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ORIGINAL ARTICLE

Regional and gender differences in population-based oral health insurance data

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Abstract

Objective Early dental monitoring contributes substantially to good oral health in children. However, little is known on whether children from different geographical regions and gender are equally reached with current preventive and curative oral health strategies. The aim of our study therefore was to explore regional and gender differences in a population-based oral health dataset of Austrian children up to the age of 14.

Materials and methods We extracted the first electronically available health insurance data of children aged up to 14 years on dental services within a 4-year observation period in Austria and performed a separate analysis in up to 6-year-old children. In addition, we used a smaller randomly selected sample dataset of 3000 children as the large numbers would result in significant, but very small effects.

Results In a total of 130,895 children, of whom 77,173 children (59%) were up to the age of six, we detected an east-west gradient: The eastern regions of Austria showed an older age at first contact and a higher number of dental services. A child aged up to 6 years who needed more than four dental services had a likelihood of 40% to be from Vienna, Austria's capital city located in the east. The smaller random sample did not show significant gender differences.

Conclusions Even in regions with a high density of dentists, such as Vienna, we obviously did not reach young children in the same extent as in other regions.

Clinical relevance Stratified interventions could be developed to overcome regional inequalities.

Keywords Pediatric dentistry · Oral health–related quality of life · Population-based data · Health services research · Machine learning

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Introduction

Oral health is an integral part of general health. It plays a key role in the overall health status and quality of life of both children and adults [1]. Although there has been general improvement in children's dental health over the last decades, dental problems are still highly prevalent during childhood, especially in the primary dentition. Dental caries is among the most common chronic diseases in childhood [2]. One of the goals set by the World Health Organization in 2003 for oral health was that by the year 2020, 80% of the 5- to 6-year-olds should be caries-free [3].

Children's quality of life, including social and emotional wellbeing, can be seriously affected by severe caries because of pain and discomfort, acute and chronic infections, and altered eating and sleeping habits, as well as a risk of hospitalization, high treatment costs, and days of absence at school

with the reduced ability to learn [4]. Furthermore, premature loss of molars is likely to result in future orthodontic problems [5] and the child may also suffer from developmental conditions involving language disorders and articulation problems [6]. Additionally, children experiencing caries early in life have a much greater risk of consecutive caries in the permanent dentitions [7].

Therefore, maintaining primary dentition in a healthy condition is important for the wellbeing of the child. For this reason, a dental home which is the ongoing relationship between the dentist and the patient should be established for every child as early as possible. In Austria, the health care system is based on statutory social insurance. All insured people have a legal right to a large number of health care benefits, including dental services. For dental services, insured individuals are eligible to contact a so called contracted dentist. In 2010, one contracted dentist was registered per 3100 inhabitants [8]. Although there was considerable variation across regions, density of dentists is highest in Vienna, with 4.3 contracted dentists per 10,000 inhabitants, and lowest in Burgenland, Carinthia, and Upper Austria, with around 2.6 per 10,000 inhabitants. Austrian preventative oral health program for children advises to visit the dentist for the first time as soon as the first tooth has erupted, but usually around first birthday of a child.

In personalized medicine, targeted interventions are provided to subgroups of patients based on certain biomarker profiles [9–11]. In addition to biomarkers, socio-demographic markers and environmental factors may also allow building patient sub-groups for specifically targeted interventions. Further reasons for implementing this are the differences in the availability of dentists or in the response to prevention programs due to gender or socioeconomic factors. However, there is a lack of data in many countries on the success of preventive strategies, the age at first contact and the subsequent dental services. The aim of our study was to explore regional and gender differences in oral health insurance data including the first contact to a dentist in the life of Austrian children, as well as frequencies and types of the subsequent dental services.

Methods

A retrospective analysis of population-based health insurance data in Austria concerning dental services in children within a 4-year observation period (from last quarter of 2012 to the third quarter of 2016) was conducted. Dental services encompassed check-ups and all kinds of dental interventions, such as treatment, dietary advice, and assessments of psychosocial factors related to oral health in children with disabilities/special needs. The observation period was set based on the earliest available dental services data in electronic format in Austria. If children had not visited a dentist for at least 2.5 years, the subsequent appointment to a dentist after this period was defined as first contact (Fig. 1). All dental interventions up to 180 days following the first contact were also recorded because they might have been related to this dental visit, but were not done in one single session. No data were available for children who never saw a dentist in their lives. Our dataset includes the governmental system, as well as partly privately-paid dental services; fully private payment of dental services in children is not common in Austria. Therefore, possible cases are negligible. The study was approved by the ethical committee of the Medical University of Vienna (EK 2218/2017).

Data sources

The health insurance data were extracted out of the databases of nine Austrian regional illness funds and of four non-regional funds covering together 98% of all insured Austrians. We included all children who had not completed their 14th year of life on the 31st of March 2015. Age was recorded at the time of the first contact to the dentist in the dataset. Data were anonymized after the database query and prior to the analysis. Children aged up to 6 years were analyzed separately because of the fact that a large number of children are known to have the first dental visit between 3 and 6 years and the most common reasons for these first consultations are caries and its complications [12]. Dental services were classified as either check-ups or interventions by a clinical expert (KB). The numbers of the total Austrian population for 2015 including the gender distribution were downloaded from the website of "Statistik Austria" (http://www.statistik.at/web_de/statistiken /index.html).

Descriptive analyses and differences between sub-groups

Descriptive statistics were calculated for age, gender, the number of dental check-ups and interventions, and the region where the children lived. Boxplots were used for graphical display of numeric variables. We assessed the distribution of numeric variables by inspecting their histograms. The homogeneity of the variances between subgroups, e.g., region and sex subgroups was determined using Bartlett test. In case of heterogeneous variances, Mann-Witney-Wilcoxon test was used to examine differences between two subgroups, e.g., girls and boys, and Kruskal-Wallis test was applied, if more than two subgroups were compared. For categorical data, we used contingency tables and chi-square test. Significant differences were assessed by an expert (KB) for clinical meaningfulness. We repeated all analyses in randomly selected sample datasets of 3000 children to restrict the analysis to larger effects, as the large number in the population-based dataset would have resulted otherwise also in significant but very small effects.

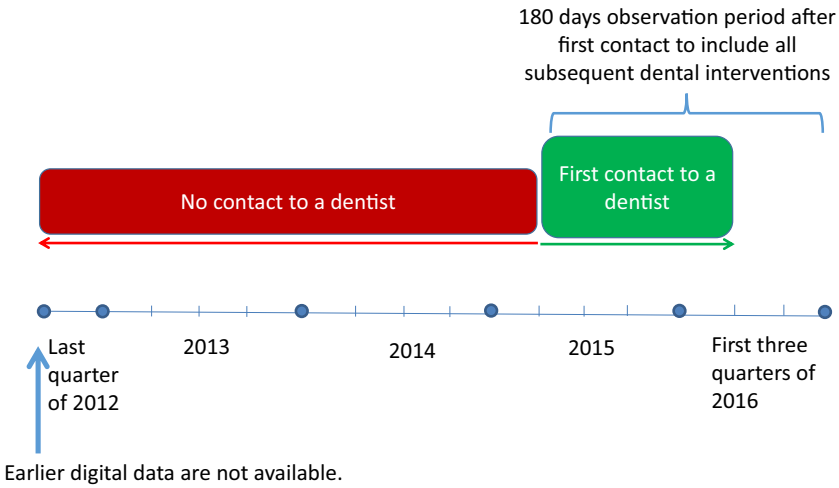

Fig. 1 Timeline of the study

Machine-learning algorithms to explore the structure of the data

Due to the large sample size and the relatively small number of variables, we decided not to use an ordinary regression model because all parameters, including age, gender, and the number of dental services, would contribute significantly to predicting the region of the child which could make the interpretation of results unreliable. Instead, we decided to use machine-learning algorithms which allowed us in exploring the structure of the data by deriving decision rules for predicting categorical classification trees without imposing any pre-assumptions on the data. We applied recursive partitioning [13, 14] to generate classification trees and randomly divided the data into a training set (2/3) and test set (1/3). Each decision node of the classification tree showed the predicted variable, its probability and the number of observations within this node.

All statistical calculations were computed with R (www.r-project.org) or Microsoft Excel. For self-learning algorithms, we used the recursive partitioning and regression trees rpart package, as well as the rpart-plot packages and Weka (Waikato Environment for Knowledge Analysis; https://www.cs.waikato.ac.nz/ml/weka/index.html) [15].

Results

In 2015, Austria had 8,629,519 inhabitants; of these, 1,232,672 were 14 years old or younger. In the present study, a total of 419,103 dental services in 131,308 children were extracted from the databases. We excluded 413 individuals with incomplete data on gender and/or age. Finally, 130,895 children were included in the analyses with a mean age of 6.3 years (± 3.6; median 5) at first contact to a dentist. Of these, 63,726 (49%) were girls. A total of 77,173 children (37,459 girls; 49%) were up to the age of six (≤ 6 years old).

Regional differences showed an east-west gradient

Table 1 and Fig. 2a–d depict the age at first contact and number of dental services needed regarding the different regions in Austria for all children of the dataset and the children aged up to 6 years. Due to the right skewed distribution of the data, we reported median values and interquartile ranges (IQR) in addition to means and standard deviations (SD). The Western regions of Austria which cover more rural areas and include Upper Austria, Salzburg, Tyrol, and Vorarlberg, as well as Styria showed a lower mean and median age at first contact to a dentist compared with the mean of total Austria. The Eastern regions of Austria, as well as Carinthia had a higher mean and median age at first contact. A similar result was found regarding the number of dental services needed (Table 1): west Austria and Styria had lower numbers of dental services needed compared with east Austria and Carinthia. The repeated analysis with the smaller, 3000-children random sample confirmed the statistically significant differences between the regions regarding the age at first contact and the number of dental services needed (p value < 0.0001; Kruskal-Wallis test). The proportion of children who needed only check-ups in comparison with children who needed also interventions showed a similar east-west gradient: the western regions of Austria had higher proportions of children with check-ups only (Table 1). Furthermore, only 130 of all children saw a dentist before their first birthday. In detail, 56 of these children came from Upper Austria, 23 from Salzburg, one child came from Lower Austria, and 50 children from the non-regional illness funds.

Table 1 Descriptive characteristics of the sample, age at first contact, number of dental services needed, and extreme values. *SD*, standard deviation; *IQR*, interquartile range

	Non-regional illness funds	Burgenland	Carinthia	Lower Austria	Upper Austria	Salzburg	Styria	Tyrol	Vorarlberg	Vienna	Total
All children of the dataset aged 0 to 14 years	33,598	2415	6706	17,594	16,957	6379	12,231	7301	4520	23,194	130,895
Mean age at first contact in years	6.6	6.7	6.5	6.4	5.6	5.8	5.8	6.0	6.1	6.5	6.3*
± SD	3.7	3.6	3.6	3.6	3.5	3.7	3.6	3.6	3.6	3.6	3.6
Median	6	6	6	6	5	5	5	5	5	6	5
IQR	3 to 10	4 to 10	4 to 9	3 to 9	3 to 8	3 to 9	3 to 8	3 to 8	3 to 9	4 to 9	3 to 9
Mean number of dental services	2.7	3.0	3.2	3.0	3.1	3.1	2.9	2.8	2.9	4.5	3.2*
± SD	2.9	3.4	3.9	3.5	3.9	3.8	3.4	3.3	3.2	5.4	3.9
Median	1	2	2	2	1	1	1	1	2	2	2
IQR	1 to 3	1 to 4	1 to 4	1 to 4	1 to 4	1 to 4	1 to 3	1 to 3	1 to 4	1 to 6	1 to 4
Proportion of children with check-ups only	43	41	46	44	50	47	49	44	41	32	43
Children aged 0 to 6 years	18,013	1301	3759	10,166	11,442	4026	7839	4580	2816	13,231	77,173
Mean age at first contact in years	3.7	3.8	3.8	3.8	3.5	3.4	3.5	3.5	3.8	3.8	3.7*
± SD	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.4	1.5	1.5
Median	4	4	4	4	3	3	3	3	3	4	4
IQR	2 to 5	3 to 5	3 to 5	3 to 5	2 to 5	2 to 4	2 to 5	2 to 5	3 to 5	3 to 5	2 to 5
Mean number of dental services	1.9	2.0	2.4	2.1	2.3	2.1	2.0	2.0	2.1	3.1	2.3*
± SD	2.1	2.2	3.2	2.5	3.0	2.5	2.5	2.3	2.4	4.2	2.9
Median	1	1	1	1	1	1	1	1	1	1	1
IQR	1 to 2	1 to 2	1 to 2	1 to 2	1 to 2	1 to 2	1 to 2	1 to 2	1 to 2	1 to 3	1 to 2
Proportion of children with check-ups only	62	60	60	61	64	65	65	60	56	48	60

*Significant p values < 0.0001, calculated by using Kruskal-Wallis test, with the same result in the smaller random sample

Frequencies of the ten most common dental services are depicted in Table 2. While in the children aged up to 6 years, the most common dental service were check-ups; curative interventions were most common in the children aged from 7 to 14 years and check-ups were only on the tenth rank of the most common interventions (Table 2).

Gender differences

Age at first contact did not show a significant difference between girls and boys. The numbers of dental services needed were significantly different between girls and boys in all children of the dataset (Fig. 2a–d), but not in the random sample including 3000 individuals. Likewise, the number of children who needed only check-ups in comparison with children who needed check-ups and interventions was significantly different between girls and boys in the complete, but not in the smaller random sample.

Prediction model of the machine-learning algorithm

The C4.5 algorithm (its implementation in Weka as J48) split the dataset of the children up to the age of six into a decision tree with two decision nodes (Fig. 3) and predicted Vienna, Austria's capital city which is located in the east, with a probability of 40% (2603 out of 6550) in children who needed more than four dental services. In the children who needed four or less dental services, a second split of the dataset was suggested, namely children who were seen by a dentist before their first birthday versus a later first contact. Gender did not induce another split of the dataset in the recursive partitioning analysis.

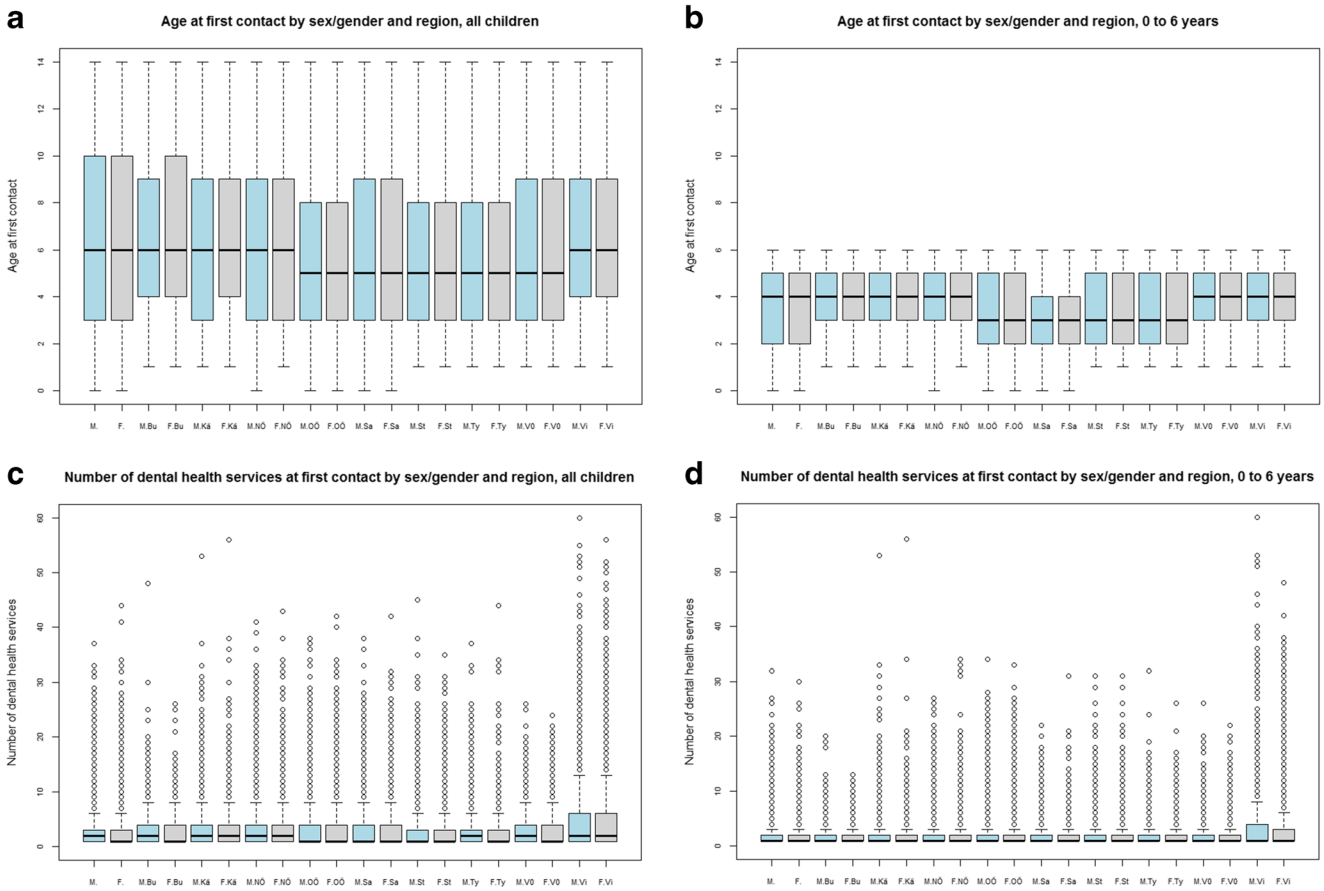

Fig. 2 **a** Boxplots of the age at first contact to the dentist stratified for gender and region. "M" stands for male/boys and "F" for female/girls. "Bu" refers to Burgenland, "Kä" to Carinthia, "NÖ" to Lower Austria, "OÖ" to Upper Austria, "Sa" to Salzburg, "St" to Styria, "Ty" to Tyrol, "V0" to Vorarlberg and "Vi" to Vienna. The boxes without a specified region (the first two boxes in each plot) refer to the non-regional illness funds. **b** Boxplots of age at first contact to the dentist stratified for gender and region. "M" stands for male/boys and "F" for female/girls. "Bu" refers to Burgenland, "Kä" to Carinthia, "NÖ" to Lower Austria, "OÖ" to Upper Austria, "Sa" to Salzburg, "St" to Styria, "Ty" to Tyrol, "V0" to Vorarlberg and "Vi" to Vienna. The boxes without a specified region (the first two boxes in each plot) refer to the non-regional illness funds. **c** Boxplots of the number of dental services needed stratified for gender and region. "M" stands for male/boys and "F" for female/girls. "Bu" refers to Burgenland, "Kä" to Carinthia, "NÖ" to Lower Austria, "OÖ" to Upper Austria, "Sa" to Salzburg, "St" to Styria, "Ty" to Tyrol, "V0" to Vorarlberg and "Vi" to Vienna. The boxes without a specified region (the first two boxes in each plot) refer to the non-regional illness funds. **d** Boxplots of the number of dental services needed stratified for gender and region. "M" stands for male/boys and "F" for female/girls. "Bu" refers to Burgenland, "Kä" to Carinthia, "NÖ" to Lower Austria, "OÖ" to Upper Austria, "Sa" to Salzburg, "St" to Styria, "Ty" to Tyrol, "V0" to Vorarlberg and "Vi" to Vienna. The boxes without a specified region (the first two boxes in each plot) refer to the non-regional illness funds

Discussion

This study explored the status of dental care utilization and its determinants to address possible gaps in oral health systems which could also reflect health care differences in children aged up to 14 years in Austria. We observed that the mean age at first contact to a dentist was 6.3 years (median 5 years) in the total sample and 3.7 years (median 4 years) in a separate analysis of the children aged up to 6 years. Although our findings are in accordance with published data of other countries and the most commonly reported age range for the first dental visit is 2 to 5 years [12, 16, 17] or even later [18], a large number of Austrian children had their first contact to a dentist substantially later in life than recommended or had no regular contact within the recommended annual interval. Guidelines from the American Dental Association, the American Academy of Pediatric Dentistry, and the American Academy of Pediatrics recommend that children should visit a dentist latest by their first birthday [19] with regular annual contacts thereafter. Early visits provide an opportunity to establish and promote an early dental home for each child, to evaluate caries risk factors and to deliver caries prevention strategies. Surprisingly, our data revealed that dentists saw a very small proportion of children (only 130) from three Austrian regions and from non-regional illness funds before their first birthday. Nevertheless, due to the lack of dental diagnosis codes, we were unable to determine if these reported early dental visits were because of existing health problems or just used for preventive measures. Based on our results, we conclude that a substantial proportion of Austrian children have not seen a dentist early enough in their lives and do not see their dentists on a regular

Table 2 Absolute and relative frequencies of the ten most common dental services of all children of the dataset, the children aged up to 6 years, and the children aged from 7 to 14 years

Most common dental services in all children of the dataset	*n*	%
Treatment of stomatitis	77,430	18.5
Check-up/consultation	57,290	13.7
Filling (one surface)	45,224	10.8
X-ray (panoramic)	42,110	10.1
Filling (two surfaces)	38,248	9.1
X-ray (periapical)	30,612	7.3
Extraction of tooth	23,968	5.7
Grinding	12,977	3.1
Removal of dental calculus	11,662	2.8
Local anaesthetics	9359	2.2
Most common dental services in the children aged 0 to 6 years	***n***	**%**
Check-up/consultation	50,371	28.9
Treatment of stomatitis	32,676	18.7
Filling (two surfaces)	18,465	10.6
Filling (one surface)	18,354	10.5
X-ray (panoramic)	9154	5.3
Extraction of tooth	6637	3.8
X-ray (periapical)	5892	3.4
Grinding	5043	2.9
Local anaetsthetics	3827	2.2
Pulpotomy	3479	2
Most common dental services in the children aged 7 to 14 years	***n***	**%**
Treatment of stomatitis	44,754	18.3
X-ray (panoramic)	32,956	13.5
Filling (one surface)	26,870	11
X-ray (periapical)	24,720	10.1
Filling (two surfaces)	19,783	8.1
Extraction of tooth	17,331	7.1
Removal of dental calculus	11,606	4.8
Grinding	7934	3.3
Hypersensitivity (of non-carious cervical lesions)	7201	3
Check-up/consultation	6919	2.8

basis, e.g., annually, for check-ups. The role of the parents is crucial in this regard. However, there might be a low awareness level among parents regarding best (early) age for a child to have first contact to a dentist and also a lack of knowledge about the

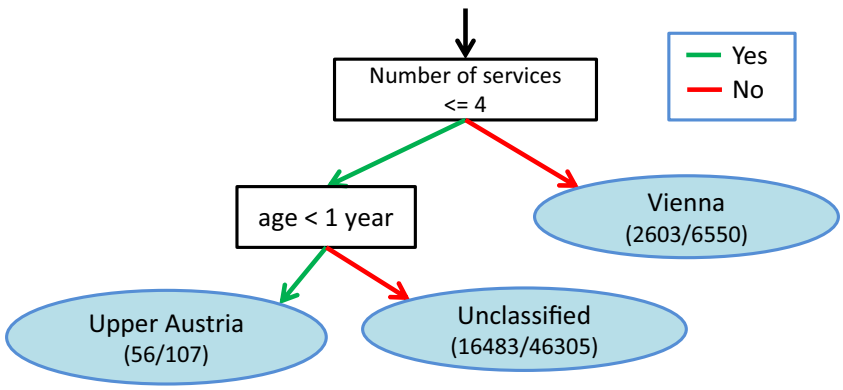

Fig. 3 The classification tree fitted with the (training) dataset of the children up to the age of six. Each decision node of the classification tree contained a rule that predicted a certain region. Each leaf showed the region with the highest number of cases in this specific leaf and the probability with which a specific region was predicted by the model. The arms of the tree represented partitions of the dataset

importance of the primary dentition: the predominant factors prompting parents to seek first dental appointments for their children are either pain [16–18] or the presence of visible caries lesions or dental trauma [20, 21], rather than prophylactic dental examinations. Moreover, because of the fact that the possibility to recognize early signs of dental caries in very young children is limited, problem initiated dental visits were largely observed [22].

Representative caries prevalence data for children in Austria underline our findings. Although largely preventable and despite the significant improvement of oral health in the past few decades, dental caries remains the most common chronic disease among children, both in developed and developing countries. Data published recently show that nearly half (45%) of the 6-year-olds have caries experience. Moreover, 6-year-olds (33%) with open deciduous tooth decay requiring treatment show an average of eight cavitated primary tooth surfaces (8.2) [23]. Unfortunately, no representative data for younger children exist in Austria. However, we assume that these would be similar to those recently found in Germany; 13.7% of 3-year-olds are already affected by caries. On average, these children have 3.6 affected teeth. The d-component takes the largest percentage (73%) [24].

We observed regional differences in the time of the first dental visit. In the western part of Austria, covering the regions Upper Austria, Salzburg, Tyrol, and Vorarlberg, as well as Styria, a lower mean age at first contact to a dentist was observed compared with the total mean. Except for Tyrol, these regions also had a higher percentage of children who only needed check-ups. A recently published nationwide oral health study on 6-year olds in Austria also indicated that treatment needs are lower in these parts of Austria (except Upper Austria) [23]. Especially Tyrol is known for having well-implemented public preventive programs for children for the last 30 years [25]. Beyond that, our study also demonstrates that areas with a dense network of dental services, such as Vienna, showed the highest mean of age for the first dental visit and also the lowest percentage of children needing only dental check-ups and no interventions. There are possible explanations for this. Firstly, it is possible that parents rely on prevention services in kindergarten and school, as well as public preventive programs and do not realize the importance of visiting a dentist. Secondly, Vienna has the highest percentage of inhabitants with migration background [26]. As shown by a recently published study, children with a migration background have a higher risk of developing caries than other Viennese children, even when the parents have received a higher education [27].

The prevalence of children who needed only dental check-ups was 43% implying that the rest (and the majority) of all dental visits recorded in our dataset was problem-driven. Similar findings were reported for the US population including children and adolescents [28]. Only 41.9% of US children aged 0–17 years reported an annual dental office–based visit for general dental care. Our findings indicate that public health interventions which specifically target children are needed to achieve the goal of regular contacts to a dentist among the general population. Fillings (one or two surfaces) and pulpotomies were part of the ten most common dental services in children aged 0–6. This result also confirms the lack of healthy oral habits which could be prevented by early interventions.

Poor oral health affects not only the quality of life of individuals but also poses a problem for society, as well as for health care systems in general [29]. The dental profession is responsible for the prevention, diagnosis, and treatment of diseases and disorders of the oral cavity and related structures. Dentists should encourage patients with families to bring a child for a dental health check-up as soon as the first tooth appears. Regular dental attendance is important in maintaining and improving children's oral health and wellbeing. These results illustrate the lack of health-promoting behavior. Early intervention could prevent tooth-damaging habits, improve quality of life, and initiate positive health behavior for the long run [30, 31].

The major strength of our study is that we used a large population-based dataset on almost all children aged 0–14 in Austria who visited dentist between 2012 and 2016. This study adds to importance on preventive dental visits from very early childhood. Further, it may serve as a base for further evidence-based decision-making in oral health promotion. Our findings could be representative not only for Austria, but potentially also for other Western-European countries. However, this study has also some limitations. The study was based on a population dataset available from insurance data. Electronic data were obtained for the available 4 years; therefore, data for the early years of the older children were not available. However, in order to make the best use of the population data and compensate for this limitation, we have set a definition for the "first contact to dentist" as no contact to any dentist for 2.5 years and included the available data accordingly. Another major limitation is that we lack information on socioeconomic indicators of children (parental education, income status) and detailed clinical data. Additional information about children and families, including information on oral hygiene habits, diet, the level of education of the parents, and their opinions about oral health would allow us a better understanding of these oral health outcomes. Future studies should integrate datasets and compare children's health data to the socioeconomic variables, education, and health literacy of parents, as well as whether or not children have participated in public oral health programs.

In conclusion, our data show that dentists commonly saw a substantial proportion of Austrian children on a problem-driven basis when it already was too late to help prevent caries and other damages in their teeth. More future public awareness and stratified interventions are needed to target all children and their parents to see a dentist for regular check-ups already at younger age. Due to the observed regional differences, studies on risk factors affecting oral health conditions in those detected regions should be further investigated.

Author contribution KB, BR, and TS planned the study. BR and LS gathered the data. VR, MO, AP, EM, and TS reshaped the dataset and analysed the data. KB, LS, VR, MO, EM, AP, MB, and TS interpreted the findings. All authors contributed to the manuscript.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The study was approved by the ethical committee of the Medical University of Vienna (EK 2218/2017). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments.

Informed consent For this type of study (retrospective analysis of population-based health insurance data), formal consent is not required.

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