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The burden and prevention of childhood caries in the European Union

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List of abbreviations

AAPD	American Academy of Pediatric Dentistry
CAMBRA	Caries Management by Risk Assessment
CAT	Caries Risk Assessment Tool
CED	Council of European Dentists
CIs	Confidence Intervals
CRA	Caries Risk Assessment
DMFT	Decayed, Missing, Filled Teeth
EAPD	European Academy of Paediatric Dentistry
ECC	Early Childhood Caries
EGOHID	European Global Oral Health Indicators Development
EU	European Union
EU-SILC	European Union Statistics on Income and Living Conditions
FAO	Food and Agriculture Organization of the United Nations
FDI	World Dental Federation
GBD	Global Burden of Disease
GDP	Gross Domestic Product
HICs	High-income Countries
IAPD	International Association of Paediatric Dentistry
ICCMS	International Caries Classification and Management System - ICCMS™
ICDAS	International Caries Detection and Assessment System
IG	Information Gain
IPC	International Patent Classification
MeSH	Medical Subject Headings

MICs	Middle-income Countries
PPS	Purchasing Power Standards
SD	Standard Deviation
SES	Socioeconomic Status
SIGN	Scottish Intercollegiate Guideline Network
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
UK	United Kingdom
US	United States
WHO	World Health Organization
YLDs	Years Lived with Disability

1. Introduction

1.1 Dental Caries and Early Childhood Caries

Dental caries represents a major burden worldwide with an impact on quality of life and also represent an economic burden. This burden can be presented by the years lived with disability (YLDs) rate, since it is a measure to estimate the impact of disease on the quality of life, or years lived in less than ideal health [1]. According to the Global Burden of Disease (GBD) database, the rate of years lived with disability (YLDs) globally per 100,000 population is 14.37 for caries of deciduous teeth among the under 5 age group. For children 5-14 year-old, this rate is 19.58 for caries of permanent teeth (Source: http://ghdx.healthdata.org/gbd-results-tool). Based on data from the United States (US), caries is the single most common chronic disease among children, appears 5 times more often than asthma [2]. However, dental caries is a largely preventable disease [3], this is why public health efforts can effectively decrease the burden of this disease.

Early childhood caries (ECC) can appear from birth to 6 years of age [4], and can progress rapidly. Unfortunately, ECC often left untreated, leading to preventable hospitalization and surgical treatments, thus having an impact also on the families' life [5] [6]. Caries in the primary dentition can result in a higher risk of caries in the permanent teeth as well [7].

The complications of this preventable disease also represent a burden for hospitals and other healthcare departments, emergency rooms [8].

The complications caused by ECC are observable in high-income countries (HICs) [9], and also these complications impact the overall health of children [10]. Early detection has a crucial role in prevention: innovative methods and materials in the area of diagnosis and treatment of caries can make the caries management processes more effective.

The treatment of caries, ECC and their consequences also have an economic impact, however, there is limited information available to estimate the exact financial burden [11] for the cost of illness or even for the cost of treatment.

Successful prevention programs would be necessary to prevent the caries development and progression. To implement successful prevention programs and public health measures, it would be crucial to have available metrics to estimate the burden and identify indicators, for national and international assessment. Standardizing these indicators would also make international comparison possible. Applying international guidelines and effective preventive measures could help countries nationally develop their own successful caries prevention programs.

1.2 Role of novel technologies

Although Geoffrey Rose pointed out in 1985 that preventive interventions addressing individuals exclusively with high risk of disease will have limited impact on population health [12], they have important roles. The use of innovative products against diseases can complement individual based prevention programs.

New medical solutions, techniques and methods are crucial to keep the applied processes up-to-date or make the available processes more effective. Patents are used to protect an innovation and the patent-holders can enjoy the benefits of exclusivity. With patenting an invention, the others are restricted from using the patented invention in any form, such as making, selling or even importing it. This exclusion lasts for a certain period of time, and generally this limit is 20 years. The patent documents are stored in patent databases. Today many of these patent databases are available for the public, with no charge. This opens the possibility to analyze these documents, discover main patenting trends and activity in different areas.

Patenting activity may also reveal the national research and development strategies. As an example, in case of rare diseases, if the national research and development was supported by the government, the patenting activity increased in that field [13]. The European Parliament and the Council of the European Union have also emphasized in a regulation (Regulation (EU) 2021/522) [14], that prevention and innovation are fundamental for successful healthcare strategy. Innovations and patenting features in the field of dentistry are also relevant in observing the trends of research activity and focus of interest in the main areas e.g. diagnostics and treatment. These novel technologies may provide new solutions to existing problems and some of these inventions can later be part of the everyday practice. Proper innovative technology, such as the use of machine learning or Artificial Intelligence (AI) could facilitate data collection, analysis or sharing [15]. Such modern technologies are already in use in other fields of healthcare to provide guidance in early detection, diagnosis and treatment of diseases [16] and the area of dentistry could also benefit of these technologies. There is a clinical need for cost-effective tools and solutions in dentistry: the FDI also emphasizes, that saliva diagnostics could add valuable information on oral and systemic health and recommends basic, translational and clinical studies on saliva analysis [17].

1.3 Burden of caries: health and financial impact, vulnerable groups

To estimate the burden of dental caries, the World Health Organization (WHO) adopted the DMFT (decayed, missing and filled teeth) score for 12-years-old children which is the only internationally available indicator for surveillance of dental caries. However, this screening method is not standardized and thus there is wide variety among European countries regarding this score [18]: this type of data is not recorded in the same frequency and among the same age-

groups within the European Union (EU). Analyzing these available data, more than half of decayed teeth remains untreated in HICs. In case of middle-income countries (MICs), this rate is even worse: two thirds [9] of the 12-year-old population have untreated caries. Eastern and Western European countries also differ from each other regarding their DMFT score: there is an observable difference between these countries [11,19]. Another concern regarding national DMFT scores is that the applied average scores can mask inequalities, and it can especially occur in Eastern European countries [11,18]. Furthermore, even with improving score values over the years, there are special groups within the countries, where the burden of the disease is higher, and the DMFT score does not reflect to these issues within countries [11,18]. On Figure 1, changes are presented in the DMFT scores over time from the EU members states, indicating reduced disease burden in most countries. Comparing the score values across countries, Some Eastern-, Central- European countries are still left behind, such as Slovakia, Croatia and Latvia [19].

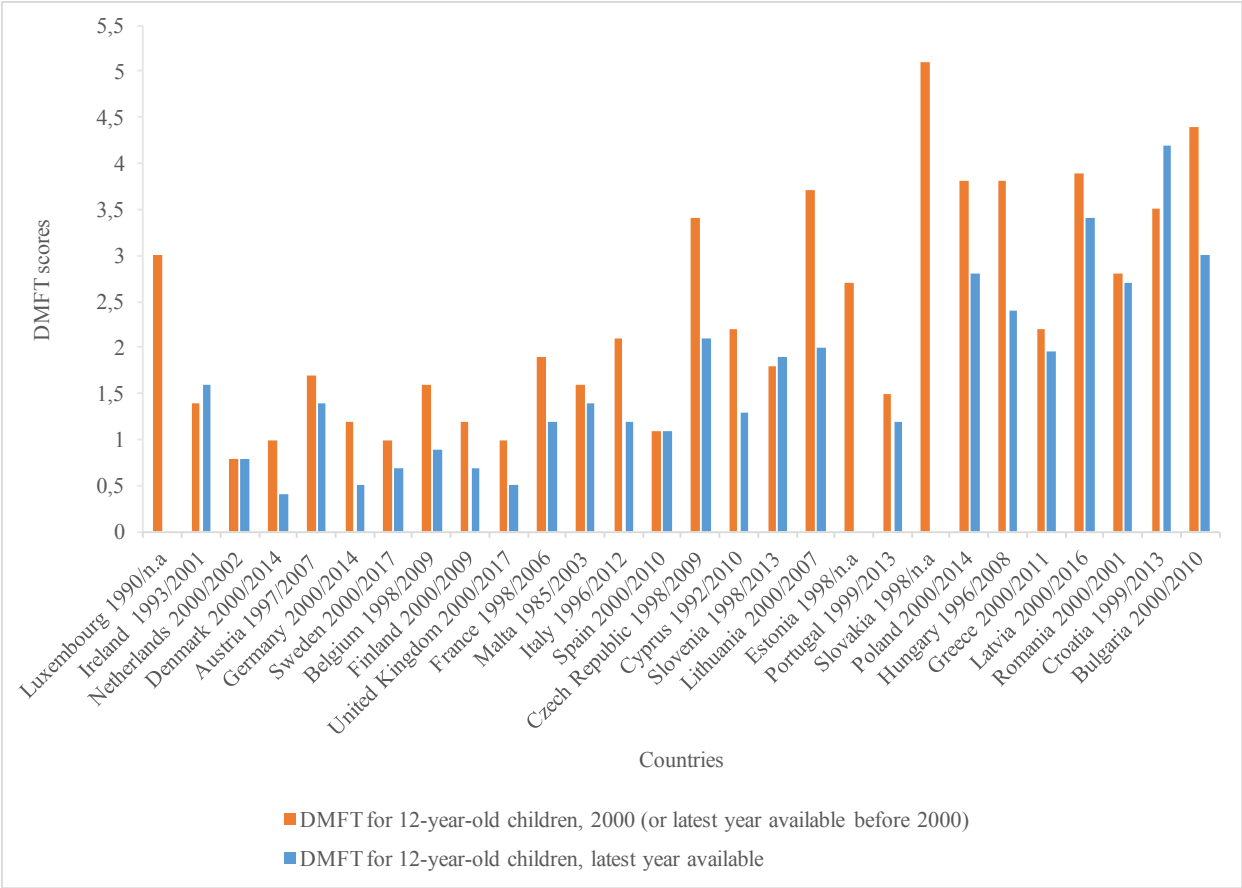

Figure 1. Comparison of DMFT score for 12-year-old children in European Union member states

Legend: Figure 1 shows changes in DMFT scores of the European Union (EU) member states between 2000 (or nearest year available) and the latest available data. The list of countries based on GDP (PPS) (gross domestic product in purchasing power standard) per capita (2017), in descending order from left to right. This comparison indicates the alteration in DMFT score for 12-year-old children in the year of 2000 (or nearest year available) and the latest updates for each member state. DMFT values reduced between since 2000 in almost all EU member states. The figure indicates that the higher GDP (PPS) is associated with lower DMFT values.

Source of GDP per capita in (PPS) data: EUROSTAT database

https://ec.europa.eu/eurostat/tgm/table.do?tab=table&plugin=1&language=en&pcode=tec00114

Source of DMFT data: CAPP database, Oral Health Country/Area Profile Project https://capp.mau.se/dental-caries/ Accessed: July 1, 2020

1.4 Prevention: Preventive methods, different approaches

Caries preventive methods and effective prevention programs can reduce the number of untreated decayed teeth, the caries experience and for high-risk groups, it is especially crucial [9]. Caries is a multifactorial disease, and it is necessary to target all possible levels, when planning effective prevention programs. Public health measures are essential to reach the whole population, especially given that socioeconomic factors play an important role in caries experience [3]. Oral health promotion should also be priority, as well as collaboration on an international and intersectoral level [20].

In early childhood, the most important factors to prevent caries are proper nutrition, the reduction of sugar-consumption and sugary drinks, as the WHO recommends [21].

Surveillance is another point to address, as it is highlighted by the WHO [22] and several studies came to the conclusions that detecting carious lesions in time can help improving caries-related health-outcomes [23–25].

Focusing on special groups of the population could also help [26], as their needs could be different and also there are correlations between the level of urbanization and sugar consumption and ECC [27]. The locally available sugary products can play a role in the development of dental caries [28].

Several approaches are being used to tackle sugar-related caries, such as taxing refined sugars or education that emphasizes the dietary risk factors. Sugar taxation is an effective method to reduce caries experience, but it is hardly applied in the EU [29].

Non-clinical prevention includes oral health education, and spreading information on the importance of oral health and dental health. Although oral health can also have an impact on the people's quality of life, thus represents an important area, oral health promotion is usually not part of the national health promotion programs. However, the World Dental Federation

(FDI) recommends that oral health related quality of life measures are essential to assess the needs of the population and to implement successful programs [30].

Effective prevention is also cost-effective, since preventive interventions are also cheaper options, than treating a developed disease. This is why it is important to identify good practices in oral health education.

1.5 Need for comparable data

Only comparable data among countries is the DMFT, but its use in studies is also criticized [11,18]. DMFT, as per the WHO definition [31], the sum of the number of decayed teeth, missing teeth caused by caries, and filled teeth in the permanent dentition. Dental screenings would be an ideal place for data collection, but still data collection is not unified, thus the acquired data is not necessarily comparable. The internationally available DMFT data also only applies to permanent teeth, for primary teeth the dmft score is in use [32], but there is no data available on this score for international assessment. According to a study, the dmft for primary teeth can be a predictor [33] for future DMFT score of permanent teeth. However, the dmft was criticized because of not being an adequate metric for the impact of ECC on healthcare, economy or families [8].

DMFT score is criticised for presenting only the average value of the score and it can mask inequalities. Other caries indices available to show these differences within the population. The Significant Caries Index (SiC) was developed to focus attention for those with the highest DMFT scores in the population and could provide a clearer view of the actual caries experience and burden within the population [34]. One third of the population with the highest DMFT scores are selected, then the mean DMFT is calculated for this selected group. This will be the

SiC index [35]. Another index is the Significant Filled and Sound-Teeth (SFS-T) index is calculated for one-third of the examined population, where the number of filled or sound teeth are the lowest [36]. Studies found that SFS-T is more useful than SiC in international comparison of dental status and SFS-T with DMFT could be useful in comparison of dental status between countries [36,37]. These indices are available for in-depth international comparison of dental status, however, these indices are not yet widely used and not widely available for analyses.

The current practice on providing national DMFT score in European countries differs significantly: DMFT data are often not from the same year, and not representing all age groups. Some countries are screening twice a year, while in others there are yearly screenings or screening even take place more rarely. In some countries every age groups are screened, in others only certain age-groups.

This fact causes challenges while analyzing or comparing this type of data. Universal, national databases with standardized indicators would also facilitate international assessment.

There are initiatives to standardize data collection, however, they are not yet part of the common practice (see EGOHID project - European Global Oral Health Indicators Development) [38].

Tools are available for caries risk assessment (CRA), such as Caries-risk Assessment Tool (CAT)[39] by the American Academy of Pediatric Dentistry (AAPD), they developed a protocol for children [40]. Other similar methods, e.g. Cariogram [41], Caries Management by Risk Assessment (CAMBRA) [42] are also available to support the decision making process for dentists, but CRA models are not widely or routinely used among member states. Although CRA models might collect local data in their own system, their application is very limited in case of national or international assessment.

However, the Council of European Dentists (CED) emphasized the need for more accessible data and information should be available for the dentists (e.g. medical history or social history)

both within the healthcare setting and also cross-borders, to facilitate data exchange and provide a platform to better understand diseases and risk factors [43].

2. Literature review and aims

There is an extensive literature on the causal relationship between the main risk factors for dental caries and its subgroup, early childhood caries, and treatment options and preventive approaches, which will be outlined in the followings. National and international professional organizations also developed recommendations, summarizing the highest level of knowledge and encouraging its translation into practice.

The relation of oral health status and caries experience are usually extensively analysed, but the complexity of the disease should be examined as well. Such studies should incorporate socioeconomic and environmental factors, since complex causal relations might present and the disease itself represents a significant burden and the children's quality of life can be negatively impacted by severe caries lesions [44,45].

2.1 Caries and its risk factors

Caries classification helps differentiate between the stages of caries and can provide guidance in caries management process and treatment path. International Caries Classification and Management System (ICCMS™) [46] was developed by FDI, US National Institute for Dental and Craniofacial Research (NIDCR) and Alliance for a Cavity-Free Future (ACFF) and can be used to define the stages of caries lesions, assess caries activity and help with the caries risk classification and caries management processes. The stages defined as 'sound surfaces', when there is no visible sign of caries, 'initial stage caries', when a visual change in the enamel occurs on wet tooth surface or after drying the surface, but it is a non-cavitated, white demineralization area. 'Moderate stage caries' means that there is a visible enamel breakdown with dark shadow

and ‘extensive stage caries’, when the dentin becomes visible [47]. The ICCMS™ system is based on the International Caries Detection and Assessment System (ICDAS), which was created in 2002 [47]. Both systems are used for staging caries lesions, and the caries stages provided by the ICDAS system can define ICCMS™ classification. The ICDAS II system provides the following codes and criteria for its caries stages: 0 – sound tooth surface, 1- first visual change, white or brown discoloration after drying the tooth surface, 2- visual change detectable even when the enamel is wet, 3- localized enamel breakdown visible (wet or dry), 4- dentine involvement visible as a dark shadow, 5- distinct cavity visible, dentine exposed, 6- extensive cavity with visible dentine [48,49]. The two system can be connected and the stages defined as ICCMS™ Sound surface – ICDAS code 0, ICCMS™ Initial stage – ICDAS code 1 and 2, ICCMS™ Moderate stage caries – ICDAS code 3 and 4, ICCMS™ Extensive stage caries – ICDAS code 5 and 6 [47]. The American Dental Association also developed a Caries Classification System [50] and defines the following stages: ‘sound surface’ with no visible caries, ‘initial caries lesion’, when there is a detectable mineral loss, limited to the enamel and on smooth surfaces, they are called ‘white spot lesions’. In this stage, the lesion is non-cavitated and with proper remineralization, it is reversible. ‘Moderate caries lesion’ is the next stage, where microcavitation on the enamel can be visible and can involve the dentin with grey discoloration. ‘Advanced caries lesion’ means that there is a visible cavitation and exposed dentin.

Caries is a multifactorial disease [42]. According to the ICCMS™ system, the risk factor contributing to caries development can be classified as individual (patient) level and intraoral level. On the patient level, the risk factors include the general health condition, sugar consumption, fluoride exposure, socio-economic status, oral health behaviour and in case of children, the caregiver’s caries experience, which can predict their children’s future caries experience. On the intraoral level, caries risk factors include the previous caries development,

dental plaque and saliva [47]. Among these risk factors, diet, especially the amount of sugar intake plays an important role in the development of caries. Examining 12-14 year-olds, a study found that older age was also associated with higher caries experience [51]. Another cross-sectional study found the same as conclusion: examining children between 12 and 15 year-old, even though the overall oral hygiene improved, the caries prevalence increased [52]. Tooth-brushing frequency and efficiency, or the type of clinic (public or private) can also have an effect on the caries experience [52].

Toothbrushing frequency and socioeconomic status (SES) are among the caries risk factors as well [53]. The greater frequency or the higher the SES, the lower the caries risk.

Dental crowding also poses as a risk factor, since it facilitates the development of dental plaque [54]. This evidence should be further studied, but other researches got to the same consequences in anterior teeth [55], and children with malocclusion have a higher caries experience [56].

ECC can appear in primary teeth in the 'under 6' age-group [4]. Among the available classification systems [57], for diagnosis and reporting purposes a classification system was developed by Drury et al in 1999 [4]. The American Academy of Pediatric Dentistry (AAPD) [58] defines two groups for this type of caries: the ECC and severe early childhood caries S-ECC. The ECC includes the presence of one or more decayed (noncavitated or cavitated lesions), missing teeth because of caries or any tooth surface filled on primary tooth for children under 6 years of age. The S-ECC is a definition for caries experience in children under 3 years old on smooth tooth surface and children between 3-5 years old, who have at least one cavitated, missing or filled smooth tooth surface in anterior primary teeth or children, whose decayed, missing and filled score equals or greater than 4 (for 3 year-olds) 5 (for 4-year olds) and 6 (for children age of 5). Such as any caries, ECC is also a multifactorial disease [23,59]. These risk factors include, but not limited to [60–63] microbiological risk factors [57], which impact the

caries experience and diet (e.g. sugar consumption) has a major role in developing caries. Frequent sugary food consumption associated with higher caries experience [64] [27] and sugar sweetened beverages also contribute to more severe ECC in children [65]. Regarding infants, the infant feeding methods and trends can also correlate with ECC experience [66]. Regarding ECC risk, we can find that environmental risk factors and socioeconomical risk factors [67] [27] also strongly correlate with higher ECC experience. Socioeconomic status can be a strong indicator for dental caries [23,68] and the mother's level of education or low family income also correlate with the experience of ECC [23,69].

These main ECC risk factors, such as low SES, maternal level of education are emphasized by the literature [23]. Low toothbrushing frequency, poor oral hygiene and the presence of dental plaque [70] can further increase the risk of ECC [71]. As protective factors, good oral hygiene and fluoride can be mentioned, since regular toothbrushing with fluoride toothpaste can decrease the risk of caries [58].

2.2 Risk assessment

Caries risk assessment (CRA) would be important to identify the caries risk for children, which can be considered low, moderate or high. The risk should be assessed regularly, since it can change over time. CRA helps identifying children most at risk of caries and with targeted preventive efforts and proper planning, early cost-effective treatments can be effective and can prevent serious complications of caries [72]. Aside from identifying risk group, CRA provides decision support for the dentist or dental professionals to plan the necessary care pathway for the patient. Children in high risk groups might have different needs from children in low risk group. According to the IAPD [73] and AAPD [40], the risk indicators for high caries risk: the

child has cavitated or non-cavitated caries, visible plaque on the teeth, missing teeth due to caries, frequent sugar consumption, low SES, mother or caregiver has active caries. The recommended care path for children in the high caries risk group: recalls should be scheduled in every 3 months, radiograph interval 6 months, application of topical fluoride varnish in every 3 months. Diet counseling, sealants and proper restoration of lesions are also recommended.

Although the available CRA tools might have their limitations and need further evidence to determine successful assessment methods, they would be a useful tool and should be further improved to identify crucial indicators and validate the best method [74]. The FDI also recommended, that the caries management system should be improved and include CRA models for risk assessment [75]. To make the most beneficial decisions on the dental care of children, caries risk should be assessed and carried out regularly, as the risk-assignment might change in even 1-2 years [76]. Protocols are necessary for decision support and should be easily applied into clinical dental practice [42].

2.3 Treatment options and prevention

Regarding the treatment options of dental caries, the minimally invasive dentistry plays an important role. The FDI also supports the minimal intervention approach over the restorative treatments in a Policy Statement [77], as the initial carious lesion is not cavitated. In this initial stage, there is a detectable visual difference at the lesion site of the enamel compared to the non-carious enamel, and remineralization (e.g. topical fluoride) of the affected area and follow-up can prevent the caries progression and cavitated carious lesions. Furthermore, patient education, follow-up and monitoring, topical fluoride and plaque-control should be part of this preventive approach [77].

Aside from fluoride, there are other caries preventive methods and minimal invasive techniques available. Self-assembling peptides can be applied to the caries lesion in the initial stage of caries. These peptides then diffuse to the lesion and attracts calcium phosphate, usually from the saliva and helps the regeneration of both the enamel and dentin. Another method is the casein phosphopeptide amorphous calcium phosphate (CPP-ACP), which is also used in the initial stage of caries and facilitates the remineralization process by providing calcium phosphate, while binding onto the tooth surfaces [78]. In case of initial caries, the nano-hydroxyapatite products [79] and ozone therapy also play important role, and they especially efficient when combined, according to a study [80]. Chlorhexidine varnish for children is proved to reduce the Streptococcus Mutans levels - which is a predominant species responsible for dental caries – and could be a potent method in caries prevention [81].

Diet and sugar intake also has an impact on the disease progression and prevention [82]. Preventive methods are quite crucial, such as the patients' active participation in this process, caries experience in primary dentition, and follow-up for regular check-up and observation of patients' oral status. This preventive approach also includes the application of pit or fissure sealants, identifying bad habits (e.g. digit sucking), providing simple orthodontic appliances, extractions in the mixed dentition or topical fluoride application [82]. Oral health education and prevention programs can help achieve a better quality of life regarding oral health [83].

However, during the diagnosis and preventative treatment process, some concerns do emerge. Problems persist regarding the successful early diagnosis of dental caries. This also applies to the caries risk assessment and the patients' or parents' cooperation in the caries preventive and oral hygiene processes. These minimally invasive dental treatments might need special equipment and diagnostic tools, which can cause an increase in the costs on the dental practices' side. Furthermore, some of the procedures still need additional evidence for their cost-effectiveness [82] [84]. Regarding caries prevention, the most important strategies

recommended by the FDI are promoting the use of fluoride toothpaste, maintaining good oral hygiene, visiting the dentist for regular dental check-ups, limitation of sugary food and drink consumption, maintaining a proper diet, providing oral health education for the individuals and communities, and on the clinical side: topical fluoride varnish, pit and fissure sealants, dental hygiene treatments for plaque removal are recommended and early detection of caries is important and if necessary, minimal-invasive dental treatments should be favoured [3].

Interprofessional collaboration would be crucial, since children at an early age attend at pediatricians' offices regularly. Paediatricians and nurses could have an important part in the prevention and detection of ECC by educating parents, caregivers or those responsible for the child about good oral hygiene, correct biofilm removal technique, proper diet and nutritional health of the infant [10][85], and the use of fluoride toothpaste as a part of oral hygiene in children [64]. It would be important for physicians or nurses to recognize the presence of carious lesions and refer patients to the pediatric dentist if necessary [10][64].

Furthermore, public health surveillance helps to identify the risk factors and aids to implement effective preventive programs.

Minimal invasive dentistry and preventive approaches are crucial, according to the FDI. The reduction of sugar intake, regular efficient tooth cleaning and the regular use of fluoridated toothpaste are identified as the key methods for the reduction of caries burden [86].

The role of oral microbiome although evidence-backed, is not commonly used in the clinical dental practice [87]. However, saliva tests at an early age might help predicting the caries risk for ECC [88] and children with or without caries lesions show differences in their oral microbiome [89]. These differences are most determining in the first 12 months of the infant's life, since altered colonization can affect the long-term dental and also systemic health [90]. The oral microbiome is changing throughout childhood as both pathogen and protective microorganism might be presented and the pathogen colonization should be prevented by

proper education of family members [91]. As a summary, ECC prevention should be based on the following key areas, according to the IAPD: healthcare professional should be aware of ECC, sugar consumption for children should be limited, regular toothbrushing with fluoridated toothpaste is necessary and preventive care for children should start before the age of 1 [92].

Based on the literature findings, research gaps and unmet needs regarding available clinical tools, causal relations of socioeconomic factor and sugar consumption with ECC and poor quality of available data on caries experience were identified and we set the project goals for analysis.

2.4 EU and professional organizations

Prevention has a major role in caries management, as dental caries is a preventable disease. This is emphasized in the FDI policy statement since 1998 (revised in 2016), where governments are encouraged to promote oral health education and widening the understanding of oral diseases among the population, e.g. through national health policies [93].

Although the organization of the healthcare system, the dental caries prevention programs and health promotion strategies are mostly determined and regulated on a state level in the European Union, the EU has an important role regarding prevention of chronic diseases, as presented in the CED White paper [94]. The EU can help improving the platform for effective co-operation between European countries by developing databases and facilitating the prevention of chronic diseases [95].

There are observable differences between the countries dental care management systems for children, but a main common point is the provided free-of-charge dental treatments for children [11]. Among the differences, the economy should be emphasized. The economic crisis of 2008

did not hit European countries equally, Western European countries, with their stronger economies remained providing more funds for public healthcare services, preventive care and interventions [96]: Good practices among European countries are also identified and described [11], but their incorporation into preventive strategies and clinical implementation into dental preventive services are very diverse within the EU.

Indicators and guidance for preventive efforts also available internationally, such as detailed in the EGOHID project, or in the Scottish Intercollegiate Guideline Network's relevant guidelines for childhood caries management (SIGN-138). [72,97]

Inequality appears not only between countries, but within countries. The FDI provided Policy Statement for governments to support the accessibility of oral health services for the vulnerable population and increase funding for research related to oral health of the underserved population with novel methods and technologies (e.g. telehealth solutions) [98].

WHO has also set its goal regarding childhood caries: by 2020, 80% of 5-6 year-old children should have been caries-free. This goal has not been met in time by most of the EU states. Additionally, Eastern European countries are even farther from this goal [99].

The WHO emphasizes the role of surveillance regarding these chronic diseases [22] and that the right dietary habits can reduce caries risk, and especially the sugar intake plays an important role [100]. This should be applied in early childhood as well. The most important factors to prevent caries are proper diet and nutrition, the reduction of sugar-consumption and sugary drinks, as the WHO recommends [101] [21]. The FDI released a policy statement and emphasized that national dental organizations should develop dietary guidelines to help curbing the sugar intake, including in childcare facilities and schools [102]. The International Association of Paediatric Dentistry (IAPD) recommends to reduce sugar consumption for children aged between 4 and 8, and sugar should only provide the 5% of energy intake, to

successfully reduce the risk of caries development. Dental professional should be part of this endeavor, according to the IAPD [103].

The European Academy of Paediatric Dentistry (EAPD) also recommends the early oral health assessment for children in their policy document. Children's oral health should be assessed before the age of 1, along with counselling, to prevent ECC. Regular dental visits, fluoride toothpaste and regular toothbrushing (twice per day) are necessary and topical fluoride varnish recommended at least twice per year for children in caries risk groups. Parents should be aware of poor dietary habits and habits causing the early transmission of mutans Streptococci to infants [104]. The first consultation for the parents should happen even before birth: parents should be informed, that their habits regarding oral health will have an impact on the child's oral health, as the etiology of ECC is also bacterial [105].

Regarding the ECC, the education of parents or caregivers on the proper dental hygiene and dental health is essential to reduce ECC. The FDI recommends that governments in every country to develop systems to monitor preschool children's dental caries experience from age 0 to 5 [106]. IAPD recommends that the caries management process for children should start before the age of 1. In a declaration, the IAPD emphasize that primary prevention of ECC should focus on the prevention of new disease. The secondary prevention, at an initial stage of caries, is aiming to minimise the impact of caries. Tertiary prevention of ECC can include non-invasive caries control treatments and restorations [92]. Interprofessional cooperation can help children to receive the oral care they need [107]. Health practitioners, such as pediatricians or nurses monitoring the child's growth and health, would have an important role in ECC prevention, as they could identify children at high risk of caries or instruct those responsible for the child on how to perform a proper, non-cariogenic diet and educate caregivers on oral hygiene habits [23].

The role of risk assessment and CRA models are also emphasized by the IAPD. Risk assessment helps targeting individual needs regarding caries prevention and caries management. This assessment should include the previous caries experience and lesion progression of previously detected cavitated caries or white spots, the family's socio-economic status and the amount and frequency of sugar consumption. The caries risk should be assessed regularly, through recall visits, where the cooperation between the dentist and the patient is an important factor. The patient's risk-group can change over time and the children with low, moderate or high risk for caries need different care paths for successful caries management or caries prevention [73].
The minimal invasive dentistry is encouraged by the IAPD: with successful prevention, surgical interventions can be avoided. Good oral hygiene, topical fluoride application, assessment of caries risk, early caries detection and enamel remineralization could prevent the need for surgical interventions [108].

Gap of knowledge

As research on the prevention of dental caries in children is not at the center of the scientific literature, this thesis contributes to understanding on research and innovation, epidemiology of early childhood caries and preventive care of childhood caries in the member states of the EU. Knowledge gaps were identified by EAPD in the area of caries diagnosis, risk assessment and minimal invasive treatments. Evaluation of novel technologies would be necessary, as well as new devices and overall more research in the primary dentition [105]. There is a demand for implementing the knowledge into everyday practice and the as per the EAPD, the suggested research or innovation areas could be caries preventive, minimal invasive infiltration methods, diagnostic techniques to support decision making, quick, reliable methods to assess caries risk or microbiological tests [105]. Caries prevention and dental health promotions would be crucial,

and EAPD also emphasizes the need for more studies on the cost-effectiveness of prevention compared to surgical treatments. In the caries risk assessment area, more factors (socioeconomic risk factors, diet, age) should be considered to better predict caries risk and thus deliver better and reduce inequalities [105].

2.5 Objectives of the PhD work

The PhD project had 3 objectives:

1) to analyze how innovative is the area of 'childhood caries' and to provide an insight to the research and development process in the area of childhood caries. Through a patent analysis, innovation trends can be identified and research interest can be estimated. We aimed to analyse the European countries' role in patenting and research.

2) to analyze the burden of ECC for children under 5-years old, focusing on both deeper analysis for the recent years and the trends over longer period of time. We aimed to examine the correlation of the ECC burden with environmental factors (such as socioeconomic factors, income), and also with sugar consumption,

3) to analyze the EU member states' childhood caries management practices and to map current practice of dental caries prevention for children, involving caries experts from the EU countries and discover the current caries management practices from both clinical and non-clinical viewpoint.

3. Materials and methods

Methods used in the project are presented according to the objectives.

3.1 Assessing novel technological solutions addressing caries: a patent analysis

3.1.1 Study design

For the patent analysis, we collected patents and patent applications from the patent database. We used Orbit Intelligence [109] for this purpose. Regarding the patent database, it was a major criteria for the patents to be available in English for full analysis. Orbit-Questel is a leading patent licensor, providing patents translated to English. It also enables searching in English, this way we could use combination of search terms in their database. The keywords were selected by using Medical Subject Headings (MeSH) database.

The applied keyword set was the following: dental caries, dental cavity, caries, decay, cavity, cariosity, tooth decay or teeth decay. In order to narrow our search for primary teeth, to reflect childhood dental prevention characteristics in the patent activity, the following keywords were added to the string: primary tooth, primary teeth, deciduous tooth, deciduous teeth, milk tooth, baby tooth, baby teeth, child tooth, child teeth or children teeth.

3.1.2 Analysis

We searched in titles, abstracts and claims of the patent documents.

The final set of patents included to the analysis was defined manually, and all applicable patents were selected, regarding all aspects of primary teeth and their carious lesions, focusing on

prevention, diagnosis and treatment. We included children of all age groups, where primary teeth were applicable.

Among the selected patents, we used a classification based on the specificity of the patents:

1) Specific patents – specifically related to the treatment, diagnostic of prevention of primary teeth caries
2) General patents –loosely related to the primary teeth caries prevention, diagnostic or treatment

3.2 Assessing burden and risk factors of ECC: an ecological study

We aimed to gather data on the burden of ECC among EU member states. We included the United Kingdom (UK) into the analysis, since throughout the examined years the UK was part of the EU. To estimate the burden of caries experience in children and analyse the connection with its risk factors, we gathered relevant data from three public databases:

1) GBD database [110]: we extracted data on the burden of disease for children under 5 years old (disease: caries of deciduous teeth) from the GBD database. Although ECC can occur under the age of 6, it was not available in the database to select 'under 6' age group. The only available data matching our criteria was for the 'under 5' age group, and we needed to use this to be able to analyse the estimated disease burden of ECC. There are multiple sources of data in this database. Regarding caries of primary teeth, data was extracted from scientific literature and surveys [111].

   We used the following measures for analysis of burden of caries of primary teeth: incidence, prevalence, years lived with disability (YLDs), age-standardized YLDs

The data is available on a yearly basis starting from 1990. The most recent data available is from the year of 2019. This database provides disease burden estimation internationally and it is beneficial for international comparison.

2) EUROSTAT [112]: Eurostat is the statistical office of the European Union, which publishes high quality statistics and indicators at European level, allowing for comparisons between countries and regions. European Union Statistics on Income and Living Conditions (EU-SILC) provides informative data on social inequality and poverty, which are shown to have an impact on caries experience in children. This type of data is available from 2003 and annual data are provided for the given states. We collected data on the possible socioeconomic determinant of oral health, such as income and living conditions. These were the proportion of people at risk of poverty, Gross Domestic Product (GDP) per capita in purchasing power standards (PPS, allowing meaningful comparisons of GDP between EU countries, by eliminating the price level differences), and the distribution of population by degree of urbanization.
3) Food and Agriculture Organization of the United Nations (FAO) [113]: The analysed data was a food balance item, and the specific item selected for analysis, were the 'aggregated items of sugars and sweeteners'. This type of data is closely related to sugar consumption and it is used to estimate the sugar consumption, since no international database on sugar consumption available. The available food supply data on food availability are usually used to estimate the sugar consumption nationally and it also makes international comparison possible. Data available for sugar consumption estimation from 2014 to 2017. This type of data on sugars and sweeteners include the different types of sugar: cane, beet as well as raw and refined, centrifugal and non-centrifugal, confectionery and also flavored versions. Among the other sweeteners,

glucose, fructose, maltose included in this category, as well as different types of syrups, maple sugar, lactose and molasses. Non-alcoholic beverages are included as well.

3.2.1 Study design

First, I would like to describe the estimated burden of early childhood caries in the EU member states. The GBD 2019 data was presented between the 1990 and 2019 time period. The examined indicator was the YLDs. The year of 2019 was described in details, and ECC incidence, prevalence and YLDs rate was analysed for children under 5 years old to identify trends over time. The gender was also part of this analysis, as prior studies found differences between male and female populations and caries experience and also this can standardize potential confounders [114].

Then, the EU countries' ecological variables were examined along with the sugar consumption data and YLDs (ECC burden) rate for children under 5 years old. Annual means (SD) were calculated and presented to show the variability of the data in the examined time-frame:

- Between 2014 and 2019, annual means were defined and compared, then absolute and relative differences were defined. During the analysis, YLDs rate was the dependent variable. Sugar consumption (kg/capita/year), proportion of people at risk of poverty (%), GDP per capita (in PPS) and degree of urbanization (%) were the independent variables [114,115].
- Sugar consumption-related data was calculated for the time period from 2014 to 2017, due to the specific data-availability.

3.2.2 Statistical analysis

For the analysis, STATA IC version 13.0 software was used and coefficients with the corresponding 95% confidence intervals (CIs) were applied. The statistical significance was defined at $p < 0.05$.

Descriptive statistics:

We analysed the changes in both the dependent and also the independent variables during the examined time period - between 2014 and 2019 -, the differences (both absolute and relative) were defined by the application of two-sample t-tests.

Linear regression analyses:

We analysed the possible correlation between the chosen inequality indicators and the burden of disease of ECC (YLDs rate). This analysis was carried out for the time period of 2014 to 2017, because the available data for sugar consumption was limited to 2014-2017 annual data. We assessed the fit of the model to the data by Akaike's information criterion and the Bayesian information criterion.

Stratified data classification was also applied to match the two main geographical region in the EU: countries in western Europe and countries in Eastern Europe. Eastern European countries were: Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia. Western European countries covered: Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Spain, Sweden, United Kingdom.

3.3 Assessing childhood caries prevention, treatment and management: a cross-sectional study

3.3.1 Study design

In this cross-sectional study an exploratory research was carried out. Since no appropriate data collection or similar questionnaire were available, we developed a unique survey to collect comparable data for international assessment. We gathered information on the management of publicly financed dental services for children under the age of 18, and our scope was to discover the dental practice and its regulatory policies in every countries in the EU, aiming to identify the characteristics of childhood caries prevention. We included the United Kingdom (UK) into the analysis, since throughout the examined years the UK was part of the EU.

According to the Donabedian model [116], information on structural, process and outcome indicators were collected. Indicators were selected based on the international guidelines, including the EGOHID project, or in the Scottish Intercollegiate Guideline Network's relevant guidelines for childhood caries management (SIGN-138) [72,97]. We also respected the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for presenting the results of cross-sectional studies [117].

3.3.2 Questionnaire

Since there were no such survey available on the caries management processes before among the EU countries, we needed to develop a survey with question that can be interpreted in most EU countries. We developed our unique questionnaire [available online at https://evasys.unideb.hu/evasys/online.php?p=caries_policy], with the following features:

- It was anonymous
- Written in English

- Presented online by the EvaSys survey automation suite.
- 70 closed questions, 6 open-ended questions
- Contents: 1) demographic details of the responding person, 2) management and structure of dental health services for children, 3) oral health education available for children under the age of 18, 4) data registry for the result of dental screening, 5) financing details of the provided services.
- It takes 15 minutes to complete
- All answers provided by respondents are confidential

The survey was made available online by EvaSys Automation Suite V8.0 (2202), license of Debreceni Egyetem.

There is a wide variety in healthcare systems within the EU, however, according to the EU manual of dental practice (2015), there are certain services and treatments provided for children through the public health service [118] in the majority of European countries including:

- For children, the EU definition was applied and were defined as under 18-years of age [119].
- 'Childhood caries' was used generally, referring to caries experienced in children under 18-years of age.
- We are also referring to a special group regarding the ECC: ECC defines caries in the primary dentition, for children who are under 71 months of age [6].

3.3.3 Participants

Selected professionals with experience and knowledge in caries prevention were invited to complete the survey online. The data collection started in July 2017 and was finished in

September 2018. To send the online survey to the targeted professionals, we used publicly available email addresses to reach out to experts in this field. It was voluntary to participate in the study.

Our focus was to gather as reliable data as possible, therefore we contacted professional dental institutions and councils and at least one dental school in each EU country. We also sent the received responses to the competent authorities of the EU countries for review and they were provided with a link, as an option to fill out the survey online or share their opinion on the results [120].

3.3.4 Data analysis

Inclusion criteria for analysis

One submitted survey per country was included in the analysis. If multiple responses were received from a country, we included the most complete dataset, we also checked the consistency of the dataset with the previous literature data and also the consistency within the same dataset. The most consistent dataset was included. If we found incoherent replies within the same dataset, those responses were excluded from the analysis, this is why the number of responses can vary per question. We did not collect any type of personal data.

Statistical analysis

We used descriptive statistics to analyse the data collected through the survey. Microsoft Excel 2010, Microsoft Excel v16.45 software were used during the analysis.

Information gain (IG) [121] is a feature selection method and the application of this algorithm was used to determine the importance of the collected indicators and to detect the difference between two previously defined groups. It also applicable as a feature weighing algorithm, since IG shows the dependence between the examined feature and its class (Zhao et al. [121]). This

method is based on two main steps: first, the entropy defines the uncertainty [122] and then IG will show the reduction of this uncertainty [123]. When the information gain is high [121], it means that the examined feature (or indicator) is considered to be relevant.

The values of IG are between 0 and 1. When this value is 0 , it means there is a full overlap between the two examined groups, with no difference. When the value is 1, it means that the greatest difference can be detected between the two examined groups.

We used the classification provided by WHO for the DMFT scores (this type of data is internationally available for 12-year-olds with WHO classification: https://capp.mau.se/dental-caries/ [19]) as follows:

- Very low: DMFT score below 1.2
- Low: DMFT score is in range of 1.2 - 2.6
- Moderate: DMFT score is in range of 2.7 - 4.4
- High: DMFT score is above 4.4

Analysis of estimated reimbursement data for preventive services

A scoring method was used to classify the data extracted from the survey's reimbursement details. Based the on the reimbursement value, we assigned a score to each examined service or treatment. The score values were varied between 0 to 5, where 0 represented the case when there was no reimbursement provided for the service, and 5 meant that the examined service was very likely reimbursed with the highest value.

The weighted average was calculated from the service/treatment scores (method described by Bland J M and Kerry S M [124], and calculated by using Microsoft Excel) and were classified according to their functional relevance.

The following classification was applied for the examined services and treatments:

1) Preventive:
    - oral health education
    - oral health screening
    - topical fluoride varnish
    - fissure sealing
    - dental hygiene treatment
    - preventive orthodontic treatment, e.g. space maintainer
2) Operative:
    - primary tooth filling
    - primary tooth pulp therapy
    - permanent tooth filling
    - permanent tooth root canal treatment
    - tooth extraction

4. Results

4.1 Assessing novel technological solutions addressing caries: a patent analysis

4.1.1 Observed trends in patenting

First, we defined 61 matching patents for our analysis. Second, we defined groups for classification of these patents, and their percentage to compare them to the total number of selected patents: (1) Patents especially related to children under 6 years of age had a percentage of 39% (2) The proportion of patents of innovations targeting children above 6 years of age, but who still having primary teeth was 43%. (3) Patents not exclusively related to children's primary teeth, and could also be used for adults had a percentage of 18% among all examined patents.

In the first group, there were oral hygiene tools for babies, or tooth-protecting cookies for babies. In the second group, there were patents for toothpastes especially for children, dental treatments designed for the primary dentition or dental screening software aiming schoolchildren's screening. In the third group, there are innovations about pain management, matrix band, or telehealth dental systems for remote access.

We also categorized the selected patents regarding to their function. In this classification we applied the widely used prevention, diagnosis and treatment categories.

General and specific patents

We found that the proportion of specific patents were 70.5% to these selected categories, and the general patents were represented by 29.5%. Thus, the largest portion was specific to primary teeth and their caries management.

Legal status of the patents

The legal status of the patents are the following: 27% of the examined patents were ‘granted’, 19% of the patents were ‘pending’, and 54% of them were ‘dead’.

The patents are also part of patent-families (FamPat), which is classified by the invention type. A patent family is ‘Granted’, if at least 1 member of the patent family is granted. When there is no available ‘granted’ patent in the family, then it is called ‘Pending’. ‘Dead’ patents are no longer in-force. It means that they might have been expired, revoked or lapsed.

Patenting timeline

In 1931, the first patent became available regarding primary teeth or caries management of primary teeth. From 1990, there was a perceptible intensification of patenting activity .

2001 was the most productive year for innovations (with 18 available patents) regarding primary teeth or caries management of primary teeth.

Territorial differences

Differences regarding patenting activity for the countries are presented on Figure 2. China has the most first filing patent families, 24. The second largest number is for the United States, which has 8. Russia and the former Soviet Union is the third on the list. The European Patent Office has 6 patents, and also these patents are not recent.

Patent applicants and technology domains

Figure 3 shows the major technological fields, which are protected by top applicants. Technology domain: The International Patent Classification (IPC) defines the categories and the patents are grouped to one or more groups. The biggest applicant is Ortho Tain, and it has 3 patents. Regarding the technology domain, the ‘Medical technology’ category is dominant.

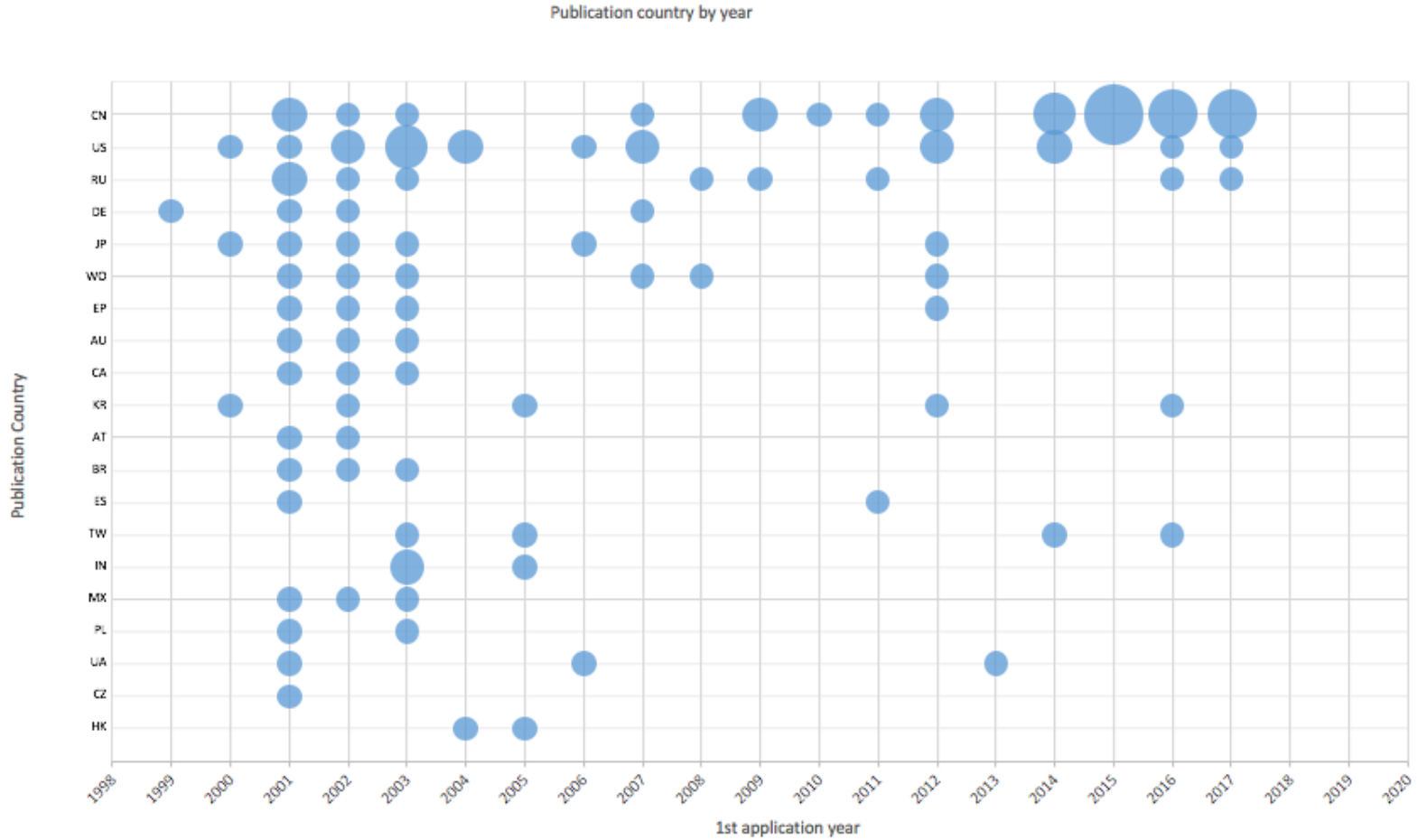

Figure 2. Publication country by year.

This graph represents the location of patent publications and their changes over time.

Abbreviations: CN-China, US-United States, RU-Russia, DE-Germany, JP-Japan, WO-World Intellectual Property Organization, EP-European, AU-Australia, CA-Canada, KR-Korea, Republic of, AT-Austria, BR-Brazil, ES-Spain, TW-Taiwan, IN-India, MX-Mexico, PL-Poland, UA-Ukraine, CZ-Czech Republic, HK-Hong Kong

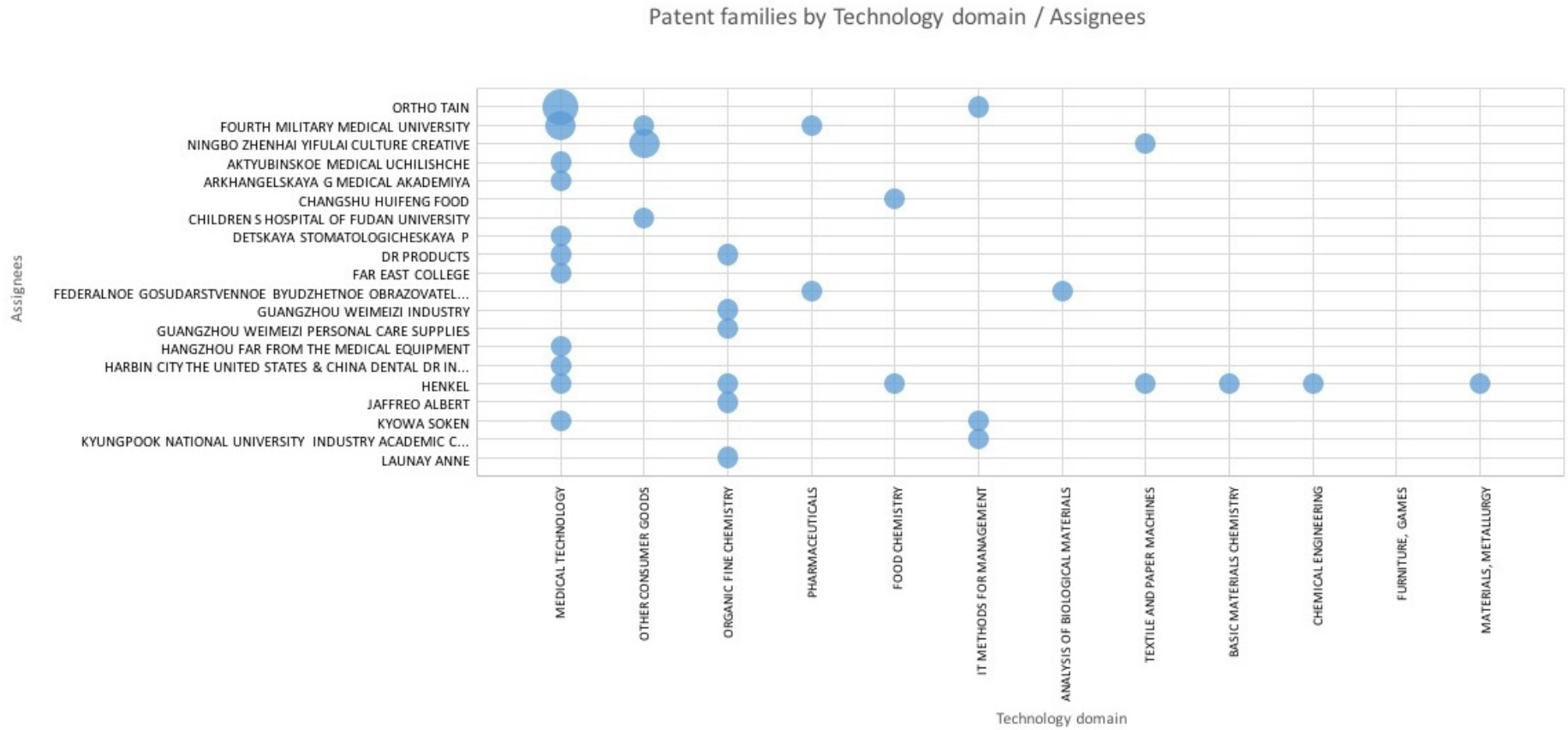

Figure 3. Patent families by Technology domain / Assignees.

This graph represents the individual or the company that has rights and title to the invention (assignee) by technology domains.

4.1.2 Types of Innovations

Regarding their functional application area, we used the classification of the selected patents as follows: among ‘prevention-related’ patents there were 37, 8 patents were ‘diagnosis-related and the number of ‘treatment-related’ patents was 16.

All treatment-related patents also belonged to the ‘Specific patent’ group, while among Prevention- and diagnostic-related patents, we could identify both specific and general patents. There were also 12 orthodontic-related patents for the early and young ages of children.

4.1.3 Timeline and territorial differences

The territorial differences in prevention-, diagnostic- and treatment-focused innovations are presented in Figure 4.

Prevention-related patent activity: Activity is observable throughout the examined period of time. From 2004, there was an increase in the number of patents. China owns the most patents in this field, with 17 patents. The US is the second, with 6 patents throughout the years, third is Russia and the former Soviet Union, with 4 patents.

Diagnostic-related patent activity: Patents in this field are from 1997 to 2018. This was the least active category in patenting (only 8 patents). Russia has the most patents in this field of innovation.

Treatment-related patent activity: Activity was accelerated in 2001, with the highest number of patents in 2016. China owns the most patents in this field.

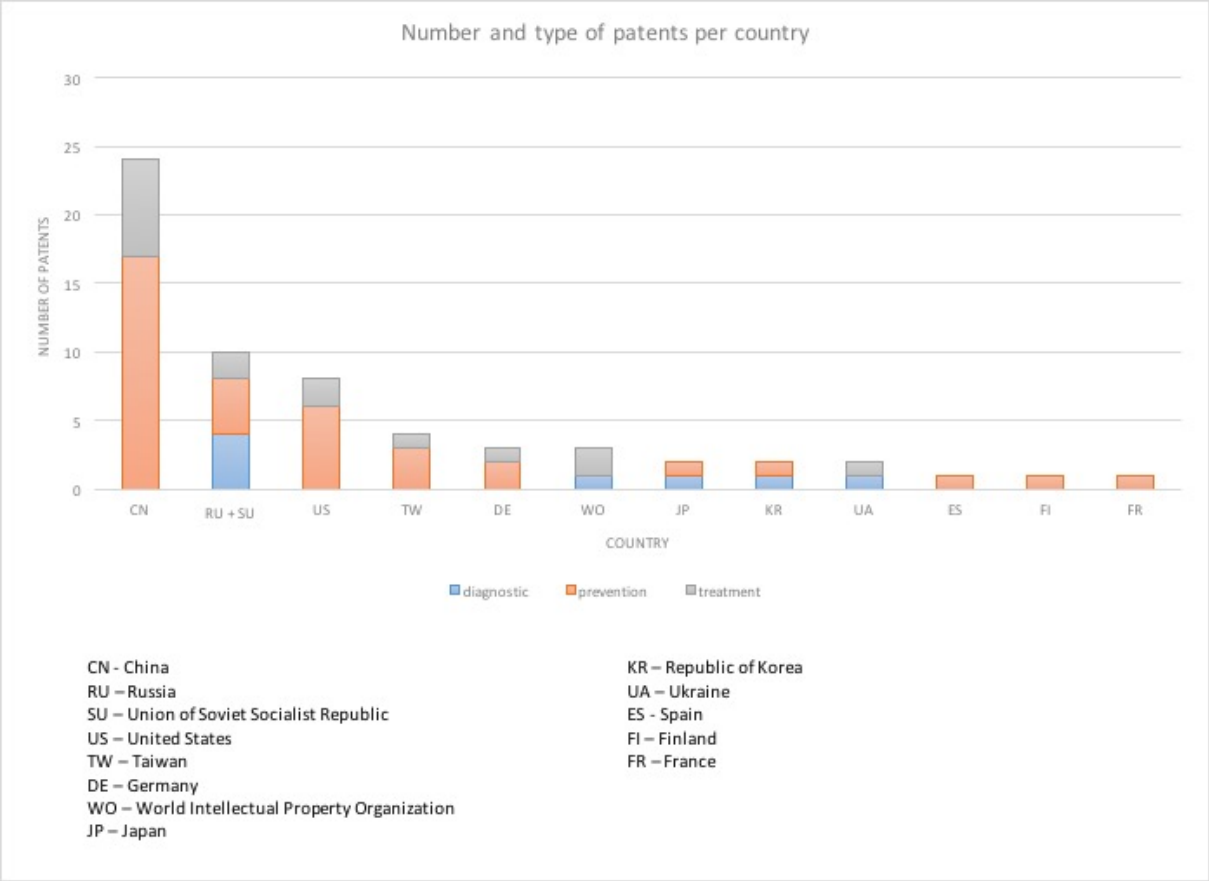

Figure 4. Number and type of patents per country.

This graph represents the number and type (diagnostic, prevention or treatment) of patents per country.

Abbreviations: CN-China, RU-Russia, SU- Union of Soviet Socialist Republic, US-United States, TW-Taiwan, DE-Germany, WO-World Intellectual Property Organization, JP-Japan, KR-Korea, Republic of, UA-Ukraine, ES- Spain, FI-Finland, FR-France

4.1.4 Patented innovations

First, the 'prevention-related' inventions will be described. Innovation in this category usually include different types of mouthwashes, toothpastes with antibacterial effect, and also specific toothpastes for children, e.g. fluoride-free toothpaste or edible toothpaste, enriched with vitamins and calcium. There are also special toothbrushes for children and other inventions, like tooth protecting lollipops or cookies. These inventions all focus on preventing the development of caries or aiding the management of caries. Inventions also include oral hygiene

tools for babies, such as small toothbrushes or oral cleaning items, and vegetable-containing dental care cookies for babies. Jaw inductors or dentition developmental guide devices are also a part of this category.

In the 'diagnostic' field there were a variety of diagnostic tools as well. This includes microbiological tools, such as Streptococcus mutans diagnosis method, remote dental systems, using telehealth for screenings of schoolchildren. Infrared diagnostic tool is also part of this category to predict the tooth eruption and identify hyperaemia in the gum.

The 'treatment' category usually includes inventions in the field of fillings, prosthetic, surgical or endodontic interventions. In this category we can find patented filling materials, excavator tool, dental matrix band, and also crowns and tooth extraction tools and methods and vital pulp extirpation tools intended for use in the primary dentition. This group also include toothache treatments or remedies, such as traditional Chinese medication.

4.2. Assessing burden and risk factors of ECC: an ecological study

4.2.1 Estimation of burden of the ECC disease among children under 5-years-old

Analyzing the available data for the year of 2019 (for male -M- , female - F- and both – B), the following results are found among EU countries: The incidence rate (per 100,000) was 43,686. This rate was highest in Poland (M, F, B) and lowest in the United Kingdom (UK) (F, B, M). The YLDs rate (per 100,000) was 11.5. This rate was highest in Romania among the EU countries (F, B, M), and lowest in the UK (F, B, M). Regarding the prevalence (%), the value is 41.4. It was highest among boys (M) in Lithuania, Latvia and Poland, lowest in the UK (F, B) and Denmark (F).

The detailed dataset for incidence rate, prevalence (%) and YLDs rate of EU countries for male, female and both is presented on Addendum 2 – Table.

4.2.2 Analysis of the long term data for YLDs rate from 1990 to 2019

Figure 5 shows the YLDs rate of caries of primary teeth per 100,000 population between 1990 and 2019 for children under the age of 5. We noticed a trend, as constantly higher YLDs rates can be observed during the examined time-period for certain countries.

Two main groups can be identified over time: (1) Countries with constantly higher YLDs rate (these countries are Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia), (2) Countries with lower YLDs rate, which could be higher on an intermittent basis. Increasing values can be detected in Belgium, Sweden (2005, 2006), France, Spain (2006, 2007), Germany and Italy (2015), Denmark, Greece, Sweden (2017).

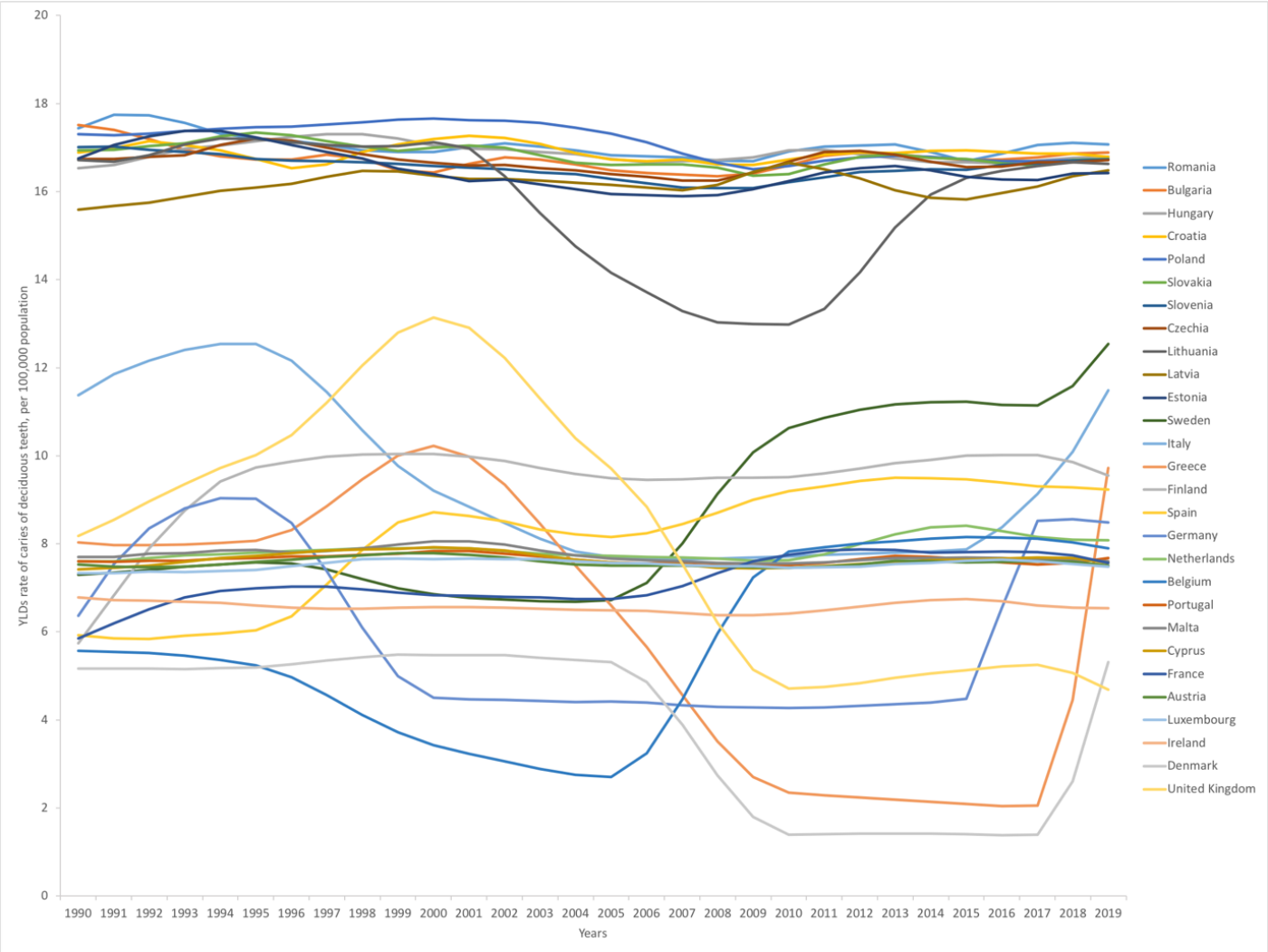

Figure 5. YLDs rate of caries of primary teeth per 100,000 population between 1990 and 2019 (presented age group: under 5 years of age).

Source: Global Burden of Disease database. YLDs: years lived with disability.

4.2.3 YLDs rate of ECC and its risk factors – comprehensive analysis

Descriptive statistics

The data on risk factors were available for international comparison from 2014 to 2019.

For this reason, changes over time were analysed for the time period between 2014 and 2019.

Table 1 presents the results of the analysis for the 28 EU countries.

Although the following changes were not considered significant, they were observable during the examined period of time:

Increased:

- The mean (SD) YLDs rate (per 100,000) has increased during this time by 6.6%
- Sugar consumption has increased during this time
- increase in GDP per capita (in PPS) was also observable

Decreased:

- proportion of risk of poverty has decreased
- degree of urbanization has decreased
- population of children under 5 years-old was also lower

Table 1. Mean change in YLDs and covariates over time (2014–2019).

	2014–2019	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**Change over Time between 2014 and 2019**		
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Absolute Difference**	**Relative Difference %**	***p*-Value**
YLDs rate	11.05 (4.86)	10.82 (5.11)	10.82 (5.09)	10.91 (5.02)	11.02 (4.99)	11.21 (4.81)	11.53 (4.51)	0.714	6.60%	0.582
Sugar consumption (kg/capita/year) *	54.92 (26.83)	54.3 (27.28)	53.9 (27.38)	55.37 (27.00)	56.11 (27.07)	-	-	1.812 *	3.34% *	0.801
At-risk-of-poverty rate (%)	16.72% (4.08)	16.85% (3.82)	17.07% (4.01)	17.05% (3.99)	16.8% (3.95)	16.79% (3.88)	15.74% (4.95)	−0.011	-6.59%	0.351
GDP per capita in PPS	101.11 (42.66)	99.57 (42.87)	101.14 (44.79)	100.82 (44.24)	101.18 (42.93)	101.82 (42.92)	102.11 (42.04)	2.536	2.55%	0.824
Urbanization (%)	38.78% (14.44)	38.54% (13.98)	38.34% (14.05)	39.02% (14.44)	39.06% (14.5)	39.91% (14.96)	37.82% (15.88)	−0.007	−1.86%	0.858
Number of observations	N = 168	N = 28								

* The change over time related to sugar consumption could be investigated between 2014 and 2017 due to the availability of data. Abbreviations: years lived with disability (YLDs), standard deviation (SD), number (N), gross domestic product (GDP), purchasing power standards (PPS).

Regression analyses

Table 2 shows the results of the second part of our analysis, the panel data regression analyses. Due to the limited data availability on sugar consumption, we could analyse this type of data in the time period from 2014 to 2017.

The following findings were observed:

With univariate models:

- between at risk of poverty rate and YLDs rate there was a positive significant association
- between GDP per capita (in PPS) and YLDs rate we could find an inverse association
- the degree of urbanization and YLDs rate was also inversely associated

With multivariate models:

- sugar consumption and YLDs rate was significantly associated
- sugar consumption showed a positive and also independent effect when analysed over time in this model: 1 unit increase in the sugar consumption (kg/capita/year) could be associated with a YLDs rate increase of 0.1 years.
- between GDP per capita (in PPS) and YLDs rate there was also a positive association, showing that the increase of GDP associated with the decrease in the YLDs rate (by 0.11 years)
- degree of urbanization and YLDs rate was also significantly associated according to the analysis: 1% increase was associated with the decrease of YLDs rate of 0.15 years.
- there was no observable effect of poverty on the YLDs rate

After stratification by the previously defined European regions (Western and Eastern European countries), this analysis was also carried out to examine the association between YLDs rate and the ECC risk factors. Regarding sugar consumption and poverty rate, there was no significant

associations detected in any strata. Regarding GDP and degree of urbanization, there were differences observed between the examined Eastern and Western European regions.

Table 2. Panel data regression models for the effect of sugar consumption, at-risk-of-poverty rate, GDP per capita, and urbanization on YLDs rate of early childhood caries over time (2014–2017).

	Univariate Analysis			**Multivariate Analysis ***		
	Coefficient	**95% CI**	***p*-Value**	**Coefficient**	**95% CI**	***p*-Value**
Sugar consumption (kg/capita/year)	−0.016	−0.050, 0.018	0.364	**0.104**	**0.072, 0.136**	**<0.001**
At-risk-of-poverty rate (%)	**0.270**	**0.038, 0.501**	**0.023**	0.023	−0.146, 0.192	0.790
GDP per capita in PPS	**−0.058**	**−0.077, −0.039**	**<0.001**	**−0.113**	**−0.134, −0.092**	**<0.001**
Urbanization (%)	**−0.100**	**−0.163, −0.037**	**0.002**	**−0.151**	**−0.195, −0.107**	**<0.001**

* Significant results are shown in bold. Abbreviations: years lived with disability (YLDs), confidence interval (CI), gross domestic product (GDP), purchasing power standards (PPS).

4.3. Assessing childhood caries prevention, treatment and management: a cross-sectional study

The online survey was sent out to 444 professionals in the EU by email. As a result of the online survey, we received 36 completely or partially filled questionnaires. These responses represent 27 countries of the EU. The non-respondent member state was Luxembourg.

Regarding the respondents' background, 52% of them was working at a higher educational institution. They could provide voluntary information about their 'title': the most of them are dentist or dental specialist (7), professor (2), associate or assistant professor (2-2), university lecturer (2) or own a PhD (2). 56% of the respondent were female and the majority of the respondents marked the '40-59 years old' age group (63%).

It was emphasized by the majority of the respondents (15), that regarding the publicly provided preventive dental services for children, no uniformity is achieved in the country, thus regional differences might have an impact on the results and the responses might show approaches from the region what the respondent represents.

Our results are classified according to the different approaches of dental prevention service.

4.3.1 Accessibility of caries preventive services

First, the most important aspect to analyse is the accessibility of public caries preventive services for children and the features of the dental screening process.

Accessibility of dental screening

We examined both the characteristics of school and pre-school dental screening. The results are shown on Table 3.

First, the schoolchildren's dental screening characteristics are presented. Regarding publicly financed school dental screenings, we received 23 responses and this type of screening is provided in 9 countries. This type of screening is offered at least once a year in the majority of the responding countries (66.7%), however, only certain age groups are included and it is not provided to every schoolchildren every year.

For pre-school children, screening is offered in only 8 countries in the EU among the 26 respondent countries. Where this type of screening is provided, it is mostly performed at least

once a year (75%), but among the respondents, the majority does not include all age groups are included in this type screening (62.5%), thus this service is not available annually for the children.

IG analysis for the accessibility of dental preventive services show, that the greatest difference between low and moderate-high DMFT groups is represented by the availability of pre-school children's screening.

Table 3. Access to screening and assessment of caries preventive services in the member states of the European Union

Function	Indicator/Data type		Countries[1] and DMFT prevalence groups																										
			Very low (<1.2)								Low (1.2-2.6)												Moderate (2.7-4.4) and high (4.4<)						
			DK	DE	UK	SE	FI	NL	BE	ES	FR	IT	PT	CY	AT	MT	IE	SI	EL	LT	CZ	HU	EE	RO	PL	BG	LV	HR	SK
Access to screening and preventive services	Free-of-charge dental treatments provided for children[2]		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Brief dental interventions available for children[3]		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*			*	*	*	*
	School dentistry is part of the public dental care		*	*			*			*			X	*			*	*				*	X	*				X	X
	Frequency of school dental screening	More often than a year		*									X									*	X					X	X
		Yearly	*							*			X	*									X	*				X	X
		Not every year					*						X				*	*					X					X	X
	Screened age groups	All	*										X					*				*	X					X	X
		Selected		*			*			*			X	*			*						X	*				X	X
	Organized dental screening available for preschool children[2]		*	*		*	*	*							*				X	*		*						
	Frequency of preschool dental screening	More often than a year		*				*											X			*							
		Yearly	*												*				X	*									
		Not every year				*	*												X										
	Screened age groups	All	*					*											X			*							
		Selected		*		*	*								*				X	*									
Effectiveness of caries preventive services	Special care available for high-caries-risk groups		*	*	*	*	*	*		*		*	*							*	*					*	*	*	
	National guideline(s)[4] available to standardize brief dental interventions		*	*	*	*	*	*				*	*		*			*								*	*		*
	Uniformity achieved throughout the country in children caries prevention		*	*		*	*				*				*					*	*		*	*		*		*	
	Caries risk assessment applied in the country		*	*	*	*	*	*		*							*								*	*	*		
	Monitoring system available for children's dental screening		*	*	*	*	*			*				*	*						*							*	

[1] Countries indicated by 2-letter country codes, grouped by DMFT scores. *Source of DMFT data and classification: CAPP database, Oral Health Country/Area Profile Project. https://capp.mau.se/dental-caries/ Accessed: July 1, 2020*

[2] Through the public health service

[3] Dental interventions: aiming for caries prevention, we included interventions of both in-practice (clinical) and non-practice (non-clinical) setting

[4] Guidelines: To standardize brief dental interventions on caries prevention for children, either in-practice or non-practice setting, e.g. on oral health instructions and promotion, health behaviour, plaque control.

Table 4 shows the indicator categories used for caries preventive services and assessment of preventive services in the European Union member states (based on the responses). Countries are presented by their most recent DMFT score, from left to right: very low, low, moderate and high DMFT. Asterisk indicates 'available', fields marked with 'X' indicates no response received or response was excluded due to contradictory responses and not included in the analysis.

EU 2-letter country codes: AT-Austria, BE-Belgium, BG-Bulgaria, CY-Cyprus, CZ-Czechia, DE-Germany, DK-Denmark, EE-Estonia, EL-Greece, ES-Spain, FI-Finland, FR-France, HR-Croatia, HU-Hungary, IE-Ireland, IT-Italy, LT-Lithuania, LV-Latvia, MT-Malta, NL-Netherlands, PL-Poland, PT-Portugal, RO-Romania, SE-Sweden, SI-Slovenia, SK-Slovakia, UK-United Kingdom,

Source: https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Country_codes

Accessibility of oral health services and education

Our analysis shows, that almost all EU countries (25 out of 27 respondent countries) make brief dental interventions available for children. These interventions aim to provide dental health education and oral health promotion. In most countries dentists (93%) and pediatric dentists (82%) provide this type of education. Other professional involved in this service are university students at dental faculty (74%) and dental hygienists (70%).

Regarding oral health education, we further examined the characteristics and content of these interventions, with the help of ten indicators. The result are presented in Table 4. The base of these interventions is teaching toothbrushing techniques, as it is provided in 85% of the respondent countries. The second most important indicator is the supervised tooth brushing, since 67% of the respondent countries marked this as a part of oral health education. The third likely included educational theme is to present bad habits for oral health and providing information on the negative effects of these habits. 63% of the respondents marked this as 'included' in the oral health education.

With IG analysis, regarding the content of oral health education, the greatest difference between the very low and moderate-high DMFT classes is shown to be the information on bad habits (0.38) and also the education of healthy dietary habits (0.26) for oral health.

We also found that professional dental nurses are also available to provide dental health education in those countries, where the DMFT score is considered very low.

Table 4. Features of oral health education in the member states of the European Union

Function	Indicator	Countries[1] and DMFT prevalence groups																										
		Very low (<1.2)								Low (1.2-2.6)													Moderate (2.7-4.4) and high (4.4<)						
		DK	DE	UK	SE	FI	NL	BE	ES	FR	IT	PT	CY	AT	MT	IE	SI	EL	LT	CZ	HU	EE	RO	PL	BG	LV	HR	SK
Access to oral health education as a part of brief dental interventions	Basic oral health education[2]	*	*	*	*	*	*	*	*		*	*	*	*	*	*	*		*	*	*	*	*	*	*	*	*	*
	Education of tooth-brushing techniques[3]	*	*	*	*	*	*		*		*	*	*	*	*	*	*		*	*	*	*	*		*	*	*	*
	Promotion of fluoride toothpaste	*	*	*	*	*	*		*			*	*	*	*	*	*		*		*	*	*		*	*	*	*
	Promoting awareness in dietary habits	*	*	*	*	*	*	*	*			*	*	*	*	*	*		*	*	*	*			*		*	*
	Education of parents, involving them in the oral care promotion	*	*	*	*	*	*	*	*			*	*	*	*		*		*		*	*			*	*	*	*
	Supervised tooth-brushing	*	*			*	*		*			*	*	*		*	*		*	*	*	*		*	*	*		*
	Motivation based on individual health behaviour	*	*	*	*	*	*		*			*	*	*	*		*		*		*	*			*		*	*
	Education of pregnant women, involving them in the oral care promotion		*	*		*	*	*	*	*		*	*	*	*		*		*		*	*			*		*	*
	Information about bad habits for oral health[4]	*	*	*	*	*	*	*	*				*	*	*		*		*		*	*			*		*	
	Introduction of special tooth cleaning methods, products[5]	*	*	*	*	*	*						*	*	*		*		*		*	*			*		*	*

[1] Countries indicated by 2-letter country codes, grouped by DMFT scores. *Source of DMFT data and classification: CAPP database, Oral Health Country/Area Profile Project. https://capp.mau.se/dental-caries/ Accessed: July 1, 2020*

[2] Importance of tooth-brushing, toothbrush, toothpaste

[3] Including frequency and duration of tooth-brushing, what time of the day etc.

[4] e.g. thumb-sucking, certain types of sports

[5] Anything other than toothbrush and toothpaste, e.g. dental floss, mouthwash, interdental brush

Table 5 shows the availability of oral health education in the member states of the European Union (based on the responses), depending on 10 indicators representing the interventions provided. Asterisk indicates 'available', in individual or group setting or both. Countries are presented by their most recent DMFT score, from left to right: very low, low, moderate and high DMFT.

EU 2-letter country codes: AT-Austria, BE-Belgium, BG-Bulgaria, CY-Cyprus, CZ-Czechia, DE-Germany, DK-Denmark, EE-Estonia, EL-Greece, ES-Spain, FI-Finland, FR-France, HR-Croatia, HU-Hungary, IE-Ireland, IT-Italy, LT-Lithuania, LV-Latvia, MT-Malta, NL- Netherlands, PL-Poland, PT-Portugal, RO-Romania, SE-Sweden, SI-Slovenia, SK-Slovakia, UK-United Kingdom,

Source: https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Country_codes

4.3.2. Assessment of available services

The examined factors regarding the assessment of services aiming caries prevention are presented in Table 1. We got responses from 27 countries for these questions of the survey and the results are detailed in the following: (1) Children, who belong to the high caries risk groups receive special attention or care during the dental screening procedure in 52% of the respondent countries. (2) National guidelines or recommendations are provided to dental health care providers' to help standardize and unify the oral health education process and brief dental interventions in 48% of the respondent countries. (3) Uniformity is obtained on a national level regarding the caries prevention programs and their implementation in 44% of the respondent countries. (4) The application of caries risk assessment methods is available in 41% of respondent countries. (5) To ensure the quality of caries preventive services, monitoring system is available in 37% of the respondent countries.

IG analysis showed the greatest different between the groups of low and moderate-high DMFT scores in the availability of monitoring systems (0.29).

4.3.3. Data collection characteristics

We analysed the features of the data report process during the children's publicly provided dental screening. We focused on 19 features, shown in Table 5, to obtain information on the recorded data. These examined features include personal medical history, full dental status and also caries risk factors, early signs of caries (e.g. white spots) and overall dental hygiene. We got replies from 25 EU member states.

The major results are show below, presenting the name of the indicator and the percentage of the responding countries marked the feature as 'available': the complete dental status is usually recorded in 92% of respondent countries, medical history is recorded in 68% of respondent

countries, oral hygiene record and cavitated ECC is registered in 56% of the respondent countries.

We found that the following indicators are less likely to be recorded: noncavitated ECC (recorded in 48% of respondent countries), white spots are recorded in 32% of respondent countries and microbiological risk factors are the least likely recorded, with 8%.

IG analysis: The greatest difference (0.24) shown in the record of fluoride usage, cavitated ECC, newly developed caries, and oral hygiene information.

Table 5. Data registration characteristics during oral health screening in the member states of the European Union

Function	Indicator/Data type	Countries[1] and DMFT prevalence groups																										
		Very low (<1.2)								Low (1.2-2.6)												Moderate (2.7-4.4) and high (4.4<)						
		DK	DE	UK	SE	FI	NL	BE	ES	FR	IT	PT	CY	AT	MT	IE	SI	EL	LT	CZ	HU	EE	RO	PL	BG	LV	HR	SK
Data recorded during the oral health screening process	Mandatory data report required on screening	*		*	*	*			*			*	*						*	*		*	*				*	*
	Complete Dental Status	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	X	*	*	*	*	*		*	X	*	*
	D – Decayed teeth	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	X	*	*	*	*	*		*	X	*	*
	F – Filled teeth	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	X	*	*	*	*	*		*	X	*	*
	M – Missing teeth	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	X	*	*	*	*	*		*	X	*	
	Medical History (Anamnesis)		*	*	*	*	*	*	*			*	*		*	*	*	X	*	*		*			*	X	*	
	Children with Disabilities		*	*	*	*	*		*		*		*		*	*	*	X			*	*			*	X	*	*
	DMF/dmf rate – newly developed caries	*	*		*	*	*	*	*	*	*		*		*			X	*	*		*			*	X		
	Untreated Decayed Teeth[2]	*	*	*	*	*	*		*			*	*		*	*		X			*		*		*	X	*	
	Oral Hygiene Record (plaque)	*	*	*	*	*	*	*					*		*	*	*	X		*			*		*	X		
	Early Childhood Caries - cavitated	*	*	*	*	*	*	*					*		*	*	*	X		*			*		*	X		
	Use of Fluoride		*	*	*	*	*	*	*				*		*		*	X		*	*				*	X	*	
	Record of Referral[3]		*	*	*	*	*		*			*			*	*		X			*	*			*	X	*	*
	Dietary Factors[4]			*	*	*	*	*	*				*		*		*	X		*		*			*	X	*	
	Early Childhood Caries – noncavitated	*	*	*	*	*	*					*	*		*			X			*				*	X	*	
	White Spots		*	*	*	*	*						*		*			X							*	X		
	Sociodemographic or Geographic Markers[5]		*		*		*	*	*				*					X							*	X		
	Salivary Flow			*			*											X							*	X		
	Microbiological Risk Factors (Streptococcus mutans)						*											X							*	X		

[1] Countries indicated by 2-letter country codes, grouped by DMFT scores. *Source of DMFT data and classification: CAPP database, Oral Health Country/Area Profile Project. https://capp.mau.se/dental-caries/ Accessed: July 1, 2020*

[2] e.g. if previously detected decayed tooth remains untreated

[3] for special needs, special dental treatments

[4] feeding practices, dietary habits, frequency of sugary drink, food consumption

[5] e.g. hard-to-reach population, children whose families live in a deprived area

Our dataset represents 25 respondent countries (Latvia and Greece did not respond for recorded data). Countries are presented by their most recent DMFT score, from left to right: very low, low, moderate and high DMFT. Asterisk indicates a specific data is recorded in school children, preschool children or both, fields marked with 'X' indicates no response received or response was excluded due to contradictory responses and not included in the analysis. Poland and Austria responded 'no data', they also responded that 'there is no mandatory data report' required by a national body. All our data represents service availability for children through the public dental health provider. We did not include any form of private dental service in our research.

EU 2-letter country codes: AT-Austria, BE-Belgium, BG-Bulgaria, CY-Cyprus, CZ-Czechia, DE-Germany, DK-Denmark, EE-Estonia, EL-Greece, ES-Spain, FI-Finland, FR-France, HR-Croatia, HU-Hungary, IE-Ireland, IT-Italy, LT-Lithuania, LV-Latvia, MT-Malta, NL- Netherlands, PL-Poland, PT-Portugal, RO-Romania, SE-Sweden, SI-Slovenia, SK-Slovakia, UK-United Kingdom.

Source: https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Country_codes

4.3.4. Reimbursement features

We also aimed to analyse the estimated reimbursement for the provided dental services for children. We created two treatment groups to discover the financial burden and also the likelihood of reimbursing the given preventive and operative treatments.

Preventive treatment aim to prevent caries development, while operative treatments used to treat already developed diseases, such as caries, pulp treatment and tooth extraction. We included such treatments provided for both primary teeth and permanent teeth.

The following treatments are available free-of charge in the marked rates of the responding 27 countries:

- topical fluoride varnish (preventive): 70%
- fissure sealants (preventive): 74%
- dental hygiene treatment (preventive): 82%
- permanent tooth filling (operative): 93%
- tooth extraction (operative): 93%
- primary tooth filling (operative): 85%

We used a scoring method to estimate and compare the reimbursement of the treatments in the 2 groups. We could collect data from 15 countries for this question.

The results are presented on Figure 6, and the scores were available from 0 to 5, with 0- not reimbursed and 5- highest value reimbursement. The estimated reimbursement value of operative treatments are higher than the preventive treatments'. Most of these operative treatments also available for children with no charge (e.g. fillings, extractions), but preventive treatments are not as accessible free-of-charge for children, not always part of the routine public dental health care.

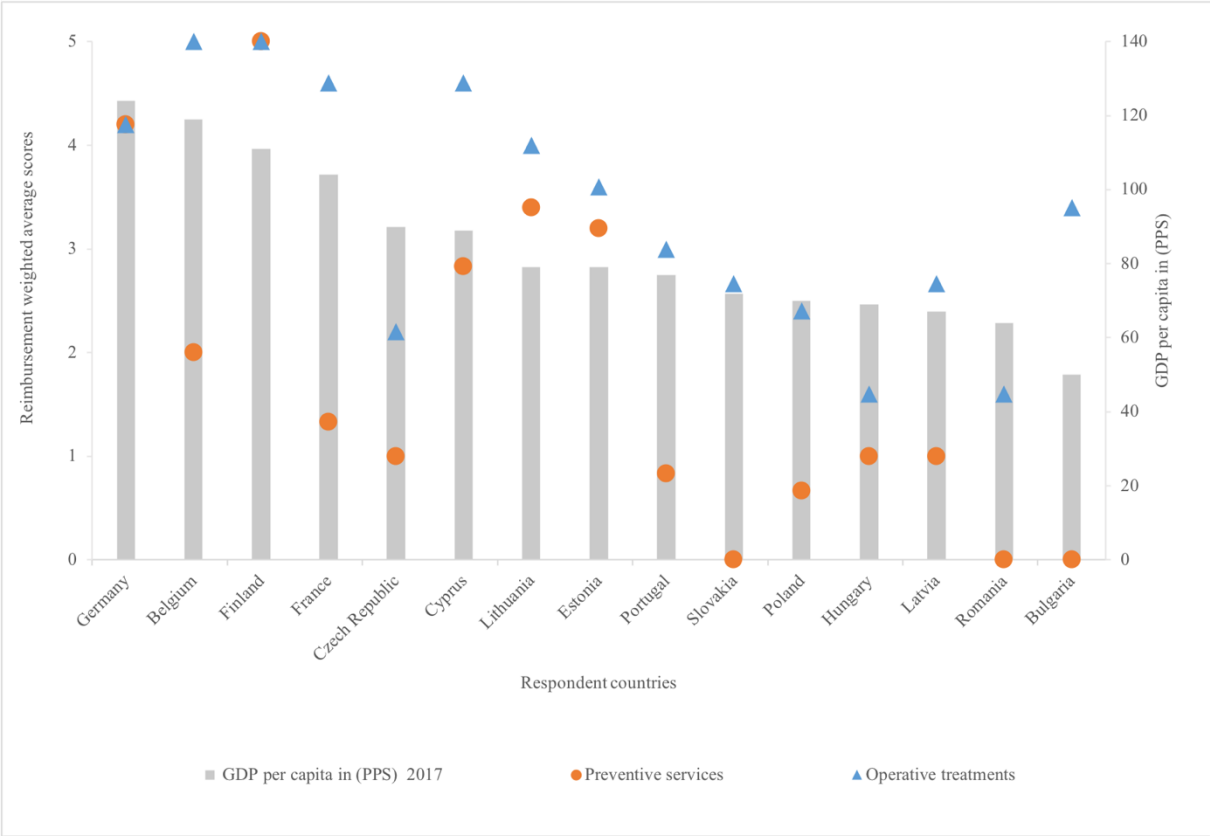

Figure 6. Reimbursement tendency estimation with scores of preventive and operative interventions

Figure 6 horizontal axis represents the respondent countries, ranked from highest GDP (PPS) to lowest, from left to right. Right side vertical axis: GDP (PPS) per capita (represented by grey columns). Left side vertical axis: represents the reimbursement weighted average scores for preventive and operative treatment categories (preventive – orange spot or operative – blue triangle).

Preventive services: fissure sealing, topical fluoride varnish, dental hygiene treatment, oral health education, oral health screening and preventive orthodontic treatment for children (e.g. space maintainer)

Operative treatments: primary tooth filling, permanent tooth filling, tooth extraction, primary tooth pulp therapy and permanent tooth root canal treatment

The scores applied from 0-5, where 0 represents the lowest interest and smaller amount provided to reimburse the category, and 5 means the highest interest and higher amount provided to reimburse the category

Source of GDP per capita in (PPS) data: EUROSTAT database

https://ec.europa.eu/eurostat/tgm/table.do?tab=table&plugin=1&language=en&pcode=tec00114

5. Discussion

In the PhD thesis, I investigated three areas: caries-related inventions, the burden of childhood caries in EU Member States and their prevention and treatment strategies to tackle the disease. In all three areas, a wide variation between Member States could be detected, with a general trend that prevention is not the focal point. The results are further detailed and discussed below.

Innovation and novel technologies (such as antimicrobial peptides, probiotics) would be very important in tackling the caries disease, since the burden what caries represents is huge, not only for the families and children but also for the healthcare systems [125]. The practical effectiveness of these novel technologies (such as remineralization agents) regarding caries prevention and treatment, were already examined and confirmed by Chen and Wang [126]. The 3D printing and different printing techniques were also great inventions, which are now widely used and accepted in the clinical dentistry [127], almost 30 years after their introduction.

Although the innovations are relatively new (only 20% have expired by 2018), the overall number of patent families (61) regarding children's dental health is very low. Especially considering, that for dental implants there are over 23000 patents (FamPat), and most of them is very recent. Most of the examined patents focused on prevention, which group includes the caries preventive innovations and also preventive orthodontic inventions. This finding is important, as orthodontic preventative treatments at an early age can help achieve the normal occlusion [128] which can contribute to preventing caries development and also have an impact on the improvement of oral health related quality of life [129] for children.

Regarding the leading participants of the patent landscape, China dominates the caries prevention and treatment sectors of the patents we analysed, having 8 of the overall 15 top assignees in those areas. The European region represents an insignificant role in all three areas:

prevention, diagnosis or treatment, as it only owns 4 co-assigned patents over the examined long period of time. With such low number of patents, it was not possible to further analyse the European patenting activity and discover the field of European innovations, but it is an important finding as this can reflect the trends in research and development. This result can also suggest that the area of childhood caries is considered low-priority for both the academic research and corporate players in Europe.

Great differences are observed in the patenting activity among the countries and many factors can impact this difference, e.g. the area and focus of research and development projects or the number of large companies in the country, but the quality of the inventions or the scope and range of these patents (only domestic or international) also have a remarkable impact, as financial stimulation can accelerate the production of high quality patents. The patenting laws also show variety in the countries [130], thus making international assessment challenging. This is especially significant in case of low quality patents and could explain why the number of patents filed domestically are so high [131].

While the number of patent applications are increasing, the different medical fields do not share equal parts on these applications. The childhood caries management and primary teeth might represent only a small portion of the market, but public policies, taxes or price-control on certain products might represent a challenging environment for new inventions [132]. We can speculate that such barriers present on both the supply and demand side, e.g. compulsory ethical license for research, while childhood caries is more frequent in the vulnerable population [133]. Furthermore, primary teeth caries might be considered as “temporary”- however, this disease might have a huge impact on the children’s oral health related quality of life and also on the caries experience of permanent teeth [134] and general health [8] [10]. ECC prevention is also the most efficient if it happens before the child turns 2 years-old [135].

We found that the burden of caries in primary teeth among under 5-year-olds is increasing and this finding also confirms the need for effective prevention programs for children. During the longitudinal analysis of ECC burden over time, the inequalities were observed between Eastern and Western European countries. In eastern Europe, the estimated burden was constantly higher than the western states. This finding reflects previous results, where ECC was found to be more frequent in the eastern countries of Europe, and less frequent in countries with more developed economy [99]. According to the WHO, 80% of 5-6 year-old children should be caries-free by 2020. This goal has not been met by most of the EU countries and eastern European countries are even farther from this milestone [99].

Inequality also present within the EU countries and socioeconomic factors are good indicators to identify the disparities. Regarding the examined socioeconomic caries risk factors, we found moderate association with the early childhood caries, and the result is the same for sugar consumption. People with lower socioeconomic status are more vulnerable. The disease burden estimation might not be correct for these vulnerable groups within countries, as the average can mask the disparities. One of these vulnerable groups is the immigrants and involuntary immigrants. The accessibility of certain services or risk of diseases can be different for these groups, even if their healthcare needs are quite similar to the average population, according to a German study [136]. The disease burden of childhood caries of primary teeth were higher in Germany in 2015 and in Sweden in 2005, 2006 and 2017. This spike in these countries could be explained by the increased numbers of involuntary immigrants. The nationality of the mothers can also affect the ECC experience according to an Italian study [137]. For younger children, the immigrant status could have an even greater impact on their health, since they have less access to certain services, dental screenings, preventive interventions or check-ups [138].

Our results show, that there is a correlation between higher GDP, degree of urbanization and lower ECC rate, which means that in economically developed countries the ECC rate will decrease. Thus, the reduction of inequality between rural and urbanized areas and higher GDP may contribute to the reduction of YLDs rate as well. There was also a phenomenon after the 2008 economic crisis: after the crisis, most European countries achieved or even increased their pre-2008 GDP level by 2013. However, in Southern Europe the situation was different, and the economic growth was not so successful as in other parts of the EU [139]. This inequality also represented by the YLDs rate for primary teeth caries of under 5-year-olds, as there is no observed equality on European level during or after the financial crisis. Western European countries have stronger economy and more funds provided for public healthcare services and preventive interventions [96]: this is in line with our findings, since Western countries showed lower YLDs rates than the Eastern countries. Risk of poverty was not a strong indicator for the YLDs rate, since we did not find correlation between these factors. The reason behind this observation could be the inequal share for the vulnerable groups regarding healthcare or other benefits within the country and also certain preventive or interventional dental services usually provided free-of-charge through the public healthcare system for children [118]. The at risk of poverty indicator focuses on income level, however, other factors, such as the availability of healthcare services, free-of-charge dental services provided for children, healthcare funding allocation, education level of the mother or caregiver, socio-economic and demographic factors may modify the association. Further studies would be necessary to examine the complex relationship [28,140–142]. GDP appeared to be a more representative indicator in our study and both urbanization and GDP level are important factors in connection with the health of the countries' population [143].

Higher sugar intake and growth in ECC rate is widely studied and confirmed [144]. The IAPD Declaration defined four key areas tackle ECC disease and the need to limit sugar-consumption

for children are emphasized in this declaration. Another important message of this declaration, that ECC inequalities should be further studied to help develop successful prevention strategies [92]. Assessing the sugar consumption's correlation with the income level, this association was the strongest in case of MICs [144]. With multivariate analysis, it was observed that the sugar intake on the population level was correlated with the increased rate of YLDs. Study of European countries also shown, that children and adolescents usually consume more sugar and sweeteners than the internationally recommended maximum amount [145]. Other review observed a similar trend: children's sugar intake tend to be higher than adults' [146] and SES and other socioeconomic factors play an important role in elevated sugar consumption. There is a complex relationship between socioeconomic indicators (including level of education) and the experience of caries and ECC. Regarding sugar intake, a dose-response connection with ECC was already confirmed and it also contributes to the higher caries disease burden [144,147]. This observation is especially prominent in Europe's less developed economies [148]. The mother's level of education is another important factor. Children of mothers with lower level of education are more prone to consume a poor diet, have a higher sugar intake or less likely engage in positive health behavior, such as attend regular dental check-ups or treatments at the dentist [11,149–152]. However, regular check-ups and dental screening would be especially important, as the available preventive measures' effect might not able to tackle the consequences caused by high sugar intake [144].

Another GBD study revealed, that it would be beneficial to include dental services into the universal healthcare service [153], as effective prevention is essential to reduce the disease burden of caries. Healthcare and prevention strategies are mainly regulated on a country level in the EU. To implement successful prevention programs, it would essential to discover the complex relation between socioeconomic factors and disease burden, and more research needed to identify key areas of action to reach vulnerable population.

Although the dentist's role is inevitable in tackling the disease, from advocacy to dental screening or explaining good dietary habits and making an impact on the health outcomes of the vulnerable population as well [27], the pediatric primary healthcare providers could also have an important role. They can teach right feeding practices, contributing to the prevention of caries disease and working together with the dental team [154], or they can notice and diagnose the caries in children, including those at an early age, and can provide parents with a dentist referral for further screening and treatment [155].

Focusing on early detection of caries, oral health education for children and parents and gathering information about caries risk indicators and preventive services should be an important part of preventive programs. However, collecting EU data on preventive dental services and comparing them is challenging. The number of indicators are limited [11] and the standardization of the data also represents a limitation: it would be necessary for international analysis, but these processes may not be widely applied [97]. Good practices are also identified [11], but their implementation in the different preventive strategies and services show a large variety within the EU. Accessibility and sustainability of healthcare services are also a challenge [156], especially regarding caries prevention for children under 18 years of age. Although the public health service provides dental treatments or interventions for children free-of-charge, these services and their reimbursement is different among EU member states.

Regarding the screening process, we found that the school dental screening is available in 39% of the responding 23 countries. Dental screening and education about oral health represent the base of dental caries prevention [157], although the school dental screening itself is sometimes criticized [158] for not being standardized. Pre-school dental screening, however, is considered crucial in preventing severe consequences of ECC [6]. This is in line with our findings, since the availability of organized dental screening for pre-school children was associated with a great difference in IG between countries with low vs- moderate-high DMFT score. Although

DMFT is not an indicator of primary teeth, higher caries experience in early childhood might predict increased caries risk among the permanent dentition [159]. Unfortunately, among the 26 respondent countries, 31% marked that pre-school screening is provided.

Accessibility to proper oral health education and knowing the right dietary habits can also reduce the caries risk, and its necessity (especially on sugar intake) is emphasized by the WHO [100]. Providing some type of education for children about dental prevention is also observable in over 90% of the respondent countries, although clinical prevention might have a greater impact on the caries experience [157].

Established and implemented standards for screening and preventive procedures would be important to provide consistency and may contribute to higher screening quality [97]. Standardization of caries preventive services, monitoring systems and recorded indicators are still not achieved [18] [97] among EU member states. Our findings support this: only 13 of the respondent countries marked that national guidelines are available for the screening process, data collection, or even oral health education. Furthermore, EU countries with higher DMFT scores are usually less likely to have monitoring systems implemented for the screening procedure or less likely provide specific guidelines for the preventive and educational services. Overall, monitoring is only available in 37% of the respondent countries (27) and this can contribute to lower quality of reported data.

Data registration is necessary for proper monitoring of processes and develop efficient public health policies and preventive strategies. The EU member states with lower DMFT scores usually perform better at data record, they record oral hygiene index or white spots (initial caries) more often than countries with higher DMFT scores. Although DMFT data usually part of the register, the early signs of caries, such as ‘white spots’ are less likely recorded. However, early detection of caries, especially initial caries, which is reversible, has a very important role in preventing caries progression [9]. Furthermore, even cavitated ECC is not widely recorded:

among the 25 responding countries 56% marked that this indicators is collected. Knowing data about these indicators also help assessing caries risk. Risk assessment and CRA models can have an important role in the caries management processes, and prevention of ECC [6] [160]. Children in the higher caries risk group might have different needs than those in a lower risk group [161], and this should be reflected in the provided care path. The risk assessment is used in 52% of the 27 responding countries. Important indicators for the children under 6 years old, such as dietary patterns or oral hygiene index, sociodemographic characteristics are emphasized [72], but less likely recorded thus making the caries risk assessment challenging.

The accessibility of children's clinical dental preventive services also differ within the EU. Regarding the financial characteristics of provision of dental services, we found that treatments for the developed diseases are usually in a higher price-range, compared to preventive interventions. However, these operative treatments are mainly provided for children at no cost, while preventive services are in a lower price-range, but less likely provided free-of-charge. Prevention would be crucial, as these services are cost effective [11]: early detection and treatment are both reduce costs and suffering [6], and according to the literature, they proved to be evidence-based interventions regarding dental caries prevention [162,163]. Dental services provided for children are mainly aiming to treat the developed caries [162] and provide operative treatments, while the preventive treatments would be beneficial for successful caries management [164]. The different healthcare systems determine the reimbursement and the capitation payments can also have an effect on the provision of dental services and treatments [165].

There is an observable gap between the identified good practices, guideline recommendations and the actual implementation of preventive services. There is a lack of data regarding the efficiency of preventive efforts, with no standardized indicators and proper monitoring systems. These would be crucial for effective public health policies and successful caries management

strategies [166]. Our study aimed to provide data on the current situation of preventive services for children in the EU, since the EU plays a unique role (CED White paper) [94] in providing a platform for effective networking between countries to facilitate chronic disease prevention e.g. by supporting database development [95].

Among the limitations of our patent analysis, we understand that although patent analysis is available to assess available patents, the clinical usefulness or market success cannot be evaluated through patent landscape analysis, all globally granted patents might not be included, as they might not covered by secondary data and not all inventions are granted.

In our ecological study the time-period (2014-2017) available for analysis was limited due to lack of data, and there were challenges to examine the socioeconomic factors in relation to ECC, as their combined effect is complicated, and the national data might mask social differences within countries. ECC is applicable for children under 6 years old, while we could only select the 'under 5' age group for analysis from the database. The data collection procedure can also be different for the countries, and key data might not be available for analysis, e.g. reimbursement or expenditure of dental preventive services, although in the EU, dental treatments are available for children free-of-charge [11], Data on the educational background of the parents and especially the mother of the child [13] was also limited, the nationality of the children's mothers are not available [137], and there is lack of information on certain vulnerable groups' access to public dental services statewide [167]. As a beneficial effect, the fluoride usage or exposure is also not recorded on a regular basis [168],

Data collection on caries preventive services was challenging for our cross-sectional study (limited number of professional organizations to reach out to, local regulations on data availability) and the provided responses might only be relevant locally, not for the whole country. The validity of responses cannot be evaluated and some answers needed to be excluded

for incomplete datasets. Questions of the survey might not be applicable in all of the EU countries, and data on reimbursement was highly limited. We also did not include private dental treatments, only collected data on publicly financed services.

5.1 Main findings and implications of the project

Innovations would have a crucial role in the caries management process, in all prevention, diagnosis and treatment areas for children. Through the patent landscape analysis, our findings showed that given the very few patent families (61) over the examined 87 years, the research field of 'caries in the primary dentition' is neglected, and also majority (54%) of the examined patents were 'Dead'. The most neglected area was the 'diagnosis', regarding children's dental caries. The role of the EU in this field of innovation was quite small and a low research interest might be speculated.

However, the burden of dental caries for children under 5-years old (ECC among under 5 year old) is detectable in Europe and shows a divided EU, both for the year of 2019 and through longitudinal analysis: there are considerable differences between Eastern and Western European countries, since Eastern European countries have constantly higher YLDs rates.

Limited international data are available for the risk factors of ECC. Analysing the available data, we observed that the sugar consumption is increasing, and so does the YLDs rate among under 5-year-olds and we could confirm with multivariate model that these were significantly associated. We also found through univariate model, that higher GDP was associated with lower YLDs rate. SES and socioeconomic factors impact the burden of ECC, but both local and international initiatives would be necessary to identify and protect the vulnerable groups of population and effectively target them with future policy actions. Further studies also necessary to untie the complex causative relation between the examined factors and ECC.

Children's dental screening could provide crucial data on the current caries prevention strategies, however only one indicator is in use (DMFT score) and this is not uniformly recorded, making the international assessment challenging. We found that the screening process shows large variety among EU states, both regarding screening frequency and screened age-

groups. Although main guidelines exists, their interpretation is different in the countries. Pre-school children's screening is widely supported by professional organizations and we found that it represents one of the differences between countries with low and moderate-high DMFT score, yet our data show it is only provided in 30% of the respondent countries. Basic education on oral health is usually provided for children, but clinical preventive services are not necessarily available for children free-of-charge, even though they are cost-effective. Meanwhile, treatments of already developed caries are in a higher price-range, still more likely provided free-of-charge. Since the focus is mainly on treatment of disease, rather than comprehensive prevention programs, relevant indicators could help evaluate current practice and strategies. The dental screening process and preventive services could be improved with reliable, internationally available indicators and monitoring systems. A universal, standardized dental care package, involving effective oral health education on caries prevention, the expansion of provided free-of-charge dental services for children and monitored screening and data report could also help reducing inequality within and between countries.

6. Summary

Caries and childhood caries represents a major burden worldwide. Although caries is largely preventable, European countries, especially Eastern European countries are struggling to curb the disease, lowering its burden on the quality of life and reducing its economic impact. However, there are international recommendations available and good practices identified, national prevention programs are still not effective enough. The main caries risk factors are known, however, the complex causal relationship between diet, socioeconomic background and educational level is the member states is hardly studied yet.

The project had 3 objectives: 1) to analyze the innovation trends in the area of 'childhood caries' by performing a patent analysis, 2) to analyze the burden of ECC for children under 5-year old, focusing on both recent years and trends over a longer period of time. The correlation between the ECC burden and environmental factors and sugar consumption were also analysed through an ecological study, and 3) to reveal caries management practice and prevention policies for children in the EU member states, with an online survey involving caries expert from the EU countries and reporting the results in accordance with STROBE guidelines.

Although innovations in the area of primary tooth caries are relatively new and most of the analysed innovations fell into the 'preventive' category, the overall patent families are considered very low. The European region does not represent a significant role, which can reflect the research and development trends: this area of research might be low-priority for both academic and corporate players. ECC prevention is the most effective when happens before the age of 2. Preventive approaches would be especially important, since the burden of caries in primary teeth among the 'under 5' age group is increasing according to our longitudinal analysis. The WHO set the target, that by 2020 80% of children aged 5-6 should be caries-free, but this goal has not been met by most of the EU. EU countries are divided regarding burden

of disease: Eastern EU countries are more prone to a constantly higher burden than the Western EU countries, this is in line with the previous literature: ECC is less frequent in more developed economies. Inequalities present within the EU and analyzing SES and socioeconomic factors showed the disparities. A correlation was found between higher GDP and lower ECC rate, thus higher GDP can contribute to lower burden of disease, and Western EU countries also showed lower YLDs rate. High sugar intake and ECC experience is widely studied and confirmed. Our multivariate model also showed that sugar intake on a population level correlated with increased YLDs rate for dental caries in children under 5. Socioeconomic factors play an important role in elevated sugar consumption and the mother's level of education is also important: lower level of education contributes to poor diet choices for children and higher sugar intake. The relationship between ECC and socioeconomic factors are very complex and should be further studied. Selecting and recording the caries risk indicators and including socioeconomic indicators in such databases would make the national and international comparison of caries preventive efforts less challenging. This need was also emphasized by the CED. Our cross-sectional study revealed that although there are good practices for caries prevention and screening available, these are not necessarily part of the everyday practice or not standardized, even on a national level. Pre-school screening is considered crucial in preventing serious complications of ECC and our finding confirmed this: the availability of organized pre-school dental screening for children was a difference between countries with low and high DMFT score, and was only provided in 31% of the respondent 26 countries. The availability of monitoring system for the screenings' quality assurance shows a similar correlation. The WHO emphasized that knowing the right dietary habits can reduce caries risk. However, during data record, indicator of dietary patterns is less likely recorded, and socioeconomic factors also not widely recorded. Although the FDI and IAPD recommended, risk assessment is only used in 52% of countries, which can have a negative impact on the decision making process, as children

with higher caries risk might need a different care path. Preventive dental services usually cost effective, early detection can prevent high costs and suffering. Upon analyzing the reimbursement characteristic, we found that the preventive services are less likely to be reimbursed or reimbursed with a lower price, while operative treatment of the developed disease usually provided free-of-charge and is reimbursed in a higher price-range. Minimal invasive treatments should be preferred as per the IAPD: with successful prevention, surgical interventions can be avoided. Although the differences in healthcare systems determine the reimbursement and provision of treatments, policies focusing on dental caries prevention should be considered, especially that preventive methods are cost-effective.

In conclusion, there are no significant differences in health values between the member countries, e.g. the importance of tooth brushing is known in all countries, they could learn a lot from each other in terms of cost-effective caries prevention programs. Furthermore, it is important that the EU itself, e.g. through its health strategy, could take actions and give priority to this childhood chronic disease in order to ensure effective caries prevention.

Összefoglalás

A káriesz és a gyermekkori káriesz jelentős probléma világszerte. Bár a káriesz megelőzhető betegség, az európai országok, különösen a kelet-európai országok nehezen tudják megfékezni a fogszuvasodást és csökkenteni az általa képviselt egészségügyi terhet. A fogszuvasodás rontja az emberek életminőségét, illetve a betegségteher pénzügyi vonatkozásai is jelentősek. Nemzetközi ajánlások elérhetőek a megelőzéssel kapcsolatban, illetve a jó gyakorlatokat is azonosították már, a nemzeti betegségmegelőző programok mégsem hatékonyak eléggé. Bár a káriesz főbb rizikófaktorai ismertek, a teljes oki kapcsolatokat még nem tárták fel a táplálkozás, szociális háttér, az iskolai végzettség, valamint a fogszuvasodás megjelenése között.

A kutatásnak 3 fő célja volt: 1) a gyermekkori kárieszre vonatkozó innovációs trendek elemzése, szabadalom-analízis segítségével, 2) 5 éven aluli gyermekek kárieszre vonatkozó betegségterhének elemzése, mind az elmúlt évekre vonatkozóan, mind a hosszútávú trendek alapján. A kora gyermekkori káriesz betegségterhét szintén összevetettük bizonyos környezeti tényezőkkel és cukorfogyasztással is a vizsgálatunk során, 3) az Európai Unió (EU) tagállamainak káriesz prevenciós és menedzselési gyakorlatát és prevenciós politikáit tanulmányoztam egy online kérdőív segítségével, melynek kitöltésére szakértőket kértem fel az EU tagállamaiból. Az eredmények a STROBE irányelveknek megfelelően kerülnek bemutatásra.

A tejfogak szuvasodásával kapcsolatos innovációk aránylag újkeletűek és a vizsgált újdonságok nagy része a prevenció területéhez tartozik, a szabadalom családok száma azonban nagyon alacsonynak számít. Az európai régiónak nincsen jelentős szerepe, és ez a megfigyelés tükrözi a kutatási és fejlesztési trendeket: ez a kutatási terület feltehetően alacsony prioritású mind az akadémia, mind a vállalatok számára. A kora gyermekkori káriesz (Early Childhood Caries - ECC) megelőzése akkor a leghatékonyabb, ha már 2 éves kor előtt megkezdődik. A megelőző

intézkedések különösen fontosak lennének, hiszen a tejfog szuvasodás betegségterhe folyamatosan nő az 5 éves kor alatti korosztályban vizsgálataink alapján. A WHO azt tűzte ki céljául, hogy 2020-ra az 5-6 éves gyermekek 80%-a káriesz mentes legyen, de ezt a eredményt a legtöbb EU-s országnak nem sikerült elérnie. Az EU tagállamai két részre oszlanak a betegségteher tekintetében: a kelet-európai országokban folyamatosan magasabb a betegségteher a nyugat-európaihoz viszonyítva és ez összhangban áll a korábbi szakirodalmi megfigyelésekkel, miszerint az ECC kevésbé gyakori a fejlettebb gazdasági háttérrel rendelkező országokban. Az egyenlőtlenségek megfigyelhetőek az EU-n belül, a társadalmi-gazdasági tényezők is ezt tükrözik. A magasabb bruttó hazai össztermék (GDP - Gross Domestic Product) és alacsonyabb ECC arány között összefüggést találtunk, így a magasabb GDP hozzájárulhat az alacsonyabb betegségteherhez is, ennek megfelelően a nyugat-európai országok között valóban alacsonyabb volt a YLDs (Years lived with disability) ráta is.

A magas cukorfogyasztás és az ECC kialakulása közötti összefüggéseket már széles körben tanulmányozták és igazolták. A többváltozós modellünk szintén kimutatta, hogy a cukorfogyasztás népességi szinten korrelált a ECC-re vonatkozó magasabb YLDs rátával az 5 éven aluli korcsoportban.

A társadalmi-gazdasági tényezők fontos szerepet játszanak a megnövekedett szénhidrát-fogyasztásban és az anya iskolázottsági szintje szintén fontos: alacsonyabb iskolázottság hozzájárul a gyermekek kedvezőtlen étrendjéhez és a magasabb cukorfogyasztáshoz.

Ezek alapján az ECC előfordulása és a társadalmi-gazdasági tényezők kapcsolata igencsak összetett és további vizsgálatokat igényelne. A megfelelő káriesz rizikó mutatók kiválasztása és az erre vonatkozó adatok rendszeres rögzítése, kiegészítve a társadalmi-gazdasági mutatók nyilvántartásával egy adatbázisban lehetővé tenné a nemzeti és nemzetközi összehasonlításokat a megelőző tevékenységek hatékonyságára vonatkozóan. Az erre való igényt már a CED is megfogalmazta. A keresztmetszeti vizsgálatunk alapján azt láthatjuk, hogy bár vannak jó

gyakorlatok a káriesz prevencióra és szűrésre vonatkozóan, ezek nem szükségszerűen képezik a mindennapi gyakorlat részét és nem szabványok alapján történnek, akár még nemzeti szinten sem. A 6 éven aluliak fogászati szűrése kritikus lenne az ECC komolyabb szövődményeinek megelőzéséhez és ezt vizsgálatunk is alátámasztotta: az óvodáskorúak számára biztosított, szervezett fogászati szűrés egy jelentős különbség volt az alacsonyabb és magasabb DMFT-vel rendelkező országok között, és a 26 válaszadó ország közül mindössze 31%-ban van jelen szervezett módon. A minőségbiztosítást célzó, fogászati szűréseket ellenőrző monitoring hasonló korrelációt mutatott.

A WHO is kiemelte, hogy a helyes táplálkozási szokások ismerete csökkentheti a káriesz rizikót. Azonban a fogászati szűrések adatrögzítése során az étkezési mintázatok mutatóit ritkán rögzítik, hasonlóan a társadalmi-gazdasági mutatókhoz.

Habár az FDI és az IAPD nemzetközi fogászati szervezetek javasolják a káriesz rizikóbecslést, ez csak az országok 52%-ban használatos rutinszerűen, és ez nehezítheti a döntéshozatali folyamatokat, pedig a magas káriesz kockázati csoportba tartozó gyermekek másfajta gondozást igényelnek, mint alacsony káriesz-rizikójú társaik.

A megelőző fogászati kezelések rendszerint költséghatékonyak, és a káriesz korai észlelésével elkerülhetők a drága fogászati kezelések és a fájdalom. A támogatási tulajdonságok vizsgálata során azt találtuk, hogy a megelőző kezelések kevésbé támogatottak, vagy alacsony összegű támogatást kapnak, míg a kifejlődött betegség kezelésére irányuló fogászati beavatkozások általában ingyenesen biztosítottak, magasabb összegű támogatás mellett.

Az IAPD szerint szintén a minimál invazív kezeléseket kellene előnyben részesíteni: sikeres megelőzés esetén a fogsebészeti beavatkozások elkerülhetőek.

Bár a különböző egészségügyi rendszerek eltérően támogatják és biztosítják a fogászati kezeléseket, a káriesz prevencióra irányuló szabályozások fontosak lennének, különös tekintettel arra, hogy ezen megelőző tevékenységek egyben költséghatékonyak is.

Összességében elmondható, hogy nincsen jelentősebb különbség az alapvető, megelőzést célzó törekvések között az EU-ban, például a helyes fogmosás ismerete minden tagállamban kiemelkedő fontosságú, mégis, a költséghatékony káriesz megelőzési stratégiák tekintetében hasznos lenne egy közös platform, valamint a közös adatgyűjtés további kutatásokhoz és hosszútávú megfigyelésekhez.

7. References

1. Institute for Health Metrics and Evaluation. IHME: Frequently Asked Questions [Internet]. Institute for Health Metrics and Evaluation; [cited 2022 Jan 13]. Available from: https://www.healthdata.org/gbd/faq#What%20is%20a%20YLD?

2. U.S. Department of Health and Human Services. Oral Health in America: A Report of the Surgeon General [Internet]. Rockville, MD: U.S. Department of Health and Human Services, National Institute of Dental and Craniofacial Research: National Institutes of Health; 2000. Available from: https://www.nidcr.nih.gov/sites/default/files/2017-10/hck1ocv.%40www.surgeon.fullrpt.pdf

3. FDI. Caries Prevention Partnership Advocacy Toolkit [Internet]. World Dental Federation; 2016 [cited 2022 Jan 12]. Available from: https://www.fdiworlddental.org/sites/default/files/2020-11/2016-fdi_cpp-advocacy_toolkit.pdf

4. Drury TF, Horowitz AM, Ismail AI, Maertens MP, Rozier RG, Selwitz RH. Diagnosing and Reporting Early Childhood Caries for Research Purposes: A Report of a Workshop Sponsored by the National Institute of Dental and Craniofacial Research, the Health Resources and Services Administration, and the Health Care Financing Administration. J Public Health Dent. 1999 Sep;59(3):192–7.

5. Hajishengallis E, Forrest CB, Koo H. Early Childhood Caries: Future Perspectives in Risk Assessment. JDR Clin Transl Res. 2016 Jul;1(2):110–1.

6. World Health Organization. WHO Expert Consultation on Public Health Intervention against Early Childhood Caries [Internet]. Thailand; 2016 [cited 2022 Mar 19] p. 1–37. Available from: https://www.who.int/publications/i/item/who-expert-consultation-on-public-health-intervention-against-early-childhood-caries

7. O'Sullivan DM, Tinanoff N. The Association of Early Dental Caries Patterns with Caries Incidence in Preschool Children. J Public Health Dent. 1996 Mar;56(2):81–3.

8. Casamassimo PS, Thikkurissy S, Edelstein BL, Maiorini E. Beyond the dmft. J Am Dent Assoc. 2009 Jun;140(6):650–7.

9. FDI World Dental Federation. The Challenge of Oral Disease - a call for global action. The Oral Health Atlas [Internet]. 2nd Edition. Geneva; 2015 [cited 2022 Mar 19]. 63 p. Available from: https://www.fdiworlddental.org/oral-health-atlas

10. SECTION ON ORAL HEALTH. Maintaining and Improving the Oral Health of Young Children. Pediatrics. 2014 Dec;134(6):1224–9.

11. Patel R. The State of Oral Health in Europe [Internet]. Platform for Better Oral Health in Europe; 2012 [cited 2020 Dec 12]. Available from: http://www.oralhealthplatform.eu/our-work/the-state-of-oral-health-in-europe/

12. McLaren L, McIntyre L, Kirkpatrick S. Rose's population strategy of prevention need

not increase social inequalities in health. Int J Epidemiol. 2010 Apr 1;39(2):372–7.

13. National Organization for Rare Disorders (NORD®). ORPHAN DRUGS IN THE UNITED STATES: An Examination of Patents and Orphan Drug Exclusivity [Internet]. National Organization for Rare Disorders; 2021 [cited 2021 Jan 13]. Available from: rarediseases.org

14. European Parliament, Council of the European Union. Regulation (EU) 2021/522 of the European Parliament and of the Council. Official Journal of the European Union. 2021 Mar 26;64:1–29.

15. Bhatia P, Celikkaya B, Khalilia M, Senthivel S. Comprehend Medical: A Named Entity Recognition and Relationship Extraction Web Service. In: 2019 18th IEEE International Conference On Machine Learning And Applications (ICMLA) [Internet]. Boca Raton, FL, USA: IEEE; 2019 [cited 2022 Jan 14]. p. 1844–51. Available from: https://ieeexplore.ieee.org/document/8999113/

16. Jiang F, Jiang Y, Zhi H, Dong Y, Li H, Ma S, et al. Artificial intelligence in healthcare: past, present and future. Stroke Vasc Neurol. 2017 Dec;2(4):230–43.

17. FDI General Assembly. Salivary Diagnostics - Policy Statement [Internet]. World Dental Federation; 2013 [cited 2021 Jun 30]. Available from: https://www.fdiworlddental.org/salivary-diagnostics

18. Patel RN. Variation in methods used to determine national mean DMFT scores for 12-year-old children in European countries. Community Dent Health. 2016;(33):286–91.

19. WHO Collaborating Centre for Education, Training and Research at the Faculty of Odontology, Malmö, Sweden. The WHO Oral Health "Country/Area Profile Programme" CAPP database [Internet]. WHO; [cited 2020 Jul 1]. Available from: https://capp.mau.se/dental-caries/

20. Petersen PE. The World Oral Health Report 2003: Continuous improvement of oral health in the 21st century - The approach of the WHO Global Oral Health Programme. Community Dent Oral Epidemiol. 2003;

21. World Health Organization, WHO, WHO/NMH/NHD/17.12. Sugars and dental caries [Internet]. 2017 [cited 2020 Dec 12]. Available from: https://www.who.int/nutrition/publications/nutrientrequirements/sugars-dental-caries-keyfacts/en/

22. Phantumvanit P, Makino Y, Ogawa H, Rugg-Gunn A, Moynihan P, Petersen PE, et al. WHO Global Consultation on Public Health Intervention against Early Childhood Caries. Community Dent Oral Epidemiol. 2018 Jun;46(3):280–7.

23. Anil S, Anand PS. Early Childhood Caries: Prevalence, Risk Factors, and Prevention. Front Pediatr. 2017 Jul 18;5:157.

24. Douglass JM, Clark MB. Integrating Oral Health Into Overall Health Care to Prevent Early Childhood Caries: Need, Evidence, and Solutions. Pediatr Dent. 2015

Jun;37(3):266–74.

25. Evans RW, Feldens CA, Phantunvanit P. A protocol for early childhood caries diagnosis and risk assessment. Community Dent Oral Epidemiol. 2018 Oct;46(5):518–25.

26. Hallett KB, O'Rourke PK. Early childhood caries and infant feeding practice. Community Dent Health. 2002 Dec;19(4):237–42.

27. Chi DL, Scott JM. Added Sugar and Dental Caries in Children. Dent Clin North Am. 2019 Jan;63(1):17–33.

28. the ECCAG, Folayan MO, El Tantawi M, Aly NM, Al-Batayneh OB, Schroth RJ, et al. Association between early childhood caries and poverty in low and middle income countries. BMC Oral Health. 2020 Dec;20(1):8.

29. Schwendicke F, Thomson WM, Broadbent JM, Stolpe M. Effects of Taxing Sugar-Sweetened Beverages on Caries and Treatment Costs. J Dent Res. 2016 Nov;95(12):1327–32.

30. FDI General Assembly. Oral Health and Quality of Life (Policy Statement) [Internet]. 2015 [cited 2021 Sep 12]. Available from: https://www.fdiworlddental.org/oral-health-and-quality-life

31. WHO. Mean number of Decayed, Missing, and Filled Permanent Teeth (mean DMFT) among the 12-year-old age group [Internet]. World Health Organization; [cited 2022 Jan 13]. Available from: https://www.who.int/data/gho/indicator-metadata-registry/imr-details/3812

32. WHO. Sugars and dental caries [Internet]. World Health Organization; 2017 [cited 2021 Jan 13]. Available from: https://www.who.int/news-room/fact-sheets/detail/sugars-and-dental-caries

33. Motohashi M, Yamada H, Genkai F, Kato H, Imai T, Sato S, et al. Employing dmft score as a risk predictor for caries development in the permanent teeth in Japanese primary school girls. J Oral Sci. 2006;48(4):233–7.

34. Ditmyer M, Dounis G, Mobley C, Schwarz E. Inequalities of caries experience in Nevada youth expressed by DMFT index vs. Significant Caries Index (SiC) over time. BMC Oral Health. 2011 Dec;11(1):12.

35. Bratthall D. Introducing the Significant Caries Index together with a proposal for a new global oral health goal for 12-year-olds. Int Dent J. 2000 Dec;50(6):378–84.

36. Namal N, Sheiham A. Comparison of ranking dental status using the Significant Caries Index and the Significant Filled and Sound-Teeth Index. Community Dent Health. 2008 Jun;25(2):103–6.

37. Namal N, Vehid S, Sheiham A. Ranking countries by dental status using the DMFT and FS-T indices. Int Dent J. 2005 Dec;55(6):373–6.

38. Bourgeois DM, Llodra JC, Nordblad A, Pitts NB. Report of the EGOHID I Project. Selecting a coherent set of indicators for monitoring and evaluating oral health in Europe: criteria, methods and results from the EGOHID I project. Community Dent Health. 2008 Mar;25(1):4–10.

39. American Academy on Pediatric Dentistry Council on Clinical Affairs. Policy on use of a caries-risk assessment tool (CAT) for infants, children, and adolescents. Pediatr Dent. 2008 2009;30(7 Suppl):29–33.

40. American Academy of Pediatric Dentistry. Caries-risk Assessment and Management for Infants, Children, and Adolescents [Internet]. The Reference Manual of Pediatric Dentistry; 2020 [cited 2021 Sep 14]. Available from: https://www.aapd.org/media/Policies_Guidelines/BP_CariesRiskAssessment.pdf

41. Bratthall D, Hansel Petersson G. Cariogram - a multifactorial risk assessment model for a multifactorial disease. Community Dent Oral Epidemiol. 2005 Aug;33(4):256–64.

42. Young DA, Featherstone JDB. Caries management by risk assessment. Community Dent Oral Epidemiol. 2013 Feb;41(1):e53–63.

43. Council of European Dentists. Dental Data Set and Access to Health Records [Internet]. CED; 2019 [cited 2021 Jun 29]. Available from: https://cedentists.eu/library/policy.html

44. Fisher-Owens SA, Gansky SA, Platt LJ, Weintraub JA, Soobader M-J, Bramlett MD, et al. Influences on Children's Oral Health: A Conceptual Model. PEDIATRICS. 2007 Sep 1;120(3):e510–20.

45. Low W, Tan S, Schwartz S. The effect of severe caries on the quality of life in young children. Pediatr Dent. 1999 Oct;21(6):325–6.

46. Ismail AI, Pitts NB, Tellez M, Authors of the International Caries Classification and Management System (ICCMS). The International Caries Classification and Management System (ICCMS^{TM}) An Example of a Caries Management Pathway. BMC Oral Health. 2015 Dec;15(S1):S9.

47. Nigel B. Pitts, Amid I. Ismail, Stefania Martignon, Kim Ekstrand, Gail V. A. Douglas, Christopher Longbottom. ICCMS^{TM} Guide for Practitioners and Educators [Internet]. International Caries Classification and Management System; 2014 [cited 2022 Jan 14]. Available from: https://www.iccms-web.com/

48. Ekstrand KR, Gimenez T, Ferreira FR, Mendes FM, Braga MM. The International Caries Detection and Assessment System – ICDAS: A Systematic Review. Caries Res. 2018;52(5):406–19.

49. Gugnani N, Pandit IK, Srivastava N, Gupta M, Sharma M. International Caries Detection and Assessment System (ICDAS): A New Concept. Int J Clin Pediatr Dent. 2011 Aug;4(2):93–100.

50. Young DA, Nový BB, Zeller GG, Hale R, Hart TC, Truelove EL, et al. The American

Dental Association Caries Classification System for Clinical Practice. J Am Dent Assoc. 2015 Feb;146(2):79–86.

51. Hu J, Jiang W, Lin X, Zhu H, Zhou N, Chen Y, et al. Dental Caries Status and Caries Risk Factors in Students Ages 12–14 Years in Zhejiang, China. Med Sci Monit. 2018 Jun 1;24:3670–8.

52. Obregón-Rodríguez N, Fernández-Riveiro P, Piñeiro-Lamas M, Smyth-Chamosa E, Montes-Martínez A, Suárez-Cunqueiro MM. Prevalence and caries-related risk factors in schoolchildren of 12- and 15-year-old: a cross-sectional study. BMC Oral Health. 2019 Dec;19(1):120.

53. Chankanka O, Cavanaugh JE, Levy SM, Marshall TA, Warren JJ, Broffitt B, et al. Longitudinal associations between children's dental caries and risk factors: Longitudinal associations between children's dental caries and risk factors. J Public Health Dent. 2011 Sep;71(4):289–300.

54. Hafez HS, Shaarawy SM, Al-Sakiti AA, Mostafa YA. Dental crowding as a caries risk factor: A systematic review. Am J Orthod Dentofacial Orthop. 2012 Oct;142(4):443–50.

55. Buczkowska-Radlinska J, Szyszka-Sommerfeld L, Wozniak K. Anterior tooth crowding and prevalence of dental caries in children in Szczecin, Poland. Community Dent Health. 2012 Jun;29(2):168–72.

56. Disha P, Poornima P, Pai S, Nagaveni N, Roshan N, Manoharan M. Malocclusion and dental caries experience among 8–9-year-old children in a city of South Indian region: A cross-sectional survey. J Educ Health Promot. 2017;6(1):98.

57. De Grauwe A, Aps JK, Martens LC. Early Childhood Caries (ECC): what's in a name? Eur J Paediatr Dent. 2004 Jun;5(2):62–70.

58. Policy on Early Childhood Caries (ECC): Classifications, Consequences, and Preventive Strategies. Pediatr Dent. 2016 Oct;38(6):52–4.

59. Meyer F, Enax J. Early Childhood Caries: Epidemiology, Aetiology, and Prevention. Int J Dent. 2018;2018:1–7.

60. Berkowitz RJ. Causes, treatment and prevention of early childhood caries: a microbiologic perspective. J Can Dent Assoc. 2003 May;69(5):304–7.

61. Nunn ME, Braunstein NS, Kaye EAK, Dietrich T, Garcia RI, Henshaw MM. Healthy Eating Index Is a Predictor of Early Childhood Caries. J Dent Res. 2009 Apr;88(4):361–6.

62. Ramos-Gomez F, Weintraub J, Gansky S, Hoover C, Featherstone J. Bacterial, behavioral and environmental factors associated with early childhood caries. J Clin Pediatr Dent. 2003 Jan 1;26(2):165–73.

63. Meyer F, Karch A, Schlinkmann KM, Dreesman J, Horn J, Rübsamen N, et al.

Sociodemographic determinants of spatial disparities in early childhood caries: An ecological analysis in Braunschweig, Germany. Community Dent Oral Epidemiol. 2017 Oct;45(5):442–8.

64. Wagner Y, Heinrich-Weltzien R. Risk factors for dental problems: Recommendations for oral health in infancy. Early Hum Dev. 2017 Nov;114:16–21.

65. Evans EW, Hayes C, Palmer CA, Bermudez OI, Cohen SA, Must A. Dietary Intake and Severe Early Childhood Caries in Low-Income, Young Children. J Acad Nutr Diet. 2013 Aug;113(8):1057–61.

66. Chaffee BW, Feldens CA, Rodrigues PH, Vítolo MR. Feeding practices in infancy associated with caries incidence in early childhood. Community Dent Oral Epidemiol. 2015 Aug;43(4):338–48.

67. Aarabi G, Reissmann DR, Sagheri D, Neuschulz J, Heydecke G, Kofahl C, et al. Oral health-related quality of life of children and adolescents with and without migration background in Germany. Qual Life Res. 2018 Oct;27(10):2619–27.

68. André Kramer A-C, Pivodic A, Hakeberg M, Östberg A-L. Multilevel Analysis of Dental Caries in Swedish Children and Adolescents in Relation to Socioeconomic Status. Caries Res. 2019;53(1):96–106.

69. Knoblauch U, Ritschel G, Weidner K, Mogwitz S, Hannig C, Viergutz G, et al. The association between socioeconomic status, psychopathological symptom burden in mothers, and early childhood caries of their children. Doering S, editor. PLOS ONE. 2019 Oct 28;14(10):e0224509.

70. Boka V, Trikaliotis A, Kotsanos N, Karagiannis V. Dental caries and oral health-related factors in a sample of Greek preschool children. Eur Arch Paediatr Dent. 2013 Dec;14(6):363–8.

71. Cagetti MG, Congiu G, Cocco F, Meloni G, Sale S, Campus G. Are distinctive risk indicators associated with different stages of caries in children? A cross-sectional study. BMC Public Health. 2016 Dec;16(1):1213.

72. Scottish Intercollegiate Guidelines Network (SIGN). Dental interventions to prevent caries in children (SIGN publication no. 138) [Internet]. Edinburgh: SIGN; 2014 [cited 2022 Jan 12]. 52 p. Available from: https://www.sign.ac.uk/

73. IAPD. IAPD Foundational Articles and Consensus Recommendations: Caries Risk Assessment and Care Pathways [Internet]. International Association of Paediatric Dentistry; 2020 [cited 2021 Jul 4]. Available from: https://iapdworld.org/wp-content/uploads/2020/04/01_Caries-Risk-Assessment-and-Care-Pathways.pdf

74. Tellez M, Gomez J, Pretty I, Ellwood R, Ismail A. Evidence on existing caries risk assessment systems: are they predictive of future caries? Community Dent Oral Epidemiol. 2013 Feb;41(1):67–78.

75. FDI General Assembly. Classification of Caries Lesions of Tooth Surfaces and Caries

Management Systems - Policy Statement [Internet]. World Dental Federation; 2012 [cited 2021 Jun 30]. Available from: https://www.fdiworlddental.org/classification-caries-lesions-tooth-surfaces-and-caries-management-systems

76. Petersson GH, Isberg P-E, Twetman S. Caries risk profiles in schoolchildren over 2 years assessed by Cariogram: Changes in caries risk profiles. Int J Paediatr Dent. 2010 Sep;20(5):341–6.

77. FDI General Assembly. Carious Lesions and First Restorative Treatment - Policy Statement [Internet]. World Dental Federation; 2019 [cited 2021 Jun 29]. Available from: https://www.fdiworlddental.org/carious-lesions-and-first-restorative-treatment

78. Amaechi BT. Remineralization Therapies for Initial Caries Lesions. Curr Oral Health Rep. 2015 Jun;2(2):95–101.

79. Mm J, Nk B, A P. Minimal intervention dentistry - a new frontier in clinical dentistry. J Clin Diagn Res JCDR. 2014 Jul;8(7):ZE04-08.

80. Grocholewicz K, Matkowska-Cichocka G, Makowiecki P, Droździk A, Ey-Chmielewska H, Dziewulska A, et al. Effect of nano-hydroxyapatite and ozone on approximal initial caries: a randomized clinical trial. Sci Rep. 2020 Dec;10(1):11192.

81. Patel PM. Comparison of the Effect of Fluoride Varnish, Chlorhexidine Varnish and Casein Phosphopeptide- Amorphous Calcium Phosphate (CPP-ACP) Varnish on Salivary Streptococcus mutans Level: A Six Month Clinical Study. J Clin Diagn Res [Internet]. 2017 [cited 2022 Mar 21]; Available from: http://jcdr.net/article_fulltext.asp?issn=0973-709x&year=2017&volume=11&issue=8&page=ZC53&issn=0973-709x&id=10409

82. Yip K, Smales R. Oral diagnosis and treatment planning: part 5. Preventive and treatment planning for dental caries. Br Dent J. 2012 Sep;213(5):211–20.

83. Radić M, Benjak T, Dečković Vukres V, Rotim Ž, Filipović Zore I. Presentation of DMF Index in Croatia and Europe. Acta Stomatol Croat. 2015 Dec 15;49(4):275–84.

84. Ladewig NM, Camargo LB, Tedesco TK, Floriano I, Gimenez T, Imparato JCP, et al. Management of dental caries among children: a look at the cost-effectiveness. Expert Rev Pharmacoecon Outcomes Res. 2018 Mar 4;18(2):127–34.

85. de Jong-Lenters M, Duijster D, Schuller A, van Loveren C, Verrips E. Dental caries and externalizing behaviour problems in a high-risk child population. Eur J Oral Sci. 2018 Oct;126(5):417–25.

86. Frencken JE, Peters MC, Manton DJ, Leal SC, Gordan VV, Eden E. Minimal intervention dentistry for managing dental caries – a review. Int Dent J. 2012 Oct;62(5):223–43.

87. Philip N, Suneja B, Walsh L. Beyond Streptococcus mutans: clinical implications of the evolving dental caries aetiological paradigms and its associated microbiome. Br Dent J. 2018 Feb;224(4):219–25.

88. Dashper SG, Mitchell HL, Lê Cao K-A, Carpenter L, Gussy MG, Calache H, et al. Temporal development of the oral microbiome and prediction of early childhood caries. Sci Rep. 2019 Dec;9(1):19732.

89. Wang Y, Wang S, Wu C, Chen X, Duan Z, Xu Q, et al. Oral Microbiome Alterations Associated with Early Childhood Caries Highlight the Importance of Carbohydrate Metabolic Activities. Ercolini D, editor. mSystems [Internet]. 2019 Dec 17 [cited 2021 Jun 20];4(6). Available from: https://journals.asm.org/doi/10.1128/mSystems.00450-19

90. Dzidic M, Collado MC, Abrahamsson T, Artacho A, Stensson M, Jenmalm MC, et al. Oral microbiome development during childhood: an ecological succession influenced by postnatal factors and associated with tooth decay. ISME J. 2018 Sep;12(9):2292–306.

91. Sampaio-Maia B, Monteiro-Silva F. Acquisition and maturation of oral microbiome throughout childhood: An update. Dent Res J. 2014 May;11(3):291–301.

92. Pitts N, Baez R, Diaz-Guallory C, et al. Early Childhood Caries: IAPD Bangkok Declaration. Int J Paediatr Dent. 2019 May;29(3):384–6.

93. FDI General Assembly. Preventing Oral Diseases - Policy Statement [Internet]. World Dental Federation; 2016 [cited 2021 Jun 30]. Available from: https://www.fdiworlddental.org/preventing-oral-diseases

94. CED. CED White Paper Oral Care: Prevention is better than cure [Internet]. Council of European Dentists; 2019 [cited 2022 Jan 12]. Available from: https://cedentists.eu/library/policy.html?filter_id=89

95. Article 168 of the TFEU: Public Health - European Public Health [Internet]. [cited 2019 Dec 27]. Available from: http://www.europeanpublichealth.com/governance/european-union/article-168-of-the-tfeu-public-health/

96. Martin G, Grant A, D'Agostino M. Global health funding and economic development. Glob Health. 2012;8(1):8.

97. Ottolenghi L, Muller-Bolla M, Strohmenger L, Bourgeois D. Oral health indicators for children and adolescents: European perspectives. Eur J Paediatr Dent. 2007 Dec;8(4):205–10.

98. FDI General Assembly. Access to Oral Healthcare for Vulnerable and Underserved - Policy Statement [Internet]. World Dental Federation; 2019 [cited 2021 Jun 30]. Available from: https://www.fdiworlddental.org/access-oral-healthcare-vulnerable-and-underserved

99. Szöke J, Petersen PE. Changing Levels of Dental Caries over 30 Years among Children in a Country of Central and Eastern Europe – The Case of Hungary. Oral Health Prev Dent. 2020 Feb 12;18(1):177–83.

100. WHO | Strategies and approaches in oral disease prevention and health promotion [Internet]. [cited 2020 Jan 6]. Available from:

https://www.who.int/oral_health/strategies/cont/en/

101. WHO. Guideline: sugars intake for adults and children [Internet]. Geneva, Switzerland: World Health Organization; 2015 [cited 2021 Jan 13]. 59 p. Available from: https://www.who.int/publications/i/item/9789241549028

102. FDI General Assembly. Dietary Free Sugars and Dental Caries - Policy Statement [Internet]. World Dental Federation; 2015 [cited 2021 Jun 30]. Available from: https://www.fdiworlddental.org/dietary-free-sugars-and-dental-caries

103. IAPD. IAPD Foundational Articles and Consensus Recommendations: Diet and Dental Caries [Internet]. International Association of Paediatric Dentistry; 2021 [cited 2021 Jul 4]. Available from: https://iapdworld.org/wp-content/uploads/2020/12/07_Diet-and-Dental-Caries.pdf

104. EAPD Board. Guidelines on Prevention of Early Childhood Caries: An EAPD Policy Document [Internet]. European academy of Paediatric Dentistry; 2008 [cited 2021 Jul 4]. Available from: https://www.eapd.eu/uploads/1722F50D_file.pdf

105. Kühnisch J, Ekstrand KR, Pretty I, Twetman S, van Loveren C, Gizani S, et al. Best clinical practice guidance for management of early caries lesions in children and young adults: an EAPD policy document. Eur Arch Paediatr Dent. 2016 Feb;17(1):3–12.

106. FDI General Assembly. Perinatal and Infant Oral Health - Policy Statement [Internet]. World Dental Federation; 2014 [cited 2021 Jun 30]. Available from: https://www.fdiworlddental.org/perinatal-and-infant-oral-health

107. IAPD. IAPD Foundational Articles and Consensus Recommendations: Management of Early Childhood Caries [Internet]. International Association of Paediatric Dentistry; 2020 [cited 2021 Jul 4]. Available from: https://iapdworld.org/wp-content/uploads/2020/04/02_Management-of-Early-Childhood-Caries.pdf

108. IAPD. IAPD Foundational Articles and Consensus Recommendations: Minimal Invasive Dentistry [Internet]. International Association of Paediatric Dentistry; 2020 [cited 2021 Jul 4]. Available from: https://iapdworld.org/wp-content/uploads/2020/04/06_Minimal-Invasive-Dentistry.pdf

109. QUESTEL SAS. Orbit Intelligence [Internet]. 2018 [cited 2018 Oct 4]. Available from: https://www.questel.com/software/ipbi/ orbit-intelligence/

110. Seattle, United States: Institute for Health Metrics and Evaluation (IHME). Global Health Data Exchange [Internet]. Available from: http://ghdx.healthdata.org/

111. Seattle, United States: Institute for Health Metrics and Evaluation (IHME). Global Burden of Disease Study 2019 (GBD 2019) About Dataset Records [Internet]. 2020. Available from: http://ghdx.healthdata.org/about-ghdx/ghdx-records-explained

112. Eurostat. Eurostat Database [Internet]. [cited 2020 Dec 8]. Available from: https://ec.europa.eu/eurostat/data/database

113. Food and Agriculture Organization of the United Nations. FAOSTAT [Internet]. [cited 2020 Dec 8]. Available from: http://www.fao.org/faostat/en/#home

114. Coggon D, Barker D, Rose G. Epidemiology for the Uninitiated. 5th ed. Hoboken: Wiley; 2009. 80 p.

115. Moynihan PJ, Kelly SAM. Effect on Caries of Restricting Sugars Intake: Systematic Review to Inform WHO Guidelines. J Dent Res. 2014 Jan;93(1):8–18.

116. Donabedian A. The quality of care. How can it be assessed? JAMA. 1988 Sep 23;260(12):1743–8.

117. Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: Guidelines for reporting observational studies. PLoS Med. 2007 Oct;4(10):1623–7.

118. Anthony S Kravitz, Alison Bullock, Jon Cowpe, Emma Barnes. Council of European Dentists: MANUAL OF DENTAL PRACTICE 2015 [Internet]. 5.1. Cardiff University, Wales, United Kingdom: The Council of European Dentists; 2015 [cited 2022 Jan 13]. 420 p. Available from: https://cedentists.eu/library/eu-manual.html

119. Child | Migration and Home Affairs [Internet]. [cited 2021 Jan 21]. Available from: https://ec.europa.eu/home-affairs/what-we-do/networks/european_migration_network/glossary_search/child_en

120. European Commission. National focal points of the Member States,Third Programme of the Union's action in the field of health (2014-2020)and participating countries. 2019.

121. Zhao Z, Sharma S, Anand A, Morstatter F, Alelyani S, Liu H. Advancing Feature Selection Research − ASU Feature Selection Repository [Internet]. Arizona State University; [cited 2022 Jan 12]. Available from: http://www.public.asu.edu/~huanliu/papers/tr-10-007.pdf

122. Jiang X, Jao J, Neapolitan R. Learning Predictive Interactions Using Information Gain and Bayesian Network Scoring. Emmert-Streib F, editor. PLOS ONE. 2015 Dec 1;10(12):e0143247.

123. Hu T, Sinnott-Armstrong NA, Kiralis JW, Andrew AS, Karagas MR, Moore JH. Characterizing genetic interactions in human disease association studies using statistical epistasis networks. BMC Bioinformatics. 2011 Dec;12(1):364.

124. Bland JM, Kerry SM. Weighted comparison of means. BMJ. 1998 Jan 10;316(7125):129–129.

125. Tyler R. Oatmen. Preventive Dentistry Techniques in the Treatment of Dental Caries and Biofilm Control: A Review [Internet]. Grand Valley State University, Honors Projects. 88.; 2011 [cited 2021 May 9]. Available from: https://scholarworks.gvsu.edu/honorsprojects/88

126. Chen F, Wang D. Novel technologies for the prevention and treatment of dental caries: a patent survey. Expert Opin Ther Pat. 2010 May;20(5):681–94.

127. Kessler A, Hickel R, Reymus M. 3D Printing in Dentistry—State of the Art. Oper Dent. 2020 Jan 1;45(1):30–40.

128. Rauten A-M, Georgescu C, Popescu MR, Maglaviceanu CF, Popescu D, Gheorghe D, et al. Orthodontic treatment needs in mixed dentition – for children of 6 and 9 years old. Rom J Oral Rehab. 2016;8(1):28–39.

129. Piassi E, Antunes LS, Andrade MRTC, Antunes LAA. Quality of Life Following Early Orthodontic Therapy for Anterior Crossbite: Report of Cases in Twin Boys. Case Rep Dent. 2016;2016:1–5.

130. Han J, Wangwoo. Patenting Activity - A Proxy of the Technology Gap? The Case of Korea and China. Intel Prop Rights. Intellect Prop Rights Open Access [Internet]. 2016 [cited 2021 May 10];4(1). Available from: http://www.esciencecentral.org/journals/patenting-activity--a-proxy-of-the-technology-gap-the-case-of-korea-and-china-intel-prop-rights-2375-4516-1000151.php?aid=76213

131. Santacreu AM, Zhu H. What Does China's Rise in Patents Mean? A Look at Quality vs. Quantity. Econ Synop [Internet]. 2018 [cited 2021 May 10];2018(14). Available from: https://research.stlouisfed.org/publications/economic-synopses/2018/05/04/what-does-chinas-rise-in-patents-mean-a-look-at-quality-vs-quantity

132. Stevens P, International Policy Network. Incentivising research and development for the diseases of poverty. London: International Policy Network; 2005.

133. van der Tas JT, Kragt L, Elfrink MEC, Bertens LCM, Jaddoe VWV, Moll HA, et al. Social inequalities and dental caries in six-year-old children from the Netherland s. J Dent. 2017 Jul;62:18–24.

134. Association of State and Territorial Dental Directors (ASTDD). Early Childhood Caries Policy Statement [Internet]. Association of State and Territorial Dental Directors (ASTDD); 2012 [cited 2021 May 10]. Available from: https://www.astdd.org/docs/early-childhood-caries-policy-statement-june-26-2012.pdf

135. Gussy MG, Waters EG, Walsh O, Kilpatrick NM. Early childhood caries: Current evidence for aetiology and prevention. J Paediatr Child Health. 2006 Jan;42(1–2):37–43.

136. Razum O, Wenner J. Social and health epidemiology of immigrants in Germany: past, present and future. Public Health Rev. 2016 Dec;37(1):4.

137. Nota A, Caruso S, Cantile T, Gatto R, Ingenito A, Tecco S, et al. Socioeconomic Factors and Oral Health-Related Behaviours Associated with Dental Caries in Preschool Children from Central Italy (Province of Ascoli Piceno). BioMed Res Int. 2019 Dec 24;2019:1–7.

138. Brzoska P, Erdsiek F, Waury D. Enabling and Predisposing Factors for the Utilization of Preventive Dental Health Care in Migrants and Non-Migrants in Germany. Front Public Health. 2017 Aug 14;5:201.

139. Eurostat. Economic recovery of EU regions after 2008 [Internet]. 2019 [cited 2020 Dec 12]. Available from: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20191023-1

140. Ferreira SH, Béria JU, Kramer PF, Feldens EG, Feldens CA. Dental caries in 0- to 5-year-old Brazilian children: prevalence, severity, and associated factors. Int J Paediatr Dent. 2007 Jul;17(4):289–96.

141. Carrada CF, Tavares MC, Drummond AMA, Correa NM de O, Mattos F de F, Moura RNV de, et al. Early Childhood Caries Experience of Children from Poor Families Living Below and Above Poverty Line. Pesqui Bras Em Odontopediatria E Clínica Integrada. 2021;21:e210057.

142. Foley M, Akers H. Does poverty cause dental caries? Aust Dent J [Internet]. 2018 Dec 16 [cited 2022 Mar 21]; Available from: https://onlinelibrary.wiley.com/doi/10.1111/adj.12666

143. Folayan MO, El Tantawi M, Schroth RJ, Kemoli AM, Gaffar B, Amalia R, et al. Association Between Environmental Health, Ecosystem Vitality, and Early Childhood Caries. Front Pediatr. 2020 May 19;8:196.

144. Folayan MO, El Tantawi M, Ramos-Gomez F, Sabbah W. Early childhood caries and its associations with sugar consumption, overweight and exclusive breastfeeding in low, middle and high-income countries: an ecological study. PeerJ. 2020;8:e9413.

145. Fidler Mis N, Braegger C, Bronsky J, Campoy C, Domellöf M, Embleton ND, et al. Sugar in Infants, Children and Adolescents: A Position Paper of the European Society for Paediatric Gastroenterology, Hepatology and Nutrition Committee on Nutrition. J Pediatr Gastroenterol Nutr. 2017 Dec;65(6):681–96.

146. Azaïs-Braesco V, Sluik D, Maillot M, Kok F, Moreno LA. A review of total & added sugar intakes and dietary sources in Europe. Nutr J. 2017 Dec;16(1):6.

147. van Loveren C. Sugar Restriction for Caries Prevention: Amount and Frequency. Which Is More Important? Caries Res. 2019;53(2):168–75.

148. Pereira JL, Caramelo F, Soares AD, Cunha B, Gil AM, Costa AL. Prevalence and sociobehavioural determinants of early childhood caries among 5-year-old Portuguese children: a longitudinal study. Eur Arch Paediatr Dent. 2020 Oct 10;

149. Goettems ML, Ardenghi TM, Demarco FF, Romano AR, Torriani DD. Children's use of dental services: influence of maternal dental anxiety, attendance pattern, and perception of children's quality of life. Community Dent Oral Epidemiol. 2012 Oct;40(5):451–8.

150. Kinirons M, McCabe M. Familial and maternal factors affecting the dental health and

dental attendance of preschool children. Community Dent Health. 1995 Dec;12(4):226–9.

151. Schroth RJ, Cheba V. Determining the prevalence and risk factors for early childhood caries in a community dental health clinic. Pediatr Dent. 2007 Oct;29(5):387–96.

152. van Ansem WJC, van Lenthe FJ, Schrijvers CTM, Rodenburg G, van de Mheen D. Socio-economic inequalities in children's snack consumption and sugar-sweetened beverage consumption: the contribution of home environmental factors. Br J Nutr. 2014 Aug 14;112(3):467–76.

153. GBD 2017 Oral Disorders Collaborators, Bernabe E, Marcenes W, Hernandez CR, Bailey J, Abreu LG, et al. Global, Regional, and National Levels and Trends in Burden of Oral Conditions from 1990 to 2017: A Systematic Analysis for the Global Burden of Disease 2017 Study. J Dent Res. 2020 Apr;99(4):362–73.

154. Wagner Y, Heinrich-Weltzien R. Evaluation of a regional German interdisciplinary oral health programme for children from birth to 5 years of age. Clin Oral Investig. 2017 Jan;21(1):225–35.

155. Pierce KM, Rozier RG, Vann WF. Accuracy of Pediatric Primary Care Providers' Screening and Referral for Early Childhood Caries. PEDIATRICS. 2002 May 1;109(5):e82–e82.

156. European Commission. Directorate General for Health and Food Safety. Tools and methodologies to assess the efficiency of health care services in Europe: an overview of current approaches and opportunities for improvement : report by the Expert Group on Health System Performance Assessment. [Internet]. LU: Publications Office; 2019 [cited 2021 Feb 5]. Available from: https://data.europa.eu/doi/10.2875/346480

157. Jürgensen N, Petersen PE. Promoting oral health of children through schools-Results from a WHO global survey 2012. Community Dent Health. 2013;30:204–18.

158. Milsom KM, Tickle M, Blinkhorn AS. Is school dental screening a political or a scientific intervention? J Dent Res. 2008 Oct;87(10):896–9.

159. Çolak H, Dülgergil C. Do the more caries in early primary dentition indicate the more caries in permanent dentition? Results of a 5-years follow-up study in rural-district. J Int Soc Prev Community Dent. 2012;2(2):48.

160. Pitts N, Melo P, Martignon S, Ekstrand K, Ismail A. Caries risk assessment, diagnosis and synthesis in the context of a European Core Curriculum in Cariology. Eur J Dent Educ. 2011;

161. Featherstone JDB, Chaffee BW. The Evidence for Caries Management by Risk Assessment (CAMBRA®). Adv Dent Res. 2018 Feb 1;29(1):9–14.

162. Watt RG, Daly B, Allison P, Macpherson LMD, Venturelli R, Listl S, et al. Ending the neglect of global oral health: time for radical action. The Lancet. 2019 Jul;394(10194):261–72.

163. Centers for Disease Control and Prevention. Promoting oral health: interventions for preventing dental caries, oral and pharyngeal cancers, and sports-related craniofacial injuries. A report on recommendations of the task force on community preventive services. MMWR Recomm Rep Morb Mortal Wkly Rep Recomm Rep. 2001 Nov 30;50(RR-21):1–13.

164. Pitts NB. Are We Ready to Move from Operative to Non-Operative/Preventive Treatment of Dental Caries in Clinical Practice? Caries Res. 2004;38(3):294–304.

165. Birch S, Listl S. The Economics of Oral Health and Health Care. SSRN Electron J [Internet]. 2015 [cited 2022 Mar 19]; Available from: http://www.ssrn.com/abstract=2611060

166. Pitts N, Amaechi B, Niederman R, Acevedo A-M, Vianna R, Ganss C, et al. Global Oral Health Inequalities. Williams DM, editor. Adv Dent Res. 2011 May 13;23(2):211–20.

167. Nobile CG, Fortunato L, Bianco A, Pileggi C, Pavia M. Pattern and severity of early childhood caries in Southern Italy: a preschool-based cross-sectional study. BMC Public Health. 2014 Feb 27;14:206.

168. Toumba KJ, Twetman S, Splieth C, Parnell C, van Loveren C, Lygidakis NA. Guidelines on the use of fluoride for caries prevention in children: an updated EAPD policy document. Eur Arch Paediatr Dent. 2019 Dec;20(6):507–16.

8. Keywords

Caries prevention, sugar consumption, European Union, public health policy, early childhood caries, innovations, caries disease burden, patent analysis

Kulcsszavak

káriesz prevenció, cukorfogyasztás, Európai Unió, népegészségügyi politikák, gyermekkori káriesz, innovációk, káriesz betegségteher, szabadalomanalízis

9. Acknowledgements

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10. Addendum

10.1 Addendum 1: List of patents

List of patents included into the analysis by publication numbers, in the 'Assessing novel technological solutions addressing caries: a patent analysis' project.

RU2661612 C1 CN108042387 A CN107625662 A KR20180001267 A CN206761096U U CN206303986U U RU2621534 C1 CN106806028 A CN106581159 A TWM539272 U CN206062509U U CN105832854 A WO200283022 A2 CN105795088 A CN105662606 A CN205268315U U CN205215392U U CN205144814U U TW201603782 A CN105266904 A CN105169375 A CN104430770 A US20150050621 A1 UA--89688U U CN103751314 A CN202698198U U CN202698175U U KR20130107519 A RU2011128892 A CN202143714U U ES2379170 A1 CN102188099 A CN201692076U U CN101889969 A RU--86448 U1 RU2376014 C1 WO200924372 A1 US20070238071 A1 CN201070106U Y UA--19012U U JP2007160073 A TWM281603 U US7500576 B1 TWM253261 U US20040058295 A1 US20040126743 A1 RU2204337 C2 JP2002169887 A WO200230313 A2 DE19936461 A1 US5882192 A FI9406191 A0 RU94028402 A SU2072786 C1 DE9013703 U1 SU1743598 A1 US5078732 A DE3437090 A1 SU1050697 A1 FR2143622 A1 US1816582 A

10.2 Addendum 2: Burden of disease of deciduous teeth caries in 2019, for the 'under 5' age group

Addendum for 'Assessing burden and risk factors of childhood caries: an ecological study'

Addendum 2 Table. Incidence rate, Prevalence, YLDs rate among children aged under 5 years old and Age-standardized YLDs Rate of deciduous caries, 2019

EU member state	Sex	Incidence rate (per 100,000 population) **(95% UI)**	Prevalence (%) **(95% UI)**	YLDs rate **(per 100, 000 population) (95% UI)**	Age-standardized YLDs rate **(per 100, 000 population) (95% UI)**
Austria	Male	39653,1	33,3%	7,8	2,1
	Female	38184,0	26,6%	7,2	2,0
	Both	38942,0	29,8%	7,5	2,0
Belgium	Male	40492,3	35,4%	8,1	2,1
	Female	38751,5	28,6%	7,7	2,1
	Both	39642,6	31,8%	7,9	2,1
Bulgaria	Male	51563,4	55,9%	16,8	3,3
	Female	51983,6	54,3%	17,0	3,3
	Both	51767,6	55,1%	16,9	3,3
Croatia	Male	51830,5	56,3%	16,7	3,3
	Female	52291,2	56,8%	16,9	3,3
	Both	52054,4	56,5%	16,8	3,3
Cyprus	Male	39115,1	31,6%	7,8	2,1
	Female	37673,9	25,2%	7,3	2,0
	Both	38419,1	28,3%	7,6	2,0
Czechia	Male	51888,2	56,9%	16,7	3,3
	Female	52038,2	56,0%	16,7	3,3
	Both	51961,3	56,5%	16,7	3,3
Denmark	Male	33944,3	25,1%	5,6	1,4
	Female	31965,2	19,3%	5,1	1,4
	Both	32981,1	22,0%	5,3	1,4
Estonia	Male	51034,3	56,8%	16,5	3,3

	Female	50990,9	54,5%	16,3	3,3
	Both	51013,2	55,6%	16,4	3,3
Finland	Male	43867,1	40,9%	10,0	2,4
	Female	41837,9	33,7%	9,1	2,3
	Both	42875,7	37,2%	9,6	2,4
France	Male	37956,1	34,0%	7,8	2,0
	Female	36876,2	28,2%	7,3	2,0
	Both	37428,1	31,0%	7,6	2,0
Germany	Male	40892,7	37,0%	8,8	2,1
	Female	37472,4	30,2%	8,1	1,9
	Both	39229,0	33,5%	8,5	2,0
Greece	Male	41687,1	41,3%	10,2	2,4
	Female	39548,7	33,1%	9,2	2,3
	Both	40643,6	37,0%	9,7	2,4
Hungary	Male	51765,9	56,5%	16,8	3,3
	Female	51893,8	55,4%	16,8	3,3
	Both	51828,1	55,9%	16,8	3,3
Ireland	Male	38046,3	30,0%	6,7	1,8
	Female	36555,3	24,2%	6,3	1,7
	Both	37319,2	26,9%	6,5	1,8
Italy	Male	45231,9	44,5%	11,9	2,6
	Female	43565,6	36,6%	11,0	2,5
	Both	44422,0	40,4%	11,5	2,5
Latvia	Male	51521,7	57,8%	16,6	3,3
	Female	51099,6	55,3%	16,4	3,3
	Both	51317,9	56,5%	16,5	3,3
Lithuania	Male	51173,6	57,8%	16,7	3,3
	Female	51077,6	55,0%	16,6	3,3
	Both	51126,9	56,4%	16,6	3,3
Luxembourg	Male	39743,8	34,4%	7,8	2,1
	Female	37730,3	26,8%	7,1	2,0
	Both	38760,1	30,4%	7,5	2,0
Malta	Male	39887,8	34,2%	8,0	2,1

	Female	37954,9	26,7%	7,2	2,0
	Both	38953,7	30,3%	7,6	2,0
Netherlands	Male	43888,0	36,5%	8,2	2,2
	Female	43285,5	29,8%	7,9	2,2
	Both	43594,3	33,0%	8,1	2,2
Poland	Male	53418,3	57,2%	16,8	3,2
	Female	53355,3	56,0%	16,7	3,2
	Both	53387,7	56,6%	16,7	3,2
Portugal	Male	39780,1	33,8%	7,9	2,1
	Female	38489,0	27,1%	7,4	2,0
	Both	39148,6	30,2%	7,7	2,1
Romania	Male	51848,0	55,4%	17,0	3,3
	Female	52452,2	54,8%	17,1	3,3
	Both	52141,6	55,1%	17,1	3,3
Slovakia	Male	51134,1	56,5%	16,8	3,3
	Female	51512,7	55,2%	16,7	3,3
	Both	51318,5	55,8%	16,7	3,3
Slovenia	Male	51933,6	57,0%	16,6	3,3
	Female	52041,3	56,1%	16,8	3,3
	Both	51986,0	56,5%	16,7	3,3
Spain	Male	41882,2	40,4%	10,3	2,4
	Female	38888,3	31,6%	8,2	2,1
	Both	40427,4	36,1%	9,2	2,3
Sweden	Male	45561,6	49,6%	12,8	2,7
	Female	43887,5	42,3%	12,3	2,7
	Both	44749,4	45,9%	12,5	2,7
United Kingdom	Male	16247,5	21,8%	4,9	1,4
	Female	15261,3	16,8%	4,5	1,3
	Both	15766,8	19,1%	4,7	1,3
European Union	Male	39535,01	40.33%	10,05	2,30
	Female	38061,91	34.24%	9,47	2,22
	Both	38817,68	37.20%	9,77	2.26

YLDs: Years lived with disability

UI: uncertainty interval

10.3 Addendum 3: Questionnaire

This survey tool was developed to discover the characteristics of caries preventive policies, practices among EU member states.

Questionnaire about Dental Caries Prevention Policies to identify the national dental practice and policy in caries prevention for children

A) YOUR DATA

Thank you very much for your assistance. First, just a few questions about you. Your responses will remain confidential and anonymous, data from this research will be reported only as a collective combined total.

1. Your country: _____
2. County /region: _____
3. Type of institute (mark only one):
    - □ Public Administration
    - □ Higher Education
    - □ Professional body
    - □ Research Institute
    - □ NGO (non-governmental organization)
    - □ Other

4. Title/Position: _____
5. Gender (mark only one):
    - □ Male
    - □ Female
    - □ Prefer not to say

6. Age (mark only one):
    - □ below 20

- 20-29
- 30-39
- 40-49
- 50-59
- above 60

7. Email (optional): _____

B) QUESTIONNAIRE ABOUT DENTAL CARIES PREVENTION POLICIES
(4 SECTIONS)

I. ORGANISATION OF DENTAL SERVICES FOR CHILDREN

Questions are about the organisation of dental services provided to children in your country. Please indicate the one that best corresponds to your answer.

1. Are there dental treatments provided for children free of charge in your country through the public health service? (mark only one)

□ Yes □ No

2. Is uniformity in management of children's caries prevention achieved in your country? (mark only one)

□ Yes □ No (e.g. there can be regional differences)

3. Is children caries risk assessment used in your country? E.g. are the children in your country classified to caries risk groups? (mark only one)

□ Yes □ No

4. Do the children at high caries risk receive special care during dental screens, check-ups or treatments? e.g. children with previous caries experience, sociodemographic risk, certain dietary habits, hard-to-reach population (mark only one)

□ Yes □ No

5. Is the school dentistry part of the public dental care (financed by the state) in your country? (mark only one)

□ Yes □ No

6. Is the school- aged children's dental screening carried out through school dentist's appointments? (mark only one)

□ Yes

□ No

- Not-applicable (e.g. school dentistry is not part of the public dental care)

7. Which age-groups/ classes are screened through school dentist appointments in your country? (mark only one)

- every class/ age group
- certain classes/ age groups
- Non-applicable (e.g. school dentistry is not part of the public dental care or screening is not through school dentistry)

8. What is the frequency of school dental screenings for children in your country? (mark only one)

- yearly
- less (than a year)
- more often (than a year)
- Non-applicable (e.g. school dentistry is not part of the public dental care or screening is not through school dentistry)

9. Are the dental treatments for school-aged children carried out by the school dentist? (mark only one)

- Yes, they do the necessary treatments if required
- No, they only do the screening
- Non-applicable (e.g. school dentistry is not part of the public dental care or screening is not through school dentistry)

10. Is there organised, free-of-charge public dental screening for PRE-SCHOOL (kindergarden) children in your country? (mark only one)

- Yes
- No

11. Which age-groups/ classes of PRE-SCHOOL children are screened? (mark only one)

- Certain classes / age groups
- Every class / age groups

□ Non-applicable (e.g. there is no organised dental screening for preschool children

12. What is the frequency of PRE-SCHOOL dental screenings for children in your country? (mark only one)

□ Yearly

□ Less than a year

□ More often than a year (e.g. in every 6 months)

□ Non-applicable (e.g. there is no organised dental screening for preschool children

13. Is there any monitoring system for the quality assurance of the children's dental screening? (e.g. rate of attendance of children) (mark only one)

□ Yes □ No

II. ORAL HEALTH EDUCATION FOR CHILDREN

Questions are about oral health education for children. Please indicate the one that best corresponds to your answer.

1. Are dental interventions to prevent caries in children used in clinical practice in your country? (in a practice or even non-practice setting, about oral health instructions and promotion, health behaviour, plaque control - mark only one)

□ Yes □ No

2. Is there any national guideline to standardise the delivery of these brief dental interventions? (mark only one)

- □ Yes, there is/are national guideline(s) or recommendtaions about how to deliver the oral health education for children
- □ No, there are no specific national guidelines or recommendations, the oral health education for children is delivered considering the general professional aspects
- □ Non-applicable (e.g. there are no individual brief interventions for children)

3. If you have national guideline to standardise the delivery of these brief dental interventions, oral health improvements, what is the name of the guideline?

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4. In your country, according to your national regulations, what is definitely included in the oral health education for children? Please indicate if these are included in an INDIVIDUAL, in a GROUP or BOTH setting or NOT. Individual setting e.g. personal demonstration and supervision of toothbrushing, group setting e.g. demonstration to class or group of children about toothbrushing. (Mark only one per row)

Name of intervention	**Individual**	**Group**	**Both**	**Not included**
Basic oral health education (importance of toothbrushing, toothbrush, toothpaste)				
Education of toothbrushing techniques (including frequency and duration of toothbrushing, what time of the day etc.)				
Supervised toothbrushing to help plaque control				
Promotion of fluoride toothpaste				
Introduction of special tooth cleaning methods, products (anything other than toothbrush and toothpaste, e.g. dental floss, mouthwash, interdental brush)				
Motivation based on individual health behaviour				
Promoting selfconsciousness in dietary habits				
Information about bad habits for oral health (thumb-sucking, certain types of sports)				
Education of parents, involving them in the oral care promotion				
Education of pregnant women, involving them in the oral care promotion				

5. In your country, who can carry out oral health education? (tick all that apply)

- ☐ Pedodontist, Pediatric Dentist
- ☐ Dentist
- ☐ Dental hygienist
- ☐ Professional dental nurses
- ☐ Dental university students, trainee-dentists
- ☐ trained volunteers
- ☐ other healthcare professionals (e.g General Practitioners, Physicians)
- ☐ Nurses
- ☐ Teachers
- ☐ Non-professional helpers, volunteers

III. DATA RECORD

Questions are about the reporting system of dental services provided to children in your country. Please indicate the one that best corresponds to your answer.

1. Is it mandatory in your country to report data of the children's oral health screening to a national body? (mark only one)

- ☐ Yes
- ☐ No

2. If you report data of the children's oral health screening, what is the name of the nation/regional database?

---

3. Please indicate, what type of data is recorded during the children's dental screenings in your Country: Data recorded of PREschool children / school children / BOTH preschool and school children /No data recorded of this indicator
Mark only one per row.

Name of indicator	**pre-school**	**school children**	**Both**	**No data**
Medical history, anamnesis				
Dietary factors (feeding practices, dietary habits, frequency of sugary drink, food consumption)				
Use of fluoride				
Oral hygiene record (plaque)				
Microbiological risk factors (Streptococcus mutans)				
Salivary flow				
Sociodemographic markers or Geographic markers (e.g. hard-to-reach population, children whose families live in a deprived area)				
Children with disabilities				

White Spots				
D – Decayed teeth				
M – Missing teeth				
F – Filled teeth				
DMF/dmf rate – newly developed caries				
Complete dental status				
Record of Referral (for special needs, special dental treatment)				
Early Childhood Caries - cavitated				
Early childhood Caries – non-cavitated				
Untreated decayed teeth (e.g. if previously detected decayed tooth remains untreated)				

IV. REIMBURSEMENT

Questions are about the reimbursement of dental services provided to children in your country. Please indicate the one that best corresponds to your answer. The last question is about how much what is the reimbursement you get for each of these dental interventions.

1. How many of these interventions are public financed for children (age 0-18) per year? Mark only one per row. (None, it is not public financed / 1 / 2 / 3 or more / As required, no limitation)

Name of intervention	**None**	**1**	**2**	**3 or more**	**As required**
Fissure sealants					
Topical fluoride varnish, topical anticaries interventions					
Filling- milk teeth					
Filling – permanent teeth					
Extraction					
Root canal treatment – milk tooth or pulpotomia					
Root canal treatment – permanent tooth					
Oral health education					
Oral health screening					
Preventive or supplementary orthodontic treatment (e.g. space maintener placement)					
Dental hygiene treatment					

2. What is the reimbursement in Euro approximately per treatment carried out? Mark only one per row. (None, it is not public financed / € 1-5 / € 6-10 / € 11-20 / € 21-30 / above € 30 / Don't know)

Name of intervention	**None**	**€ 1-5**	**€ 6-10**	**€ 11-20**	**€ 21-30**	**above € 30**	**Don't know**
Fissure sealants							
Topical fluoride varnish, topical anticaries interventions							
Filling- milk teeth							
Filling – permanent teeth							
Extraction							
Root canal treatment – milk tooth or pulpotomia							
Root canal treatment – permanent tooth							
Oral health education							
Oral health screening							
Preventive or supplementary orthodontic treatment (e.g. space maintener placement)							
Dental hygiene treatment							

11. Publications

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Registry number: DEENK/528/2021.PL
Subject: PhD Publication List

Candidate: Zsuzsa Bencze
Doctoral School: Doctoral School of Health Sciences

List of publications related to the dissertation

1. **Bencze, Z.**, Kovalecz, G., Marton, S., Gáll, T., Mahrouseh, N., Varga, O.: Childhood caries management in the European Union: a cross-sectional study.
   Heliyon. 7 (2), 1-10, 2021.
   DOI: http://dx.doi.org/10.1016/j.heliyon.2021.e06198
2. **Bencze, Z.**, Mahrouseh, N., Andrade, C. A. S., Kovács, N., Varga, O.: The Burden of Early Childhood Caries in Children under 5 Years Old in the European Union and Associated Risk Factors: an Ecological Study.
   Nutrients. 13 (2), 1-12, 2021.
   DOI: http://dx.doi.org/10.3390/nu13020455
   IF: 5.717 (2020)
3. **Bencze, Z.**, Fraihat, N., Varga, O.: Patent Landscape Analysis of Dental Caries in Primary Teeth.
   Int. J. Environ. Res. Public Health. 16 (12), 1-8, 2019.
   DOI: http://dx.doi.org/10.3390/ijerph16122220
   IF: 2.849

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List of other publications

4. Fraihat, N., Madae'en, S., **Bencze, Z.**, Herczeg, A., Varga, O.: Clinical Effectiveness and Cost-Effectiveness of Oral-Health Promotion in Dental Caries Prevention among Children: systematic Review and Meta-Analysis.
Int. J. Environ. Res. Public Health. 16 (15), 1-33, 2019.
DOI: http://dx.doi.org/10.3390/ijerph16152668
IF: 2.849

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