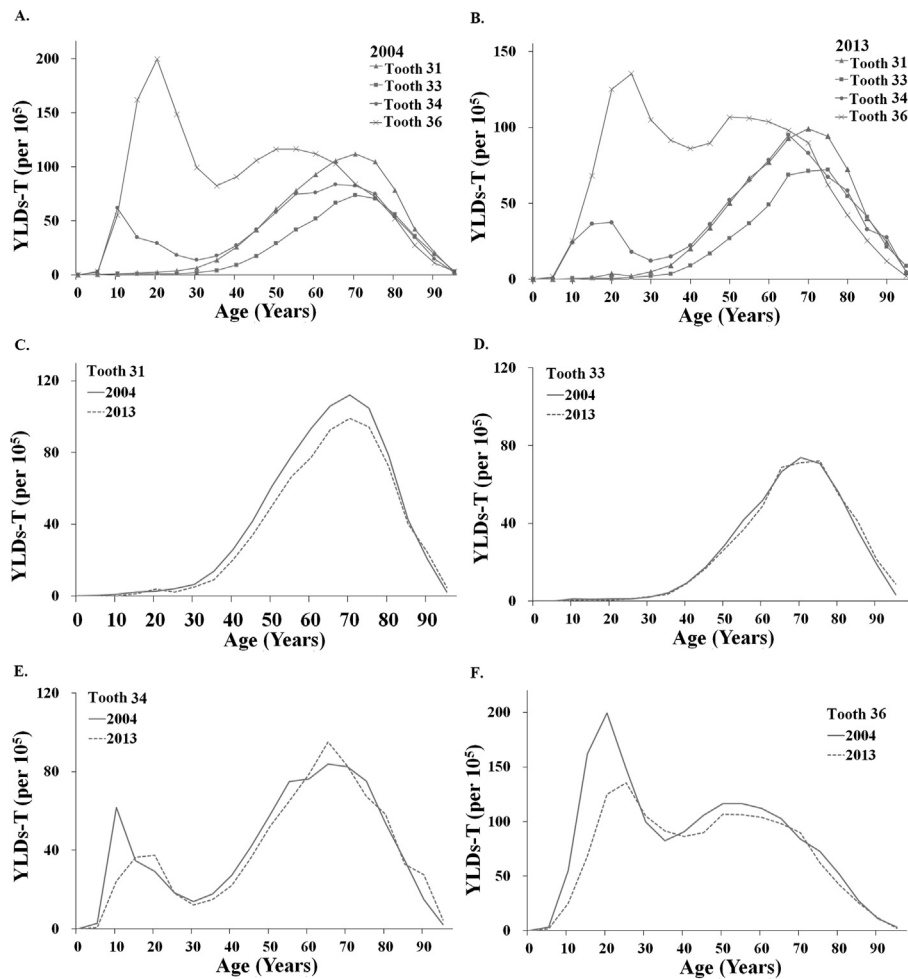
Figure 3 YLDs-Ts for teeth 36, 34, 33, and 31 in 2004 and 2013. The YLDs-Ts for the four teeth in 2004 (A) and 2013 (B) were presented and varied among teeth. For each tooth 31, 33, 34, or 36 the YLDs-Ts obtained in 2004 and 2013 showed much comparable (C to F) (YLDs-T = the years lived with disability for tooth loss).

the numbers of the patients and the teeth (received extraction) were both recorded in 2004 and 2013 (Table 1). Our results showed that the tooth-extraction rate in Taiwan was 7689 and 8623 per 100,000 population (7.7% and 8.6%) in 2004 and 2013, respectively (Table 1). Previous studies have reported the tooth-extraction rates.[18—20] However, the rates varied and ranged from 5% to 37% in specific populations, considering the different countries, areas, or age intervals and the reasons for tooth-extraction.[19,21—23] About our results, an increased pattern before a certain age was noted for both ASMR and ASTER. However, gaps were observed between the two parameters (the maximal ASMR/ASTER were recorded at age 98/75 years old in 2004 and 98/74 years old in 2013, respectively) (Fig. 1B). Burdens were therefore noted, and the detailed analysis, such as that of YLDs, was indicated.

The 28 ASTER-Ts were calculated in 2004 and 2013 accordingly to elaborate on the role of tooth individuality on the ASTER. We observed that the values for ASTER-Ts were varied among teeth, despite 2004 and 2013 (Fig. 2A—B). The pattern of ASTER-Ts for molars/premolars showed two peaks, whereas that for incisors/canines presented a single peak. For example, two peaks were noted for the

mandibular left first molar (0.78% at 21 years and 0.84% at 65 years) and the mandibular left first premolar (0.26% at age 12 and 0.81% at 76 years) in 2004. Similar peaks were also observed in 2013. The exact reasons for the appearance of two peaks need further investigation; however, the orthodontic reason might be part of the explanations for the first peaks observed in the early loss of premolars.[24] The high caries rate in the first molars at a young age in Taiwan[12] and other countries[25] also possibly caused the tooth loss observed in this study. Nevertheless, the present study is the first to report the ASTER-T for 28 individual permanent teeth based on the national population.

Theoretically, the LE is a hypothetical value. However, in this study, the LE and LET are calculated based on substantive documents of Taiwan. Our result showed that the LE at birth in Taiwan is 77.4 years in 2004 and 79.8 years in 2013 (Table 2), which is similar to that obtained from some of other countries (e.g., USA, 77.6 years; Norway, 79.7 years; NZ, 79.5 years in the year of 2004; and USA, 78.9 years; NZ, 80.6 years in the year of 2013) (http://publichealthintelligence.org/content/life-expectancy-progress-1990-2013). Similar to ASTER-Ts, 28 LETs could also be achieved (Table 2), and their gaps with LE also
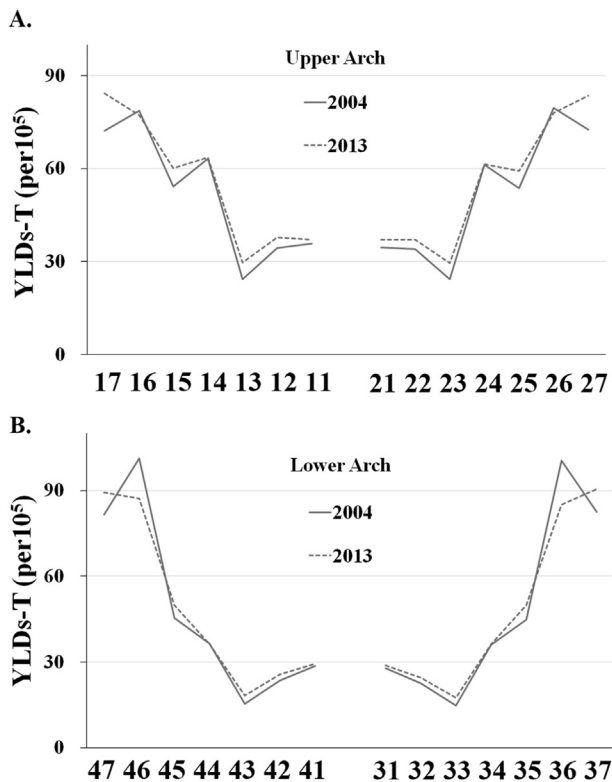
A.

B.

Figure 4 The 28 YLDs-Ts in 2004 and 2013. Comparison of YLDs-Ts according to the teeth in maxilla (A) and in mandible (B). In 2013, the YLDs-Ts for the first molars, particularly in mandible, were decreased when compared with that in 2004 (YLDs-T = the years lived with disability for tooth loss).

varied accordingly, regardless of the year of 2004 and 2013. It is generally believed that teeth are individualized because of their anatomy, physiology, and occlusion,[8] whereas the reasons for their loss might also vary. Such conditions may further imply the burdens suffered by different teeth at varying ages.

In this study, 28 YLDs-Ts were obtained (Fig. 3A—B) to elaborate on the national burden of tooth loss. Among these YLDs-Ts, one- and two-peak patterns were observed, like those of ASTER-Ts (Fig. 2A—B). However, the distribution of age-specific YLDs-Ts considerably differed compared with that for ASTER-Ts, particularly for the two-peak patterns. For the mandibular left first molar, for example, the peak value of YLDs-T at 21 years (214 and 117 per 100,000 population for 2004 and 2013, respectively) was more extensive than that at 65 years (114 and 100 per 100,000 population for 2004 and 2013, respectively) (Fig. 3F). However, the ASTER-T value at the age of 21 years old (0.78% and 0.37% in 2004 and 2013, respectively) was less than that at age 65 (0.84% and 0.68% in 2004 and 2013, respectively) (Fig. 2F). Moreover, high (with a maximum) YLDs-T values were noted for the mandibular left first molars at young ages less than 35 years.

In the present study, the sum of the 28 YLDs-Ts was obtained, that are, 1380 and 1445 per 100,000 population in 2004 and 2013. GBD studies have reported disability-adjusted life years (DALYs) for total tooth loss (for those having fewer than nine remaining permanent teeth)[3,7] and

predicted DALYs of 117 and 113 per 100,000 person-years in 1990 and 2015, respectively. Given the dissimilarity among the 28 YLDs-Ts, the exact burden for tooth loss might be over- or under-estimated, including the application of LE to estimate the length of the missing tooth. In this study, nevertheless, the YLDs-T was accounted for based on the LET obtained, and the amount of tooth lost accumulated for that tooth, as well as the selected disability weight (0.00429). The burden of total tooth loss observed in the past studies and the sum of 28 YLDs-Ts measured in the present research might yield different insights; nevertheless, both might provide certain directions for the health sector.[7] Moreover, the global burden of tooth loss reported was based on the definition of "having fewer than 9 remaining permanent teeth".[3,7,17] In this definition, the burden of tooth loss is collecting the information located in edentulous or a severe condition of tooth loss. The present results may offer a further detailed information related to the individual tooth loss, which may be much fitting the definition of public health - preventing disease, prolonging life, and improving health.

This study encountered several limitations. First, the cross-sectional data examined and analyzed were limited to the years 2004 and 2013. Second, the disability weight selected in this study was still arbitrary. Third, the data related to the disability-adjusted of life years (DALYs) did not present in this study. One of the reasons is asymmetrical between the years of potential life lost due to premature deaths (YLL) and that due to premature tooth loss (YLL-T). If selecting the YLL as the YLL-T, the overestimation of tooth loss might be occurred because of the involving the decedent patients, including those teeth were not lost. Forth, the claims data set excluded the exact reasons for tooth extraction. Nevertheless, this study may provide novel insights into tooth loss and the burden due to tooth loss based on tooth individualism, whereas longitudinal evaluation is indicated.

In conclusion, the national ASTER, LET, and YLDs-T for each permanent tooth were estimated based on the empirical data from NHI of Taiwan in 2004 and 2013. For the tooth types of incisors, canines, and premolars, similar ASTERs, LETs, and YLDs-Ts were obtained in 2004 and 2013. However, in the first molars, particularly for mandibles, the values between the observation years were much varied at young ages: LETs increased but ASTERs/YLDs-Ts decreased in 2013 if compared to that in 2004. The findings implicate the results from the efforts of the entire dental care program according to the individual tooth type of molars, while the superior interventions for dental public health in early prevention are still needed.

Declaration of competing interest

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

Acknowledgments

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