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Towards More Evidence-Informed Policy Making for Preventing Oral Diseases

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Abbreviations

CI	confidence interval
DALY	disability-adjusted life year
DiD	difference-in-differences
FME	free market experiment
NCD	non-communicable disease
NHS	National Health Service
OOP	out-of-pocket
OR	odds ratio
PSI	Periodontal Screening Index
SD	standard deviation
SE	standard error
SSB	sugar-sweetened beverage
RCT	randomized controlled trial
UI	uncertainty interval
WHO	World Health Organization

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1 Introduction

Although oral diseases are largely preventable, disease burden is still considerably high, with 3.5 billion people affected worldwide in 2015 (Kassebaum et al. 2017). The most prevalent condition, dental caries, affects 20% to 90% of 6-year old children in Europe and nearly 100% of the adult population (World Health Organization (WHO) 2018). Besides negative effects on quality of life and social functioning throughout the lifespan, mainly caused by untreated dental diseases, these conditions impose a considerable economic burden to the society (Righolt et al. 2018). Therefore, improving oral health poses a continuous challenge to policy makers and effective evidence-based approaches are needed to tackle this public health issue.

An integrated oral health promotional approach builds upon interventions that address the broader determinants of oral health (Watt 2005). Hereby, efforts aim at improving individual behaviour-related risk factors, especially nutrition and oral hygiene, as well as utilization of prevention-oriented oral healthcare services (Dahlgren and Whitehead 2007; Petersen 2004). This requires behaviour changes of both the individual and the provider. Economic incentives constitute one option for inducing modifications in behaviour. Those incentives can influence health-related risk behaviour of individuals (Summers 2018); patients are sensible to the price they face when seeking care and at the same time providers of care react to financial incentives induced by remuneration schemes (Robinson 2001; Sintonen and Linnosmaa 2000). However, evidence about the effect of specific interventions targeting oral prevention is still scarce.

This dissertation aims at providing useful evidence to policy makers about how policy interventions based on economic incentives may serve as a helpful tool for preventing oral diseases. By means of qualitative and quantitative health-economic methods, the effects of different population- and provider-sided interventions were evaluated, specifically focusing on European oral healthcare settings.

1.1 An integrated approach to oral prevention

Traditionally, prevention in dentistry has followed a clinical preventive approach with efforts focusing on clinical interventions as well as approaches to promote patients' knowledge about

strategies how to maintain oral health (Watt 2005). Oral health is not limited to dental health, but also includes the absence of diseases affecting other tissues of the oral cavity, lips and oropharynx.

From a chair-sided perspective, this includes providing oral hygiene advice in order to prevent caries and periodontal diseases, sealing pits and fissures of erupting molars, the promotion of fluoride toothpaste use and application of fluoride varnishes as well as screening for oral cancer. On a population level, efforts have mainly focused on an appropriate fluoride intake in order to prevent dental decay. This has been tried to be achieved by community water fluoridation as well as supplementation of certain foods, like salt and milk. Concomitant with a movement towards more evidence-based dentistry, the efficacy and cost-effectiveness of these interventions have been questioned and analysed over the last decades (Elderton 2001; Richards and Lawrence 1995; Worthington et al. 2015).

Hereby, especially population-based water fluoridation has proven to be effective and cost-effective in preventing caries over the whole life course (Griffin et al. 2007; Iheozor-Ejiofor et al. 2015; Murray et al. 1991; Ran and Chattopadhyay 2016; Rugg-Gunn and Do 2012). Since community water fluoridation does not necessitate active participation of the single individual, it reaches the whole population regardless of socio-economic background and is therefore able to reduce inequalities in oral health (O'Mullane et al. 2016). The most widely self-administered fluoride delivery method is utilization of fluoride toothpaste. Fluoridated toothpaste has been dominating the European toothpaste market for more than 30 years with a market share of over 90% (European Commission 2010). Its widespread use is considered to play a major role in the reduction of dental caries in industrialized countries in recent decades (Bratthall et al. 1996). A meta-analysis conducted by the Cochrane Institute reports a caries increment reduction of 24% in permanent teeth due to fluoridated toothpaste use (Marinho et al. 2003). In addition, delivery systems that prolong contact of fluoride with the tooth surface, such as fluoride varnishes and mouth rinses, can reduce caries increment in primary and permanent teeth to a large extent (Marinho et al. 2013; Marinho et al. 2016). When focused on moderate to high risk individuals fluoride varnishes also constitute a cost-effective intervention (Schwendicke et al. 2018b).

In the context of chair-sided prevention, a recent Cochrane review concluded that resin-based sealants on permanent molars are an effective measure to prevent caries in children and

adolescents (Ahovuo-Saloranta et al. 2017). Moreover, risk-based sealant programmes constitute a cost-effective intervention (Akinlotan et al. 2018; Griffin et al. 2016). With regard to oral cancer screening, evidence exists that a population-based screening program including a visual examination is able to reduce mortality rates of oral cancer in high-risk individuals consuming tobacco, alcohol or both (Brocklehurst et al. 2013a).

Another approach in oral prevention ties to the promotion of oral health through health education. However, evidence suggests that the success of mass media campaigns is restricted to raise awareness for the topic but fails to improve knowledge or induce behaviour change (Kay and Locker 1998). School-based dental health education programs and one-to-one advice on oral hygiene behaviour are able to achieve short-term effects with regard to plaque reduction and knowledge about oral health (Kay and Locker 1996; Stein et al. 2018; Watt and Marinho 2005). However, it is not possible to draw conclusions about behaviour changes in the short- or long-run or regarding effects on caries reduction or improvements on gingivitis.

Although fluoride-based approaches have proven to be successful in reducing populations' caries burden substantially in the last decades, oral health-related burden of disease in Europe still remains high (Institute for Health Metrics and Evaluation 2018). Most notably, populations have not benefited equally from oral health improvements since socially disadvantaged groups experience a disproportionally higher burden of oral disease. In fact, a social gradient in oral health is observable, which describes a linear inverse relationship of prevalence for oral conditions and social status (Costa et al. 2012; Sanders et al. 2006).

Several studies have demonstrated the extent of oral health inequalities within European societies: Although caries experience has decreased in German children and adolescents over the last decades, remaining caries lesions concentrated in groups with lower socioeconomic status (Jordan and Micheelis 2016). Similar developments were observed in the British adult population: Burden of oral disease has decreased substantially, especially in younger age groups (White et al. 2012). But negative impacts of oral conditions on their daily life were more likely experienced by people with lower socioeconomic status. Guarnizo-Herreño et al. 2014 also provided evidence for socioeconomic inequalities in subjective oral health among adults in England, Wales and Northern Ireland with stronger gradients for those at younger age. In England, a clear gradient for edentulousness among older adults was observed for

several different socioeconomic measures (Tsakos et al. 2011). With regard to oral health-related quality of life, evidence shows income gradients among adult populations in the UK and Finland, but not in Germany (Sanders et al. 2009). Based on European SHARE data, Listl et al. 2018 reported that childhood socioeconomic background even affect oral health in later life.

It has been criticized that conventional clinical preventive measures cannot reduce the burden of oral diseases and may even widen inequalities in oral health (Watt et al. 2015). Isolated behavioural and knowledge-based approaches, which target patients' oral hygiene, nutrition and tobacco use were not able to induce sustainable health improvements going beyond a short-run effect. Due to their narrow focus on aetiological factors, these approaches fail to tackle the underlying broader factors causing poor oral health: "the causes of the causes" (Dahlgren and Whitehead 2007; Watt 2005). Accounting for the fact that oral diseases are largely preventable, this demand embeds oral healthcare provision into the larger context of influencing the social, community, environmental and economic determinants of oral health.

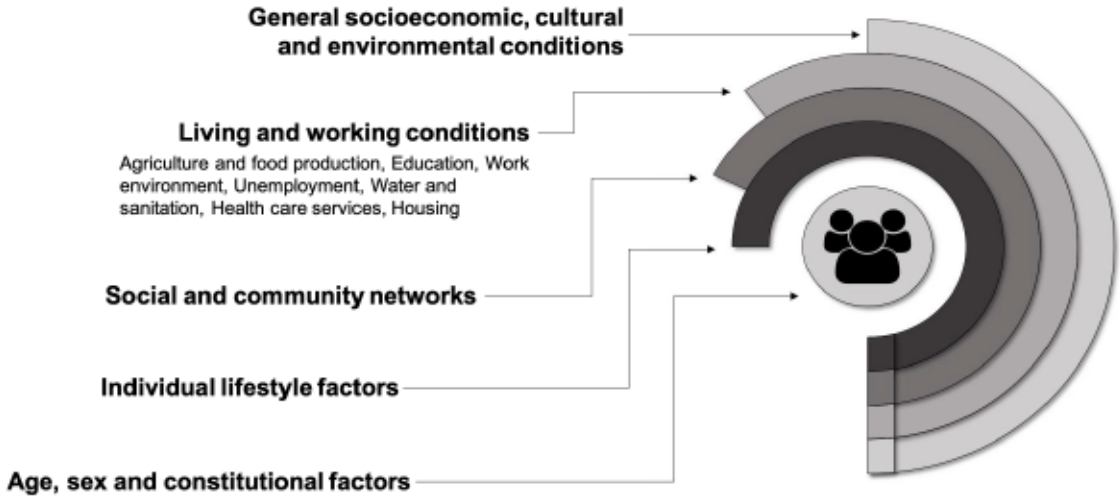

Figure 1: The Dahlgren-Whitehead rainbow model of main determinants of health

The Dahlgren and Whitehead rainbow model of main determinants of health integrates these factors into a broader context of social determinants of health (Figure 1). Dahlgren and Whitehead conceptualize these determinants of population's health as a multi-layered approach in which individual behaviour is determined by individual lifestyle, social and community influences, living and working conditions as well as socioeconomic, cultural and environmental conditions (Dahlgren and Whitehead 2007). Each of these layers has a direct influence on the health of the individual but interactions between layers also affect the impact

of each group of determinants. Whereas individual characteristics as age, sex and physical constitution are fixed, individual behaviour is influenced by social networks and norms and the living and working conditions we are confronted with. In a wider context these conditions are determined by our socioeconomic and cultural environment.

All of these layers can be influenced through specific policies: Personal behaviour factors, such as an unhealthy diet or tobacco use, can be targeted directly and through interventions in the outer layers, for example by generating a health promoting community environment or supply-sided control strategies. Interventions on the third layer ensure adequate access to goods and services such as healthy nutrition, adequate housing, education as well as appropriate access to healthcare services, necessary to enable individuals to maintain their health. The macro-policy environment requires upstream interventions, for example redressing social and income inequalities through redistribution policies.

This broad set of determinants implies that prevention strategies aiming at a sustainable improvement of populations oral health should not be single-targeted to specific skills and behaviours but must aim at a broader set of measures which also includes the underlying social determinants of health (Watt 2005). Hence, highest efficacy may be reached by a multi-layered approach targeting different levels of determinants at the same time with a range of complementary strategies.

Oral diseases share same behaviour-related risk factors with other major non-communicable diseases (NCDs) like cardiovascular diseases, cancer, diabetes and chronic respiratory diseases (Petersen 2004). Modifiable behaviours, such as an unhealthy diet with high fraction of free sugars, tobacco use as well as harmful consumption of alcohol increase the risk of NCDs. Considering all causes, tobacco use accounted for the highest disease burden with 171 million disability-adjusted life years (DALYs) globally in 2015, followed by 85 million DALYs attributable to alcohol consumption and 1.5 million DALYs caused by a diet high in sugar-sweetened beverages (SSBs) (GBD 2015 Risk Factors Collaborators 2016). While the disease burden caused by alcohol and tobacco consumption slightly decreased compared to 2005, burden of disease attributed to high SSB intake increased by 17% within the same period.

Excessive intake of sugar is a major risk factor for caries development (Moynihan and Kelly 2014). The sugar-related burden of oral diseases accounted for 4.1 million DALYs globally in 2012, which represented 26% of total dental disease burden (Meier et al. 2017). With 172 billion USD, global economic losses due to sugar-related diseases constituted 35% of the total economic impact of dental diseases. Tobacco use is especially connected to the development of periodontal disease: The global smoking- attributable burden of periodontal disease was 251,160 DALYs in 2015 (Schwendicke et al. 2018a). Thereby, smoking is responsible for more than half of the periodontitis cases among the adult population and constitutes a major risk-factor for adult periodontal disease (World Health Organization 2017c). Moreover, smoking tobacco increases the risk of periodontal disease by two times and the risk of tooth loss by 1.5. Tobacco cessation is significantly associated with better oral health outcomes, as measured by the number of lost teeth, periodontal health and the risk of new malignancies. Tobacco and alcohol consumption are regarded as the major risk factors for oral cancers (Hashibe et al. 2007). At least 75% of head and neck cancers diagnosed in industrialized countries are attributable to the combination of cigarette smoking and alcohol drinking (Blot et al. 1988). A recent review conducted by the WHO reports that tobacco use increases the risk for oral cancer and leucoplakia, a precancerosis, by five to six times (World Health Organization 2017c).

Against this background, policies to improve populations oral health should adopt a common risk factor approach accounting for the wider socio-environmental milieu that fosters these NCDs (Petersen 2009; Sheiham and Watt 2000). This implies a closer integration of oral and general health strategies. The WHO's oral health action plan emphasizes that by tackling these common risks and their underlying social determinants through joint action improvement in a range of non-communicable and chronic conditions can be achieved more effectively and efficiently (World Health Organization 2006).

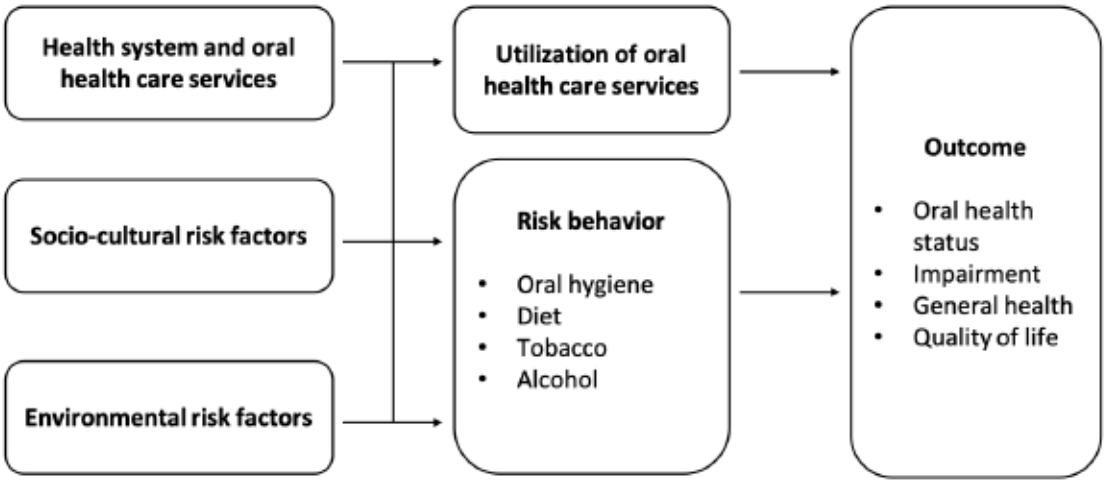

Figure 2: The risk factor approach in the promotion of oral health (according to Petersen 2004)

Appreciating a common risk factor approach and the main determinants of health, Petersen (2004) provides an integrated oral health promotional approach, outlined in Figure 2. Political measures may target whole populations with a combination of multi-layered legislative, regulative, health policy and public health approaches to address the broader determinants of oral health, defined as environmental and socio-cultural risk factors as well as health system variables. Hereby, improvements in risk behaviour and utilization of prevention-oriented oral healthcare services are intended by tackling these underlying drivers. This can eventually improve populations' oral and general health.

Action influencing individuals' risk behaviour by means of a common risk factor approach may include regulation of the distribution of processed sugary products and food labelling as well as generating health supporting environments in pre-schools, schools and workplaces (Langford et al. 2015; Petersen 2004; Watt and Sheiham 2012). According to WHO's best buys - a list of cost-effective interventions for tackling NCD's - political action may include, among others, increasing excise taxes for alcohol and tobacco, taxation of sugar-sweetened beverages, comprehensive bans of tobacco and alcohol advertising as well as front-pack-labelling (World Health Organization 2017b).

Promoting utilization of prevention-oriented oral healthcare services includes supply- and demand-sided measures. A multi-layered approach may involve reforms on a health system level considering social and community influences in order to enable adequate access to prevention-focused oral healthcare. This includes reducing financial barriers to care and strengthening primary care infrastructures, for example by promoting community-based oral

healthcare services and facilitating service use through school-based oral care programs (Niederman et al. 2017). Moreover, interventions may include needs-based planning and allocation of resources, promotion of performance-based remuneration systems and dissemination of clinical guidelines (Baum et al. 2009).

1.2 Economic incentives and the prevention of oral diseases

A sensible integrated approach to the prevention of oral diseases ties to both determinants of risk behaviour by means of a common risk factor approach as well as access to and utilization of oral healthcare services. For both aspects, interventions building upon the steering mechanism of economic incentives has been increasingly proposed by health economists and are already implemented in various settings related to general healthcare (Edelstein et al. 2015; Mendelson et al. 2017; Niederman et al. 2017; Summers 2018). Although it is evident that individuals and firms do change their behaviour as a reaction to financial incentives, evidence how interventions based on these mechanisms are able to influence oral health and utilization of prevention-oriented oral healthcare services is scarce.

1.2.1 Fiscal measures to address oral health-related risk behaviour

With regard to risk behaviour, taxes and minimum price regulations for goods with a health-threatening effect and subsidies for healthy products have proven to be effective in influencing consumers' behaviour and are eventually able to improve population's health (Niebylski et al. 2015; Stockwell et al. 2013). Hereby, these instruments are able to create behavioural incentives for health improvement by tackling the biggest contributors to preventable NCDs, an unhealthy diet high in sugar and saturated fats, inappropriate alcohol consumption and tobacco use by means of a common risk factor approach.

Taxation of unhealthy products constitutes the most prevalent fiscal strategy to discourage and therefore reduce the consumption of products that are associated with health-threatening effects (Sassi et al. 2018). Up to now taxes on tobacco and alcohol are well established fiscal instruments in many industrialized countries to both reduce consumption and generate revenues (World Health Organization 2011; World Health Organization 2017a). Public policies raising the price of alcoholic beverages reduce alcohol consumption and have significant effects on reducing alcohol-related disease and injury rates (Wagenaar et al. 2010). Consistent

evidence also shows that increases in tobacco taxes are highly effective in controlling tobacco consumption and lead to significant improvements in public health (Chaloupka et al. 2012).

Such taxes constitute a market intervention and interfere with individual consumer and producer choice. However, economic theory justifies fiscal policies of this kind with market failure caused by negative externalities generated by the consumption of these products (Sassi and Hurst 2008). In this case, consumers do not bear the full costs of consumption, which also include compensation for the harms to others (for example from second-hand smoking, treatment costs covered by publicly financed health insurance schemes, alcohol-related crime). Since these costs are not reflected by the actual market price, consumption of these products is higher than socially desirable. In this context, taxes that increase the market price constitute a market-compliant approach to reduce market failure.

Besides alcohol and tobacco consumption, an unhealthy diet is a leading risk factor for NCDs (GBD 2015 Risk Factors Collaborators 2016). Especially sugar constitutes a major source of discretionary calories in the diet, particularly for children and adolescents as indicated by national dietary surveys (World Health Organization 2016). Sugar-sweetened beverages are one of the main sources of added sugars and have become more and more affordable throughout the last two decades (Blecher et al. 2017). Over the past 50 years, sugar consumption has even tripled worldwide (Lustig et al. 2012). Considering the adverse effects of SSBs, this raises serious public health concerns and several interventions have been proposed to reduce SSB consumption. These considerations tackle SSBs in particular since they don't provide any nutritional benefit apart from additional calories, healthier substitutes are easily available and they can be clearly defined by policy makers (Briggs 2016). In recent years, fiscal policies, mainly additional ad valorem taxation, have increasingly been advocated for and are already implemented in various settings worldwide (Smith et al. 2018; Thow et al. 2018).

Evidence from natural experiments in Mexico and Berkeley, California, suggests that taxes on SSB were effective in reducing purchases. Colchero et al. 2016 showed that sales decreased by 6% on average in Mexico in 2014, the year of tax implementation. Even higher average decreases were reported for the second year with a 9.7% reduction (Colchero et al. 2017). This suggests a sustainable effect of taxation on reducing SSB consumption. Correspondingly, a 10% reduction in purchases was observed in the first year following the introduction of a

soft drink tax in Berkeley, California (Silver et al. 2017). Applying simulation-based approaches, several studies have demonstrated the positive impacts of this health policy strategy on obesity, diabetes and cardio-vascular diseases in terms of health benefits, reduced treatment costs, and fewer productivity losses (Barrientos-Gutierrez et al. 2017; Briggs et al. 2017; Lal et al. 2017; Long et al. 2015; Sánchez-Romero et al. 2016).

However, excessive intake of sugar is also a major risk factor for caries development (Moynihan and Kelly 2014). Previous modelling-based studies showed that SSB taxation is able to reduce caries incidence and DMFT increment (Briggs et al. 2017; Schwendicke et al. 2016; Sowa et al. 2019). Sowa et al. estimated that a 20% ad valorem tax for SSBs in Australia would yield to 3.9 million DMFT units averted and A$666 million in cost saved over 10 years. Applying the same taxation rate, Schwendicke et al. 2016 reported 0.75 million caries lesions prevented and avoided treatment costs of 0.8 billion euros over a 10-year horizon in Germany. Briggs et al. 2017 evaluated a specific tax proposed by the UK Government providing incentives for the industry to reformulate SSB in order to reduce sugar intake. Their results suggest that SSB reformulation would be most effective and would result in 0.27 million DMFT units averted per year. It is not yet known, how SSB taxation influences caries experience over the whole life course, going beyond direct restorations of caries lesions and including the whole restorative cycle. Moreover, little evidence exists about the extent to which the effects of SSB taxation may be influenced by consumers replacing SSBs by other (non-taxed) sugar-containing drinks.

The most common objection with regard to taxing the consumption of goods with negative percussions on health is the argument that such taxes are regressive (Allais et al. 2010; Warner and Fulton 2000). This means, fiscal interventions aimed at reducing consumption by increasing prices might impose an unfair financial burden on low-income households. This argument is weakened, when not only monetary effects are considered but also resulting health effects of taxation. Recent evidence from Finland identified potential effects of health-oriented food tax reforms (Härkänen et al. 2014). The authors showed that even though burden of taxation, in percentage terms, is highest for low income individuals, health effects appear to be most pronounced in this group. Hence, taxation may be able to reduce health inequalities in a population. Verguet et al. 2015 showed that increased taxation can even decrease the expenditures in low income groups. For a tobacco tax in China, they evaluated

that raised tobacco taxation can be a pro-poor policy instrument providing both financial and health benefits to the population.

Sin taxes are also an important source for tax revenues. In Germany, revenues from tobacco and alcohol excise taxes constituted 2.7% of total tax revenues in 2016 (Statistisches Bundesamt 2017). In the UK and Hungary, excise taxes on alcohol and tobacco accounted for about 3.3% of total tax revenues (Sassi et al. 2018). Positive health impacts of such taxation policies are even greater when some of the revenues generated by those taxes are used to strengthen health promoting action, for example by funding education campaigns, healthy food subsidies or physical after school activities (Chaloupka et al. 2012; Smith et al. 2018). Hereby, earmarking of tax revenues is able to limit the potentially regressive impact of taxation, since those health-promoting programs may offer greater benefits to members of lower income groups (World Health Organization 2016).

1.2.2 Economic incentives and utilization of prevention-oriented oral healthcare services

Utilization of oral healthcare services is influenced by both patients and providers (Breyer et al. 2005: 15). While the patient decides whether to seek care or not based on need and barriers to care, the decision about amount and type of care consumed is highly influenced by the provider due to the presence of asymmetric information (Chandra et al. 2011; McGuire 2000). Hereby, economic incentives affect the supply and demand side. High OOP (out-of-pocket) contributions may act as a barrier to seeking care and financial incentives induced through remuneration systems are able to influence the care provided to the patient once they sought care. Porter 2009 emphasizes, that sustainable improvements in populations' health under the premise of efficient resource use require both considerations around the financial burden of seeking care and improving the value of care provided, for example through outcomes-tied payment structures.

1.2.2.1 Patient-sided incentives

Health economic evidence suggests that dental care utilization is significantly determined by the service price and it is more sensitive to price changes than utilization of general medical care (Manning and Phelps 1978; Yule and Parkin 1985). For a Finnish population, it was shown that OOP prices have a small but significant effect on utilization, both on the probability of visiting a dentist and the amount of care consumed (Sintonen and Maljanen 1995). The

majority of studies found a relatively inelastic price elasticity of demand for dental services. This means, that a specific percentage increase in prices leads to a relatively lower percentage decrease in demand. Evidence also suggests that price elasticities for dental care are smaller in groups with insurance coverage for dental care expenditures compared to that of non-insured individuals. In insured populations, estimates on OOP price elasticities for dental services range from 0 to -0,47 (Beazoglou et al. 1993; Grembowski et al. 1988; Meyerhoefer et al. 2014). Based on a sample of Finish employees, Sintonen and Maljanen 1995 estimated an OOP price elasticity of -0.069 for dental care. Hence, evidence suggests that changes in demand for dental care are rather small as a reaction to price changes.

Following the argumentation of Pauly 1978, it is also reasonable to assume that OOP price elasticities of demand differ between types of dental services due to different levels of asymmetric information. Manning and Phelps 1978 estimated significant price elasticities of demand for preventive and check-up services between -0.56 and -1.34 and between -1.51 and 0.58 for restorative care. Here, no clear pattern of differentiating price elasticities of demand is observable. In contrast, price elasticities of demand estimated by Meyerhoefer et al. 2014 were not significant and close to zero for preventive, basic restorative and extensive restorative services.

Little to no evidence exists how the composition of dental care demanded changes with altering OOP prices. Evidence from general healthcare shows undesired "offsets" towards greater use and spending on other services such as acute care when cost shares for preventive and chronic care increase (Chandra et al. 2010; Hsu et al. 2006; Trivedi et al. 2010). This unintended effect may also be of relevance for oral healthcare systems since it emphasizes a specific feature of oral healthcare: Preventive services, such as fluoride varnish or sealants are effective measures to prevent oral diseases (Ahovuo-Saloranta et al. 2017; Marinho et al. 2013). In fact, recent evidence suggests that having preventive dental care results in fewer visits for expensive restorative procedures and reduced OOP expenditures (Moeller et al. 2010). Therefore, many dental insurance schemes have no co-payments for routine preventive services in contrast to other dental services (Sintonen and Linnosmaa 2000).

In general, literature provides evidence that insurance coverage is associated with increased use of prevention-oriented oral healthcare since coverage reduces the financial barriers to care. Based on U.S. survey data, a recent study showed that dental coverage increased the

probability of preventive care use by 19% and the use of restorative services by 11-16% (Meyerhoefer et al. 2014). Exploiting the same survey data source, Munkin and Trivedi 2008 found that dental insurance coverage increased the total number of general dental visits by 0.37 on average.

Public policy interventions can change the financial burden of seeking dental care. Evaluations of those interventions provide evidence how altering demand-sided financial incentives can affect utilization of prevention-oriented dental services and oral health.

Ikenwilo 2013 examined the effect of free dental check-ups on utilisation in the NHS (National Health Service) system in Scotland. She showed that there was a 3-4% increase in NHS dental check-up in Scotland, compared to the rest of the UK.

A number of recent studies provide evidence about access to care by means of policy interventions in U.S. public coverage programs, such as Medicaid and SCHIP (State Children's Health Insurance Programs). Wang et al. 2007 demonstrated that the introduction of SCHIP reduced the probability of unmet dental care needs for low income children by 40% and Choi 2011 estimated that Medicaid dental benefits increased the probability that adults visited a dentist by 16–22%. According to Abdus and Decker 2019, adult Medicaid coverage for non-emergency dental services was also associated with a higher use of preventive services. Medicaid enrolees with coverage were 7 percentage points more likely to have any preventive dental service than those enrolees from states not providing this benefit. Moreover, they were also 9 percentage points more likely to have a dental visit. For those visiting the dentist with non-emergency dental coverage, OOP share of dental expenditures was approximately 19 percentage points lower. With regard to effects on health outcomes, Decker and Lipton 2015 showed that Medicaid dental coverage for adults is associated with an increase in the likelihood of a recent dental visit and a reduction in the likelihood of untreated dental caries. Moreover, a significant positive effect on self-reported oral health outcomes was notified.

Evidence from the RAND Health Insurance Experiment suggests that reducing cost sharing for dental services improves oral health for those younger than age 35 and especially for those subgroups of the population with the poorest oral health (Bailit et al. 1985).

All in all, evidence suggests that lowering financial barriers to care increases utilization of prevention-oriented dental care and eventually improves populations' oral health.

Besides changes in the coverage provided, policy interventions can also influence the financial burden patients face indirectly, through market-oriented reforms such as price liberalizations. Whereas the former has a direct effect on patients' OOP payments when seeking care, the effect of the latter highly depends on market characteristics. The introduction of market mechanisms is intended to improve the quality of care and to contribute to cost containment, but increasing health expenditures for individuals have been observed in this context (Harrison and Calltorp 2000). Whereas comprehensive insurance coverage often mitigates such effects for care relating to more life-threatening health conditions, dental care frequently gives rise to a different picture because dental coverage is rarely as universal as coverage for other types of healthcare (Sintonen and Linnosmaa 2000).

Norway deregulated its fee system for adult dental care in 1995 (Grytten and Sørensen 2000). This replaced a system with fixed fees determined by annual negotiations between governmental bodies and provider representatives. In the short run, this price competition led to small variations among the fees which dentists charge. The authors concluded that dentists didn't exploit their market power since their action was constrained by motives other than self-interest. In contrast to the interpretation of Grytten and Sørensen, an alternative reason for the small impact of market deregulation on equilibrium prices might be that fixed prices based on negotiations were already close to the market equilibrium with deregulated prices.

In Sweden, prices for dental care are also market-determined. Chirico 2013 showed that the effect of competition on prices in the Swedish system is small. This means that prices are set above the competitive level and the market does not promote competition among suppliers to the intended extent. Moreover, her results suggest that competition has different effects on different types of services. Whereas price competition is more intense for informative first-stage services, such as oral examinations, competition for therapeutic follow-on services is weaker. This emphasizes different levels of asymmetric information for different services (Dranove and Satterthwaite 1992; Pauly 1978). Patients are better informed about procedures they use on a regular basis, such as check-up examinations, than about complex and less frequently used interventions, such as endodontic treatments or extractions. Demand is therefore more price sensitive for first-stage services than for uncommon therapeutic interventions. In turn, the potential for dentists to increase revenues from follow-on services

with a greater level of information asymmetry will be higher than for first-stage services. Market liberalization promoting competition among suppliers is expected to have heterogeneous effects on service prices.

Market-oriented reforms, such as price liberalizations, affect the OOP prices patients face not uniformly and it remains unclear how such policy interventions influence utilization patterns of prevention-focused oral healthcare services.

1.2.2.2 **Provider-sided incentives**

Turning to the evidence regarding the effect of economic incentives on dentist behaviour. The extant literature shows that healthcare providers react to financial incentives associated with different payment schemes with regard to scope and structure of services provided (Chalkley and Tilley 2006; Robinson 2001). Hence, providers' reimbursement should be organized in such a way that desirable behaviour is rewarded whereas undesirable behaviour isn't incentivized (Grytten 2005). However, pure payment schemes, such as salary, fee-for-service and capitation come all with both strengths and weaknesses and are therefore not able to align dentists' economic incentives with patients' needs alone (Brocklehurst et al. 2013b). While salary based payment allows the treatment of complex cases and therefore doesn't encourage a pre-selection of patients with regard to expected revenues, it fails in imposing an incentive for high productivity (Robinson 2001). In contrast, fee-for-service remuneration promotes productivity and secures quality. This often goes along with increasing costs as fee-for-service also incentivizes maximization of service delivery and number of patients (Grytten 2017). This direct link between income and the level of activity may lead to an increase in the quantity of service provided going beyond the minimum necessary to achieve the treatment goal (Robinson 2001). This is supported by empirical findings from dental care, which point towards incentives for overtreatment under fee-for-service (Birch 1988), higher check-up utilization under this scheme compared to salary-based remuneration (Listl and Chalkley 2014) as well as increased treatment intensity for patients with payment exemptions under a fee-per-item remuneration compared to salaried dentists (Chalkley and Tilley 2006). Recent evidence from an experimental setting confirms the empirical results that salary yields to lower output but highest quality whereas fee-for-service payment induces high quantity (Lagarde and Blaauw 2017). Capitation, on the other hand,

secures effectiveness but is prone to patient selection and under-treatment (Brocklehurst et al. 2013b; Grytten 2005).

Both healthcare payers and health economists have long been proposing innovations in dental remuneration systems in order to overcome drawbacks of pure salary or fee-for-service systems and to face increasing expenditures without concomitant increases in population's oral health (Edelstein 2018; Voinea-Griffin et al. 2010a). Specifically, innovations that combine existing remuneration with performance-oriented and value-based payment structures are in experts' focus (Niederman et al. 2017). These blended payments link financial incentives to providers' performance based on their scores on a set of predefined performance measures. However, consistently positive associations of performance-oriented payment with improved health outcomes have not been demonstrated yet in any healthcare setting. Lessons from general medicine provide evidence for improved processes of care as a result of pay-for-performance programs as well as a reduction in hospital readmissions (Damberg et al. 2014; Mendelson et al. 2017).

In comparison to other fields of medical practice, experiences and empirical evidence of such arrangements in dental care are still very limited. A pilot program to establish quality incentives is currently underway in the British NHS. Based on the so-called Dental Quality and Outcomes Framework parts of dentists' remuneration were linked to dentists' performance measured by quality indicators. The Dental Quality and Outcomes Framework focuses on patients' safety (recording of up to date medical history), clinical effectiveness (improvements in patients' oral conditions), patient experience indicators (patient reported measures) and data quality (timeliness of data transmission) (Department of Health 2011; Department of Health 2016). After two years, the new blended contract showed significant improvements in oral health-related quality of live (Hulme et al. 2016). However, the effect size was smaller than the specified minimally important difference. Differences in generic health-related quality of life were negligible.

A major reason why dissemination of pay-for-performance in dentistry is limited is the lack in evidence-based performance measures in dental care (Campbell and Tickle 2013b). To fulfil this need, routinely available data describing clinical practice and the development of measures are needed (Schnackenberg and Tomlinson 2016; Starfield 1998).

In oral health, there is neither a diagnostic oral health coding system nor a set of oral healthcare quality measures that are generally accepted, implemented, or used. The FDI World Dental Federation recently established a new theoretical definition for oral health and highlighted the development of consensus-based measures for implementation in clinical practice as a key challenge for the research community (Glick et al. 2017; Lee et al. 2017). An important step in the development of relevant measures for oral healthcare is the identification of topics that are valid, important, and relevant to 1) measure the quality of care, 2) describe aspects of oral health in patients and populations, and 3) identify and describe the factors that potentially affect delivery of care or oral health and may therefore explain warranted, as opposed to unwarranted, variation (Baâdoudi et al. 2016; Navathe and Emanuel 2016). The measures outlined in the literature are often focused on supply measures on a system level, such as number of dentists. These measures overlook important aspects of dental care delivery and might even act as a barrier for developing effective policies to address problems in oral healthcare delivery by putting emphasis on measures that do not show a clear relation to daily practice (Pourat et al. 2015). Moreover, existing literature does not include all relevant stakeholders in their development. Stakeholder engagement is essential in the development and execution of valid measures in order to ensure that information needs are met as efficiently and appropriately as possible (Delnoij et al. 2010).

In recent years, emphasis has been put on developing quality measures in dentistry taking into account patients' outcomes (Baâdoudi et al. 2017; Hummel et al. 2017). But experiences with and wider implementations of such quality measures are still missing. In order to overcome this lack of quality indicators, surrogate measures have been applied to assess dentists' performance in a performance-oriented payment system. Here, performance and thus additional payments are often related to measures based on the provision of specific "desired" dental services. Such a pay-for-performance incentive program is currently implemented in a large dental group practice in Oregon, U.S. (Conrad et al. 2018). Performance incentives are based on the proportion of enrolled clients receiving care and the provision of dental check-ups and fluoride application to patients with increased dental care needs. An evaluation of the program's effectiveness hasn't been available yet. Another initiative in the U.S. connected dental provider incentives to tobacco cessation assistance and resulted in a substantial increase in incented provider behaviour; however, the intervention

was less effective with respect to ultimately effectuating smoking cessation among patients (Little et al. 2009). Similar effects were observed in a pay-for-performance program in Minneapolis where incentive payments were linked to a completed risk assessment target (Voinea-Griffin et al. 2010b).

Besides linking payments with performance targets, specific treatments can also be directly incentivized through higher per-item-remuneration. Those alterations in reimbursement schemes provide general evidence about the effect of explicit financial incentives on the provision of care. For example, a $10 rise in Medicaid prophylaxis reimbursement (from $20 to $30) was shown to increase dentists' participation in Medicaid program and to be associated with a 4 percentage point increase in the chance that a child or adolescent covered by Medicaid had seen a dentist (Decker 2011). More recent evidence also expands these finding to the adult population (Decker and Lipton 2015). A similar effect was observed in Ireland where a 62% increase in payments for amalgam direct restorations led to a significant increase in restorative care and a decrease in extractions indicating a shift to a more tooth-conserving focus (Woods et al. 2010). Successful enhancement of prevention through financial incentives was also achieved in a Scottish study: An additional service fee for sealing newly-erupted first molars led to a 10% increase in sealants application (Clarkson et al. 2008).

Beneath reaching intended results through financial incentives, attention needs to be paid to unintended side effects of these payment arrangements. In contrast to economists' view that perceives performance-oriented financial incentives as the major motivator, laboratory studies pointed towards potential crowding out of intrinsic motivation through establishing financial incentives (Deci et al. 1999). This can eventually lead to poorer performance when the negative crowding-out effect exceeds financial incentive's positive impact (Kao 2015). In addition, when incentivizing the provision of specific services, the general effect of pay-for-volume – increase in service utilization – comes into play. Whereas an increase in service provision through financial incentives is intended for some treatments, attention must be paid to intervention's impact on potentially harmful procedures. For example, decision about X-ray provision should weigh clinical benefits against the risks of X-ray exposure and provider's payment incentives shouldn't come into play here. However, it was shown that X-rays increase significantly when dentists switch from salary to fee-for-service reimbursement in the absence of patient co-payments (Chalkley and Listl 2018). These previous experiences show that

careful evaluation of payment reforms is needed that focuses on both targeted parameters as well as potential side effects.

1.3 Aim and scope of the dissertation

Prevention of oral diseases remains a challenge for health policy makers in Europe. This raises the question, how oral health can be influenced in a sustainable manner by tackling different aspects in the broader social determinants of oral health. Financial incentives play a major role in this context. Little is known about how interventions exploiting the steering effect of those incentives can actually affect utilization of preventive oral healthcare services or influence oral health-related behaviour. The aim of this dissertation is to provide useful evidence to policy makers about how policy interventions based on economic incentives may serve as a helpful tool for preventing oral diseases. Hereby, this work focuses on incentives on the population and patient side as well as provider-sided incentives in the context of European (oral) healthcare systems. In order to enhance evidence-informed policy making a series of qualitative and quantitative methods were exploited.

Policy making is decision-making under uncertainty and under the premise of efficient use of scare resources. Hence, sufficient scientific evidence is needed about potential indented and unintended effects of reforms. When considering quantitative approaches, research designs using random assignment are the most credible and influential. However, providing useful evidence from quantitative approaches is often perceived as a challenge when randomized controlled trials (RCTs) are not feasible due to ethical or economic concerns (Angrist and Pischke 2008: 6). Simulation-based ex-ante approaches and ex-post evaluations based on quasi-experimental designs constitute an alternative in this context. While these approaches are extensively applied in economics, social sciences and general healthcare research, dissemination of those methods in dental research is scarce (Listl et al. 2016).

Simulation-based approaches are a tool to generate evidence were RCTs are not feasible and at the same time suitable natural experiments and appropriate observational data aren't available. In this case, ex-ante approaches, such as Markov simulation models, provide a framework to make best use of current clinical and economic evidence from different sources through a structured consideration (Drummond et al. 2015: 3). Such approaches enable simulation-based economic evaluations of different policy options. Due to their systematic

character these approaches can increase the explicitness and accountability in decision-making.

Compared to other diseases, health economic evaluations of oral prevention are scarce, especially with regard to long-run cost and effects (Källestål et al. 2003; National Institute for Health and Care Excellence 2014). However, this is crucial since health benefits and savings from averted dental disease accrue over a whole life cycle. In contrast, health economic assessments mainly focus on short-run comparison of different materials or preventive and restorative techniques leaving the effects of uncontrolled disease progression aside.

Exploiting a simulation-based ex-ante method, Section 2 of this dissertation examines the impact of a fiscal policy intervention that targets nutrition-related risk behaviour based on the common risk factor approach. The study aims to answer the question, how can the sugar-related caries burden and caries related treatment costs be reduced over a lifetime horizon by the introduction of a 20% ad valorem tax on sugar-sweetened beverages. Using a Markov decision-analytic model, SSB taxation was compared with the current standard of no SSB taxation for the current Dutch population. It was chosen to focus on the Dutch population since it belongs to the top three sugar-consuming countries in the world (Pariona 2017). At the same time, Dutch population's levels of SSB consumption are comparable with those of other western European countries, such as the UK, Germany or France (Singh et al. 2015). The analysis may therefore be able to serve as a template that is transferable to other country profiles.

Beneath fiscal policy interventions targeting populations' risk behaviour, interventions may also focus on the utilization of prevention-oriented oral care in order to improve populations' oral health. Section 3 and 4 of this dissertation analyse changes in dental payment structures that affect economic incentives for patients or providers and their impact of utilization of (prevention-oriented) dental care.

Establishing a causal link between payment structure and utilization of care requires suitable natural experiments when conducting randomized controlled trials is not possible. While random assignment solves the selection problem by eliminating selection bias, the application of suitable identification strategies allows to approximate real experiments by exploiting natural variation form observational data (Angrist and Pischke 2008: 6).

Those natural or quasi-experiments mimic randomized trials by changing the variable of interest while other factors are kept balanced (Angrist and Pischke 2008: 16). Examples are sharp class-size cut-offs (Angrist and Lavy 1999), policy interventions that affect years of compulsory schooling (Matsuyama et al. 2019), birthweight thresholds in hospital reimbursement systems (Reif et al. 2018) or changes in provider remuneration (Chalkley and Listl 2018). Appropriate exploitation of those interventions allows to control for unobserved confounders and can therefore seek causal inference from non-experimental settings. Several types of quasi experimental designs exist. Among these are instrumental variables approaches, fixed and random effects models, difference-in-differences (DiD) analyses and regression discontinuity designs.[1] Increasing availability of administrative data enables an application of these methods to oral health policy research questions (Listl et al. 2016).

Based on a fixed-effects regression approach, Section 3 evaluates the effect of a market-oriented reform in the Dutch oral healthcare delivery system where dentists were allowed to set the prices for their dental services themselves. This so-called "free market experiment" (FME) replaced a system with fixed service prices. Whereas those market-oriented reforms are intended to meet consumer preferences more efficiently, increasing OOP expenditures for patients were observed in this context. Therefore, this section examines the effect of altering economic incentives induced by the FME on utilization patterns of prevention-focused dental care. Hereby, price changes following the reform, altering utilization patterns and price elasticities of demand were analysed. The overriding question to be answered is: Are market-oriented reforms a suitable policy option to improve prevention-oriented dental service use, given the existing market environment? In order to examine patients' utilization patterns a fixed-effect panel regression was applied. This quasi-experimental design allowed to control for unobserved characteristics of the individual that are fixed over time but may correlate with the outcome of interest (Stock and Watson 2012: 396).

As outlined previously, utilization of care is also sensitive to financial incentives induced through provider remuneration. Section 4 examines the impact of combining salary payments with performance-oriented financial bonuses on the utilization of dental care. Hereby the

[1] For an overview of those quasi-experimental designs please refer to Angrist and Pischke 2008 for a general introduction and to Listl et al. 2016 for an introduction with a specific focus on dental research.

question is addressed, whether financial incentives for providers are an effective measure to increase utilization of dental services. Hence, does performance-oriented payment work and do potential side effects exist?

The analysis exploited natural variation in financial incentives in a large ambulatory care setting at Heidelberg University in which dental health professionals receive salary payments but only one subgroup of dental care providers was exposed to the introduction of performance-oriented bonus payments. Hereby, provider's performance was assessed by a surrogate measure that builds upon the provision of specific "desired" service items. The availability of a suitable comparison group within an isolated clinical environment constitutes a quasi-experimental setting that allowed the application of a difference-in-differences approach. In short, DiD is a pre-post with-without comparison (Angrist and Pischke 2008: 169). Under this approach, the effect of the intervention on the outcome of interest is calculated by comparing the average change over time in the outcome variable for the treatment group, compared to the average change over time in the control group (Dimick and Ryan 2014). A suitable identification strategy requires that both groups follow the same time trend while only the treatment group is exposed to the intervention. If this assumption is fulfilled, the intervention's impact can be separated from general influences affecting both treatment and control group to the same extent.

The definition of performance parameters applied in the intervention evaluated in Section 4 followed a rather pragmatic approach. To contribute to the aim of the dissertation – how can economic incentives promote oral health through the prevention of oral diseases – Section 5 focuses on defining relevant target parameters for patient-centred and prevention-focused oral healthcare delivery. These are able to serve as suitable target parameters for performance-oriented payment structures that incentivize prevention-focused oral healthcare delivery. In combination with the previous section, Section 5 provides evidence about potential content and effect of performance-oriented payment systems in dental care. Therefore, quantitative research about the impact of performance-oriented payments is enriched by a qualitative approach. A structured 4-stage research design based on stakeholder involvement was applied to define a consensus-based set of relevant measures. Beneath literature search and appraisal, this approach included expert discussions, a two-stage Delphi process and a World Café meeting. The aim was to create consensus through

structured conversations among oral healthcare stakeholders from different European countries.

2 Taxation of sugar-sweetened beverages and caries prevention

2.1 Background

As outlined in the previous section, excessive intake of sugar is a major risk factor for caries development and other major NCDs (GBD 2015 Risk Factors Collaborators 2016; Moynihan and Kelly 2014). In order to prevent sugar-related diseases, including caries, the World Health Organization recommends that sugar intake should not exceed 10% of total energy intake and should ideally be no more than 5% of total energy intake (World Health Organization 2015).

Sugar-sweetened beverages are one of the main sources of added sugars and have become more and more affordable throughout the last two decades (Blecher et al. 2017). Considering the adverse effects of SSBs, this raises serious public health concerns and several interventions have been proposed to reduce SSB consumption following a common risk factor approach. In this context, fiscal policies, mainly additional ad valorem taxation, have increasingly been advocated for and are already implemented in various settings worldwide (World Health Organization 2015). Additional taxation targets individual risk behaviour by lowering accessibility of these goods through increased prices. Hereby, this political measure doesn't target individual risk behaviour directly, as knowledge-based approaches for example do, but by means of influencing the broader social determinants of health. In this context, socio-cultural risk factors located in people's living and working conditions are addressed. Influencing access to unhealthy food eventually improves nutrition-related risk behaviour.

Is SSB taxation a helpful policy intervention for caries prevention? So far, little is known about the caries-related impacts of SSB taxation, about the extent to which the effects of SSB taxation may be influenced by consumers replacing SSBs by other (non-taxed) sugar-containing drinks and about the amount of costs saved from avoided treatments over the whole life cycle. Therefore, the purpose of this section was to assess the potential caries-related effects and associated saving in treatment costs of introducing a 20% ad valorem tax on SSBs.

2.2 Methods

From a societal perspective, the potential health economic impact of introducing a 20% ad valorem tax on sugar-sweetened beverages with respect to occurrence of dental caries and associated treatment costs was assessed. Using a Markov decision-analytic model, SSB taxation was compared with the current standard of no SSB taxation. Markov models are stochastic state-transition models that enable synthesis and analysis of the published evidence, considering benefits, harms and costs in order to support decision making under conditions of uncertainty (Sonnenberg and Beck 1993). As shown in Figure 3, the analysis assumed that SSB taxation will result in increased market prices, which will subsequently result in reduced demand for SSBs according to the price elasticity of demand for those products. This will lead to changes in sugar consumption and consequent reduction in caries increment. Reducing caries burden within the society eventually reduces caries-related treatment costs. Moreover, tax revenues will be generated from additional taxation. SSBs were defined to include liquids with added sugar, that are: carbonated drinks, soft or isotonic drinks, fruit drinks and diluted syrups.

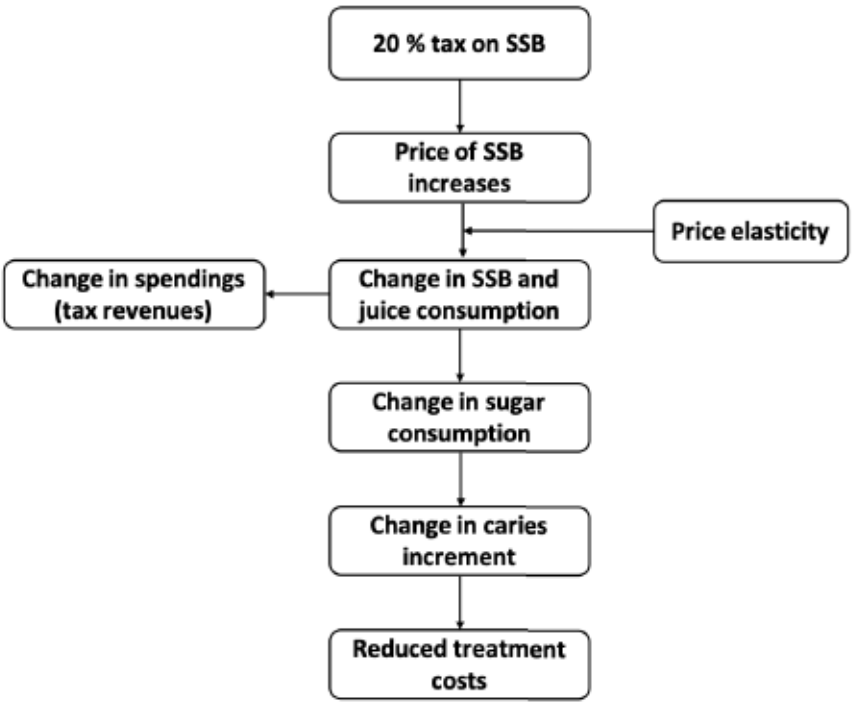

Figure 3: Conceptual model of SSB taxation and its effects

2.2.1 Target population and time horizon

As the analysis focused on the effects on permanent dentition, those aged younger than 6 years were not included. The model was designed with reference to the Dutch population

aged 6 to 79 years in 2016, thereby aiming at simulations which can be considered relevant for the context of high-income countries. The composition of the population, stratified by age and sex, was retrieved from Statistics Netherlands (Centraal Bureau voor de Statistiek 2017). The demographic characteristics are comparable to other Western European countries. The model was run for a lifetime-horizon (i.e. until the 2016 Dutch population reached mean life-expectancy). The Dutch population was chosen as the model's target population as the Netherlands is the third country in the world with highest sugar consumption (Pariona 2017). Only 10% of Dutch children have sugar intake below the values recommended by the WHO (van Rossum et al. 2016). Furthermore, preventable oral disorders belong to the ten health problems responsible for a large part of disability in the Netherlands (Institute for Health Metrics and Evaluation 2018). In 2015, costs of dental healthcare in the Netherlands exceeded 3.75 billion euros (Righolt et al. 2018).

2.2.2 SSB consumption and (cross-)price elasticities

Beverage consumption data was extracted from the Dutch National Food Consumption Survey (van Rossum et al. 2016). This survey collects periodical data on food consumption and nutrition status for a representative sample of people living in the Netherlands. The data were obtained at an individual level, which allowed the derivation of population-representative consumption estimates for different age groups (6-8, 9-18, 19-50, 51-79 years) (Appendix Figure A1 - 1 and Figure A1 - 2). Non-alcoholic beverages of interest were divided into two groups: (1) fruit juices (not subject to SSB taxation); and (2) SSBs (subject to taxation): diluted syrups, carbonated, soft or isotonic drinks. After estimating the change in volume of beverages consumption due to taxation, changes in sugar intake were calculated according to beverages' sugar content provided by the Dutch Food Composition Database (Dutch Food Consumption Database (NEVO online version 2016/5.0) 2016).

Since no estimates of own- and cross-price elasticities were available for SSB consumption in the Netherlands, the analysis relied on estimates of price-elasticities as available from a meta-analysis (Long et al. 2015). According to the results of Long et al. 2015, a price elasticity of demand for SSBs of -1.21 (95% CI (Confidence Interval) -3.87 to -0.69) and a cross-price elasticity of demand for fruit juices of 0.637 (95% CI 0.14 to 1.447) was used.

2.2.3 Outcomes

The number of caries lesions prevented and caries-free tooth years gained were estimated. A caries-free tooth year represents a year spent without caries experience per tooth. Additionally, treatment costs avoided, administrative costs of SSB taxation and tax revenues were calculated (see below for more details).

A tooth-level Markov state-transition model was developed to evaluate the cost and effects of SSB taxation on caries and oral healthcare (Figure 4). Transition patterns were adjusted according to the Dutch clinical routine and implemented in the model. Assuming that dental check-ups would take place every 6 months, a 6-month cycle length was applied (OECD 2018). In case a treatment need is determined during diagnostic assessment, it was assumed that the required treatments are carried out immediately. Hence, the required treatment is always provided at the start of a new state.

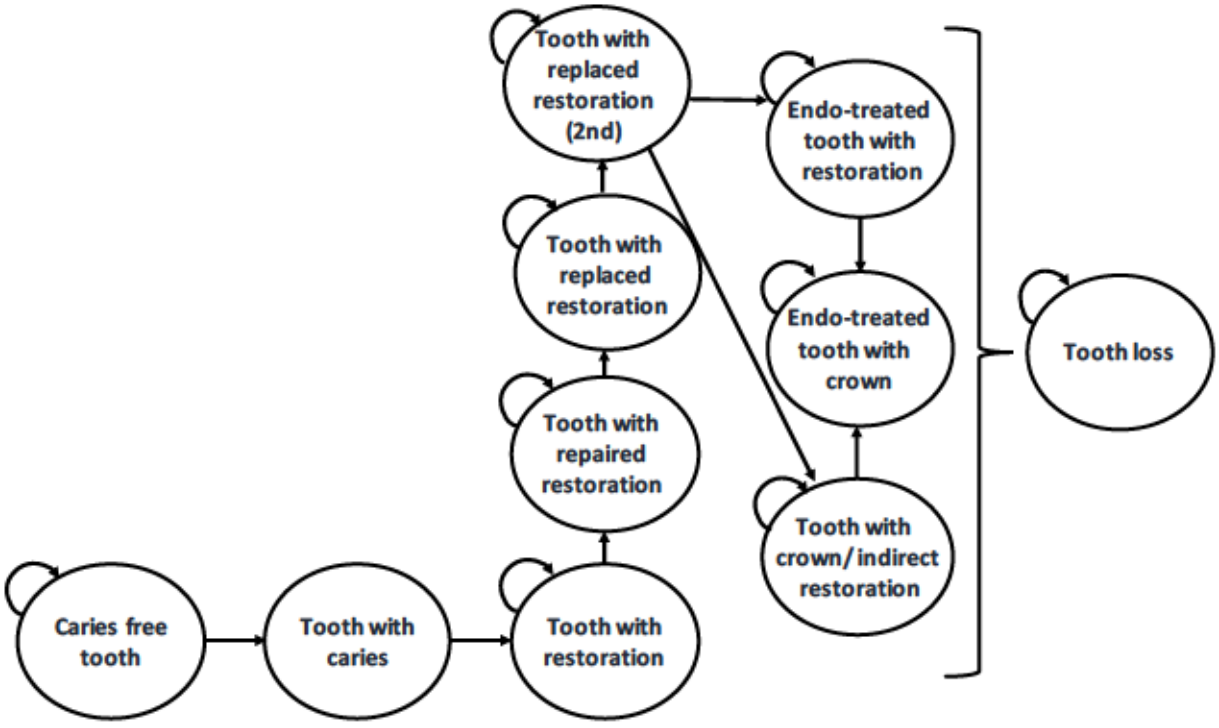

Figure 4: Conceptual framework of the Markov model: tooth exposure to caries and dental healthcare

Note. Arrows indicate possible transitions between Markov states (states of a tooth within the restorative cycle) represented by the circles. However, for better readability not all possible options are included. The full transition list is provided in Table 1.

Transition probabilities among the different Markov states were derived from the literature (Table 1). It was assumed that the cohort starts in the caries free state and in case of developing caries within a six months interval between two check-up examinations, restoration would be the only possible treatment. Repairing the original restoration was defined as partial replacement involving only one surface. Replacement of restoration was assumed to generate one additional treated surface (Brantley et al. 1995). Endodontic re-treatment was not considered within the model. An individual-level perspective generated through a simple aggregation of the tooth-level model was adjusted for the time of permanent teeth eruption and the impact of a declining number of teeth over the life course (American Dental Association 2012; Stock et al. 2015).

Data on caries incidence were obtained from the publicly available open-source platform of the Institute for Health Metrics and Evaluation (Institute for Health Metrics and Evaluation 2018). The relationship between the amount of consumed sugar and caries was derived from a Finnish longitudinal study (Bernabé et al. 2016). The 6-month probability of caries development per tooth was calculated for every 10g of sugar additionally consumed on a daily basis. A detailed depiction of the calculation is provided in Appendix A1.1.

Table 1: Six-months transition probability between Markov states

State	Transition to	Probability	Source
Restoration	Restoration	0.991967773	Pallesen et al. 2013
	Repair restoration	0.000803223	Pallesen et al. 2013
	Replace restoration	0.003614502	Pallesen et al. 2013
	Endo + restoration	0.001228931	Pallesen et al. 2013, Skupien et al. 2013 (adjusted)
	Endo + crown	0.000779126	Pallesen et al. 2013, Skupien et al. 2013 (adjusted)
	Crown	0.000803223	Pallesen et al. 2013
	Extraction	0.000803223	Pallesen et al. 2013
Repaired restoration	Repaired restoration	0.9507216	Gordan et al. 2015
	Repair repaired restoration	0.012812384	Gordan et al. 2015
	Replace repaired restoration	0.019760638	Gordan et al. 2015, Pallesen et al. 2013 (adjusted)
	Endo + restoration	0.003646602	Gordan et al. 2015, Skupien et al. 2013 (adjusted)
	Endo + crown	0.002266806	Gordan et al. 2015, Skupien et al. 2013 (adjusted)

	Crown	0.004385778	Gordan et al. 2015, Pallesen et al. 2013 (adjusted)
	Extraction	0.006406192	Gordan et al. 2015
Replaced restoration	Replaced restoration	0.9729898	Gordan et al. 2015
	Repair replaced restoration	0.00405153	Gordan et al. 2015
	Replace replaced restoration	0.00950759	Gordan et al. 2015, Pallesen et al. 2013 (adjusted)
	Endo + restoration	0.004807816	Gordan et al. 2015, Skupien et al. 2013 (adjusted)
	Endo + crown	0.003025142	Gordan et al. 2015, Skupien et al. 2013 (adjusted)
	Crown	0.002106796	Gordan et al. 2015, Pallesen et al. 2013 (adjusted)
	Extraction	0.003511326	Gordan et al. 2015
Replacement of replaced restoration	Replaced replaced restoration	0.9729898	Gordan et al. 2015
	Endo + crown	0.007832958	Gordan et al. 2015
	Crown	0.015665916	Gordan et al. 2015
	Extraction	0.003511326	Gordan et al. 2015
Endodontic treatment + restoration	Endo + restoration	0.9850134	Skupien et al. 2013
	Endo + crown	0.00180644	Skupien et al. 2013, Pallesen et al. 2013 (adjusted)
	Endo + repaired restoration	0.00180644	Skupien et al. 2013, Pallesen et al. 2013 (adjusted)
	Endo + replaced restoration	0.008129	Skupien et al. 2013, Pallesen et al. 2013 (adjusted)
	Extraction	0.00324472	Skupien et al. 2013
Endodontic treatment + crown	Endo + crown	0.99034689	Skupien et al. 2013
	Endo + crown replacement	0.0014557	Skupien et al. 2013, Burke and Lucarotti 2009 (adjusted)
	Endo + crown recementation	0.00291141	Skupien et al. 2013, Burke and Lucarotti 2009 (adjusted)
	Extraction	0.005286	Skupien et al. 2013
Crown	Crown	0.987267712	Burke and Lucarotti 2009
	Crown replacement	0.002597386752	Burke and Lucarotti 2009
	Recementation	0.005385757824	Burke and Lucarotti 2009
	Endo + crown	0.001338418115	Burke and Lucarotti 2009, Trautmann et al. 2000 (adjusted)
	Endo + crown + restoration	0.0005204959334	Burke and Lucarotti 2009, Trautmann et al. 2000 (adjusted)
	Extraction	0.002890229376	Burke and Lucarotti 2009

2.2.4 Cost

Costs for different treatment modalities were extracted from the national price list for dental services (Nederlandse Zorgautoriteit 2017). Additionally, the dental technician fee was added to the dental costs for crowns, based on the price list of a large University Policlinic in the Netherlands (Table 2). Tax revenues of a potential ad valorem tax on sugar-sweetened beverages were calculated based on estimated consumption under taxation and 2015 beverage consumer prices (Eurostat 2015). The latter were accumulated to the baseline year by adjusting for inflation rates. Calculations were performed for the life-time horizon of the current Dutch population. Sensitivity checks were performed to account for different levels in price elasticities of demand. According to Dutch average administrative cost of tax collection, administrative expenditures were assumed to be 1.07% of tax revenues from the SSB taxation (OECD 2015).

Table 2: Costs per dental intervention (€)[†]

Course of treatment	Cost (€)	Course of treatment	Cost (€)
Examination	20.44	Replace 2-surface restoration	95.74
1-surface restoration	71.54	Replace 3-surface restoration	114.57
2-surface restoration	84.99	Replace more than 3-surface restoration	114.57
3-surface restoration	95.74	Endodontic th + restoration	359.3
More than 3-surface restoration	114.57	Endodontic th + crown[‡]	948.64
Repair 1-surface restoration	71.54	Crown[‡]	632.37
Repair 2-surface restoration	71.54	Crown replacement[‡]	659.26
Repair 3-surface restoration	71.54	Crown recementation	21.51
Repair more than 3-surface restoration	71.54	Extraction	55.4
Replace 1-surface restoration	84.99		

[†] Nederlandse Zorgautoriteit, Tandartstarieven 2017
[‡] Radboudumc Department of Dentistry

Following the guideline for economic evaluation in healthcare in the Netherlands, future costs were discounted at 4% and future health effects were discounted at 1.5% (Zoorginstituut Nederland 2016).

2.2.5 Sensitivity and scenario analyses

Uncertainty in several input parameters was considered with their specified distributions (caries incidence - Beta distribution, sugar content in beverages of interest - Triangular distribution, transition probabilities - Beta and Dirichlet distribution, dental treatment costs - Gamma distribution). Due to unavailable standard deviation for transition probabilities and

costs of dental interventions, standard deviations were defined as +/-10% of the mean reported value.

To determine the extent of the uncertainty, Monte Carlo simulation using 5000 iterations was employed. This allowed estimating the means and 95% confidence intervals. In the base case, mean values for the price and cross-price elasticities for SSB and fruit juices were used as reported in the literature. Additionally, deterministic sensitivity analysis was performed to address the uncertainty in relationship between caries incidence and the amount of sugar consumed using lower and upper bound for caries incidence reduction.

Due to high uncertainty around the Dutch (Western European) preferences for SSB beverages (price elasticity) and fruit juices (cross-price elasticity), alternative scenarios were examined, replacing the abovementioned mean values with lower and upper bounds. Scenario 1 reflects the strongest possible reaction of the Dutch population to taxation. Own price elasticity of -3.87 for SSBs and cross-price elasticity for fruit juices of 0.14 were used in the simulation. The least elastic demand for SSB was evaluated in Scenario 2, taking the upper values for price-elasticity and cross-price elasticity from the literature (-0.69 for SSBs and 1.45 for fruit juices) as input parameters in the model. To compare the impact of uncertainties in different parameters on the outcomes of interest (number of caries lesions prevented, amount of caries-free tooth years gained and amount of treatment costs avoided) tornado diagrams were created as a graphical presentation of sensitivity of the results. All analyses were performed using the TreeAge Pro Healthcare Module 2017 software (TreeAge Software, Inc., Williamstown, MA).

2.3 Results

In the base case scenario, introducing the 20% SSB taxation would prevent development of 1,030,163 (95% UI (Uncertainty Interval) 1,027,903 to 1,032,423) caries lesions (Table 3), which comprises an absolute reduction of 0.55% as compared to the current situation. On a person level, each individual in the population would on average benefit with 2.13 (95% UI 2.12 to 2.13) caries-free tooth years. With a lifetime horizon, a total of 159.01 (95% UI 158.67 to 159.35) million euros of caries-related treatment cost would be saved on a population level. For boys aged 6-12 years the intervention would be most beneficial with 162,213 (95% UI 161,095 to 163,330) caries lesions prevented and 6.17 (95% UI 6.14 to 6.20) millions of caries-

free tooth years gained. In girls and women, the benefits in terms of caries-free tooth years per person are lower as compared to boys and men, 1.64 and 2.61 caries-free tooth years, respectively. The estimated lifetime tax revenues (3.49 billion euros) are larger than the administrative costs for tax collection (37.30 million euros).

Table 3: Oral health benefits and treatment costs avoided due to 20% SSB taxation, lifetime horizon, mean values for price-elasticities, mean value for caries incidence reduction

	Caries lesions prevented (total)	Caries-free tooth years (per person)	Caries-free tooth years (total, million)	Treatment costs avoided (million €)
Boys & men				
Boys aged 6-12	162,213 (161,095 to 163,330)	9.07 (9.03 to 9.11)	6.17 (6.14 to 6.20)	23.83 (23.73 to 23.93)
Men aged 13-18	103,270 (102,941 to 103,598)	5.82 (5.80 to 5.83)	3.64 (3.63 to 3.65)	15.90 (15.86 to 15.95)
Men aged 19-35	197,449 (196,819 to 198,079)	3.42 (3.40 to 3.44)	6.16 (6.13 to 6.19)	32.32 (32.20 to 32.44)
Men aged 36-55	134,201 (132,873 to 135,530)	1.33 (1.32 to 1.35)	3.16 (3.12 to 3.20)	20.23 (20.00 to 20.46)
Men aged 56-79	45,929 (456,62 to 46,195)	0.32 (0.32 to 0.32)	0.68 (0.67 to 0.69)	5.46 (5.42 to 5.51)
Girls & women				
Girls aged 6-12	101,068 (100,329 to 101,806)	6.35 (6.31 to 6.38)	4.12 (4.10 to 4.14)	16.12 (16.05 to 16.20)
Women aged 13-18	62,371 (62,173 to 62,570)	3.70 (3.69 to 3.71)	2.21 (2.21 to 2.22)	10.05 (10.01 to 10.08)
Women aged 19-35	13,622 (123,244 to 124,001)	2.22 (2.21 to 2.23)	3.92 (3.90 to 3.94)	20.47 (20.40 to 20.55)
Women aged 36-55	77,446 (76,523 to 78,369)	0.78 (0.77 to 0.79)	1.84 (1.81 to 1.87)	11.94 (11.78 to 12.10)
Women aged 56-79	22,594 (22,464 to 22,725)	0.15 (0.15 to 0.15)	0.33 (0.33 to 0.34)	2.69 (2.67 to 2.71)
Total	**1,030,163 (1,027,903 to 1,032,423)**	**2.13 (2.12 to 2.13)**	**32.25 (32.18 to 32.31)**	**159.01 (158.67 to 159.35)**

Deterministic sensitivity analysis shows that the model was highly sensitive for caries reduction input values. Figure 5 shows the number of caries lesion prevented, ranging from 313,516 for the lowest reported caries incidence reduction, to 1,549,627 for the highest reported value. Avoided treatment costs range from 49.84 million euros to 238.83 million euros (Figure 6) and the total amount of caries-free tooth years range from 12.86 million to 48.19 as shown in Figure 7.

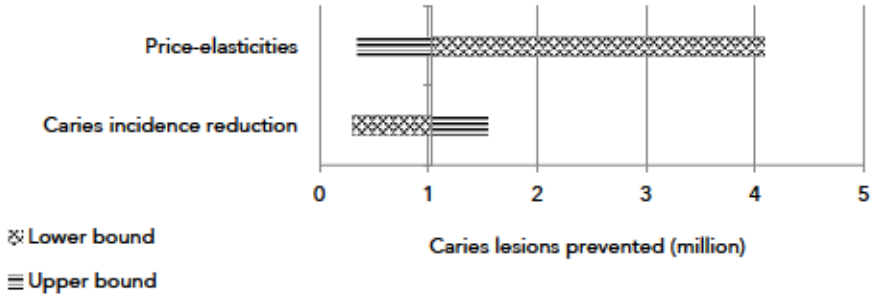

Figure 5: Tornado diagram: caries lesions prevented

Note. The bars indicate the effect of different input values for price-elasticities and caries incidence reduction on the number of caries lesions prevented

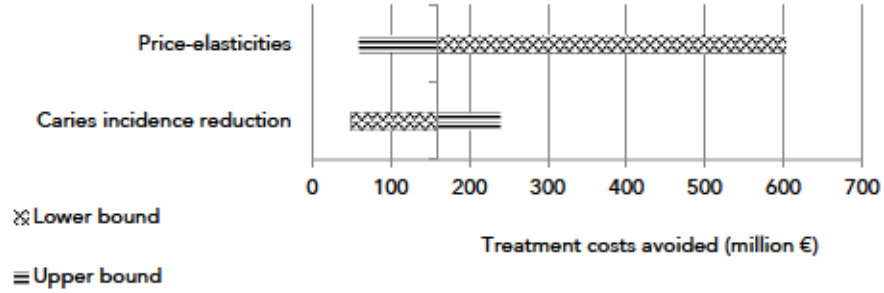

Figure 6: Tornado diagram: treatment costs avoided

Note. The bars indicate the effect of different input values for price-elasticities and caries incidence reduction on avoided treatment costs

Figure 7: Tornado diagram: total caries-free tooth years gained

Note. The bars indicate the effect of different input values for price-elasticities and caries incidence reduction on the total amount of caries-free tooth years

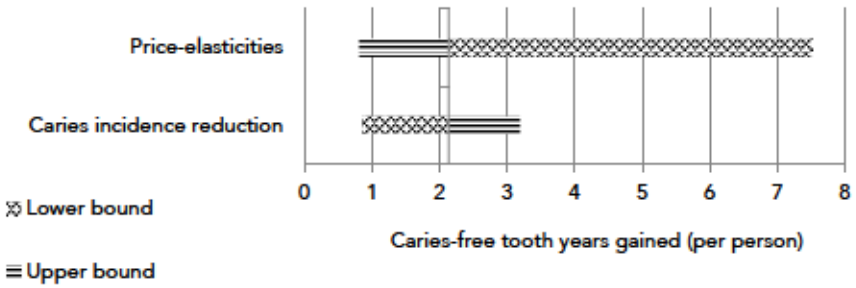

Figure 8: Tornado diagram: caries-free tooth years gained per person

Note. The bars indicate the effect of different input values for price-elasticities and caries incidence reduction on the amount of caries-free tooth years gained per person.

In the alternative scenario with lower values for SSB price and cross-price elasticity (scenario 1, -3.87 for SSB and 0.14 for fruit juices), taxation would yield 7.52 (95% UI 7.51 to 7.54) caries-free tooth years per person (Figure 8) and prevent 4.09 (95% UI 4.09 to 4.10) million caries lesions (Appendix Table A1 - 1). SSB taxation would subsequently result in a saving of 603.17 (95% UI 601.92 to 604.43) million euros dental healthcare expenditures on a population level. Assuming a high reduction in demands for SSB as a response to increased taxes, tax revenues will amount to 1.03 billion euros with 11.00 million euros of administrative costs.

Even in case of a very strong preference for SSBs and a less elastic demand (-0.69 for SSB and 1.45 for fruit juices), as depicted in scenario 2, taxation appears to be a cost-saving intervention resulting in 0.81 (95% UI 0.80 to 0.81) caries-free tooth years per person, 350,694 (95% UI 349,658 to 351,730) caries lesions prevented and 59.44 (95% UI 59.27 to 59.27) million euros as averted caries-attributable treatment costs (Appendix Table A1 - 2). With this reaction to SSB taxation, the tax revenues will be 3.96 billion euros, whereas the administration of taxation will be 42.42 million euros.

2.4 Discussion

Model results show that a total of 1,030,163 (95% UI 1,027,903 to 1,032,423) caries lesions could be prevented with SSB taxation, while gaining a total of 32.25 (95% UI 32.18 to 32.31) millions of caries-free tooth years. The introduction of SSB taxation would reduce caries-related dental expenditures by 159.01 (95% UI 158.67 to 159.35) million euros over a lifetime horizon. The estimated lifetime tax revenues (3.49 billion euros) are larger than the administrative costs for taxation (37.3 million euros).

This the first study to assess the potential benefits of SSB taxation on dental care, considering short and long-term consequences of taxation and the whole caries treatment cycle until potential tooth loss. The major strength of this study is the use of country-specific data for beverages consumption and caries incidence, stratified by age and sex. Moreover, to estimate taxation-related changes in sugar consumption, the analysis accounted for reduced SSB intake and potential substitution with fruit juice. To arrive at more precise estimates tooth eruption time and a specific tooth loss trajectory were incorporated in the model.

Some potential limitations should also be discussed. First, country-specific estimates for SSB price and cross-price elasticities were not available. However, the range of values reported in the literature was employed and evaluated in alternative scenarios. Second, due to a lack of more detailed evidence, possible substitution with sugar-containing foods was not considered. Therefore, it should be clear that the magnitude of the effect of SSB taxation is highly dependent on people's behaviours affecting absolute sugar intake. Price-elasticities for SSBs and fruit juices were derived from panel-based data, mostly containing purchases for at-home consumption. Hence, in case of strong consumers' preferences for SSBs within away from home markets (e.g. restaurants), total sugar intake as assumed in the analysis, might be underestimated.

Another important consideration to be taken into account are meal deals that could diminish the price difference and motivate consumers to select high-sugar products, which they perceive as the most expensive alternative, in order to maximise the cost-benefit-ratio of the purchase (Williams 2018). This could particularly affect the amount of health benefits estimated for children and the population under the age of 18 as they are the most frequent consumers of combo meals (Cantor et al. 2016). A SSB tax may potentially induce a reduction in drink waste, as suggested by Smith and colleagues (Smith et al. 2018). Yet, this effect hasn't been quantified. The analysis assumed a constant ratio between the purchased and consumed amount of SSBs. Further research should address the uncertainty around people's preferences as well as substitution patterns with sugar-containing beverages and foods.

Third, the same sensitivity to taxation across the whole population was assumed. With this assumption potential differences within educational or income groups are neglected. Low socioeconomic households possibly have higher reductions in SSB purchases reflecting the differential impact of taxation, as found in a recent study by Colchero et al. 2016.

Fourth, societal changes will likely result in availability of alternative drinks with reduced or no added sugar. It implies that the effect of SSB taxation will not be constant over the entire life course, as presupposed in the present analysis.

Finally, the results are simulation-based and all inputs for beverage consumption and costs are based on Dutch data. The consumption of SSBs and fruit juices in the Netherlands is, however, comparable to consumption in the UK, Ireland, Germany, France, Spain, Portugal and Australia (Singh et al. 2015). The price-elasticities for SSBs and fruit juices that were used for the present simulation were pooled through a meta-analysis that was based on several studies performed in different high-income settings. Therefore, these estimates are also applicable to the abovementioned countries (Seale et al. 2003). Healthcare prices, administrative costs of taxation as well as tax revenues may also differ across countries. In addition, disease-related parameters (e.g. caries incidence) for the Netherlands are similar to the rest of the Western European countries or Australia (Institute for Health Metrics and Evaluation 2018). Considering the aforementioned extent of generalisability of input parameters, simulations for these countries would most likely yield similar results with regard to health benefits in Australia and Western Europe. In contrast, sugary drinks consumption is higher in the US and Canada thus analyses with country-specific parameters for these settings are likely to produce different results. However, given the detailed presentation of the model and its input parameters, those interested can straightforwardly assess the transferability of the cost estimates to their specific situation.

The present results are in agreement with previous studies that have shown the reduction in caries incidence and DMFT increment due to SSB taxation (Briggs et al. 2017; Schwendicke et al. 2016; Sowa et al. 2019). Though, none of the studies accounted for any further consequences of caries except for restoration placement. Sowa et al. 2018 estimated that SSB taxation in Australia would result in 3.9 million units of DMFT averted and 0.43 billion euros in cost saved over 10 years. Nevertheless, in their study they did not consider potential substitution with sugar-containing beverages not subjected to taxation. Schwendicke et al. 2016 reported 0.75 millions of caries lesions prevented and avoided treatment costs of 0.8 billion euros over a 10-year horizon in Germany. A specific novelty of the present study is that the effects on oral health are illustrated by the total number of caries lesions prevented and caries-free tooth years gained. Considering these two outcomes enabled the analysis of the

effect of taxation on oral health in a more comprehensive way taking into account patterns from clinical practice. By postponing caries onset and entering the restorative cycle to a later stage in life more invasive treatments could be avoided. Consequently, this leads to prevention of tooth loss.

Briggs et al. 2017 showed that the industry response is of substantial importance for the actual SSB tax effect. However, its exact reaction cannot be precisely predicted. Currently available evidence from natural experiments suggests that the industry could opt for reformulation of products by reducing the amount of sugar in high- and mid-sugar drinks as done by Lucozade Ribena Suntory and Tesco when tiered taxes were introduced (Lucozade Ribena Suntory 2019; Tesco PLC 2016). Based on the findings from a UK modelling study, this scenario would result in the highest amount of health benefits gained (Briggs et al. 2017). Similarly, producers could aim for innovations by developing new versions of sugar-free alternatives and shifting their marketing strategies towards healthier brands (The Coca-Cola Company 2018). This may eventually reduce sugar consumption even further. However, recently estimated cross-price elasticities for regular soft drinks and their diet versions have shown that these products are rather complements than substitutes (Dharmasena and Capps 2012). Also note that both regular and diet sodas may imply risks of dental erosion (Ehlen et al. 2008). In addition, the effects of SSB taxation could be offset by price increases for other drinks. Dependent on the specific setting, the impact of SSB taxation could potentially be diminished by cross-border shopping. For example, a recent study has shown that after a tax was introduced in Berkeley, California, SSB purchases increased by 7% in surrounding regions without this fiscal policy (Silver et al. 2017). All important determinants should be considered through engagement of relevant stakeholders to secure that the maximum in terms of health benefits is achieved.

Policy makers face considerable barriers to fiscal policy implementation, especially from the food and beverage industry (World Health Organization 2016). Moreover, such an intervention can be seen as an intrusion in individual autonomy to make choices and contribute to the mistrust of true intention of taxation (Thomas-Meyer et al. 2017). In order to overcome those barriers, a comprehensive campaign should be launched in advance of tax implementation to inform the general public about potential harm caused by those products (World Health Organization 2016). This should involve a broad coalition of supporters, including the civil society, health professionals and health organizations. Moreover,

promotion of such a tax may include an obligation of earmarking tax revenues, as done by the UK Soft Drinks Industry Levy, in order to target populations' health through further interventions (Long et al. 2015; Smith et al. 2018). The present simulation of a 20% ad valorem tax on SSBs in the Netherlands estimates lifetime tax revenues of 3.49 billion euros providing plenty of budget for additional health promotional programmes.

In conclusion, this section shows that taxation of SSB consumption may be a suitable policy option to substantially improve oral health and reduce the caries-related economic burden.

3 Utilization of preventive services in a market with free prices

3.1 Background

An integrated and multi-layered approach to oral disease prevention ties to the determinants of risk behaviour, as evaluated in the previous section, and utilization of prevention-focused oral care. From a macro-policy perspective, addressing the wider market environment of oral healthcare delivery can constitute a starting point for upstream interventions. Market-oriented reforms are intended to organize oral healthcare delivery more efficiently, hereby improving quality of care and contributing to cost containment. However, an abundance of theoretical frameworks highlights the peculiar characteristics of healthcare markets causing market failure, including uncertainties, externalities, and asymmetric information, and therefore emphasize the relevance of market regulation (for example Arrow 1963; Culyer 1971). At the same time, it is rarely possible to empirically observe the impacts of interventions which were explicitly intended to improve the efficiency of healthcare by means of deregulation.

In 2012, the Netherlands embarked on the so-called "free market experiment", which introduced that dentists could set the prices for their dental services by themselves. The previously existing price ceiling for dental care fees was temporarily abolished. This intervention is one out of several examples for market liberalizations in healthcare which have been taking place in various European countries throughout recent years and decades (Dan and Andrews 2016; Maarse et al. 2016). Although intended to organize delivery of care more efficiently, increasing health expenditures for individuals have been observed in this context (Harrison and Calltorp 2000). Developments of this kind can have negative impacts on utilization of care, including oral prevention.

This section exploits this unique natural experiment in order to identify, by means of large-scale administrative claims data, the impacts of market liberalization on the utilization of prevention-oriented dental care. It aims to answer the following questions: Do price liberalizations constitute a suitable policy option to improve utilization of prevention-oriented oral care by meeting consumer preferences more efficiently? Or do the specific peculiarities of healthcare markets hamper a smooth functioning of the market and negatively affect utilization of preventive dental services?

In order to contribute to this question, changes in short-run price developments, utilization patterns and price elasticity of demand following the introduction of the FME were analysed. This the first study to comprehensively examine these effects with a specific focus on prevention.

In accordance with existing evaluations (Milliman 2013; Nederlandse Zorgautoriteit 2012b; Nederlandse Zorgautoriteit 2012c), it was assumed to find price increases following the reform. This is supported by recent evidence pointing towards limited supply of dentists in the Netherlands due to market access barriers and therefore an increased supply-sided bargaining power (Ketel et al. 2018). Additionally, variations in price changes were expected for different kind of procedures due to different levels of asymmetric information for first-stage services, such as preventive examinations, and therapeutic follow-on services, such as extractions. Under fixed reimbursement rates, OOP prices for prevention may increase with raising prices for dental care. This may change patients' motives for seeing a dentist from a regular-prevention-oriented approach to symptom-based visits. Therefore, it was hypothesized that an increase in OOP prices will lead to a decreasing share of treatment session including preventive services, while at the same time the share of sessions including restorative interventions, such as extractions, increases.

Price variations following the FME implementation enabled the evaluation of short-run OOP price elasticities of demand providing a standardized measure for reactions in demand to price changes. This allowed the analysis of demand reactions of different services to price changes. It was expected that different levels of asymmetric information are also reflected in different OOP price elasticities for different procedures.

3.2 Institutional background: the Dutch free market experiment

In 2006, a major healthcare reform introduced a system of managed competition in the Dutch health insurance market and initiated implementation of competition in health-care purchasing and delivery (Kroneman et al. 2016). In this process of establishing market mechanisms, the introduction of price liberalization in dental care was also subject of political debate (Felder et al. 2018). In 2011, the government decided to introduce such liberalizations in the dental care market on an experimental basis (Schippers 2011). Besides cost containment and the improvement of service quality, the experiment's main objective was to

promote entrepreneurship and to provide incentives for the dissemination of product innovations in the market (Nederlandse Zorgautoriteit 2011b). The experiment should provide the opportunity to examine how prices, quality and accessibility develop in a liberalized market. Dental care is reimbursed on a fee-for-service based system in the Netherlands. Prior to the experiment a price ceiling with maximum tariffs existed for dental services determining a maximum remuneration for each dental service item. The experiment introduced on January 1st, 2012 allowed dental care providers to set the prices for their dental services on their own.

This price liberalization for dental services was accompanied by a major overhaul of the fee schedule (Nederlandse Zorgautoriteit 2011a). In order to promote service transparency and provide better comparability for patients, the 400 items of the previously existing fee schedule were summarized into 150 more comprehensible, wider diagnostic and treatment codes. To maintain price transparency, dental care providers had to make their price lists openly available for the patients, for example in the waiting rooms and on their websites (Nederlandse Zorgautoriteit 2011b).

Although the experiment was initially planned to last for three years, it was terminated at the end of 2012. This was mainly due to observed increases in service prices. Analyses of market prices for a small basket of services shortly after the start of the experiment indicated a 4% increase in prices for dental services (Nederlandse Zorgautoriteit 2012a). Subsequent analyses of price changes following the price liberalization showed heterogeneous effects. Repeated official reports by the Dutch Healthcare Authority (Nederlandse Zorgautoriteit: NZa) concluded price increases by 9,6% and 10,7% based on the comparison of a subgroup of service items (Nederlandse Zorgautoriteit 2012b; Nederlandse Zorgautoriteit 2012c). In contrast, a report commissioned by the Dutch Dentist Association (ANT) found a price increase of 3% attributable to the price liberalization (Milliman 2013). They claimed that the main proportion of the increase observed by NZa's official report trace back to the extensive rearrangement of the fee schedule.

Short-term changes in dental care fees are of interest for people without insurance coverage for dental care. However, for those people with coverage for dental services, changes in OOP payments are a relevant decision criterion determining their utilization of oral healthcare. While dental care is provided under the basic insurance coverage for children and adolescents in the Netherlands, the majority of adult dental services aren't covered by this basic package.

88% of the insured population purchased additional insurance coverage in 2012 and 76% of these contracts also covered dental care (Nederlandse Zorgautoriteit 2012d). This means that two thirds of the adult population took out additional insurance coverage for dental care in the reform year.

Most insurance companies defined maximum reimbursement rates for 2012, the year of the FME (De Volkskrant 2012). The fraction of the fee that exceeds maximum compensation rates must be paid out-of-pocket by the patient. Although these maximum rates where adjusted over the course of 2012, to account for increased service fees, patients faced increases in OOP prices during the year of the experiment (Achmea 2012).

3.3 Methods

3.3.1 Data

Anonymized claims-level administrative data spanning a 3-year period from 2011 to 2013 were obtained from the *Achmea Health Database*. The dataset included all services that were provided to *Achmea* customers within this period. These were patients with additional dental insurance as well as children and adolescents having received care under basic health insurance coverage. The dataset provided information about procedure codes, the calendar week of service provision, unique patient and provider identifiers, patients' age groups (in five-year intervals), patients' sexes and insurance statuses, as well as complete cost information. Cost data included provider fee, co-payments and insurance reimbursements. In total, the dataset comprised 41,145,107 claims from 19,542,857 treatment sessions for 3,118,517 unique patients. Services were mainly performed by dentists. Only 10% of claims were made by dental hygienist. A patient treatment session was defined as "all treatments provided to a patient within one week".

3.3.2 Data harmonization

The present analysis faced the same challenge as previous evaluations of the FME (Milliman 2013; Nederlandse Zorgautoriteit 2012b; Nederlandse Zorgautoriteit 2012c), which was an adequate harmonization of treatment codes. Although procedure codes changed substantially in 2012, the NZa did not release a translation scheme. In order to enable a comparison of services provided over several years, procedure codes from 2011-2013 were harmonized into service baskets (see Table 4) (Nederlandse Zorgautoriteit 2011d;

Nederlandse Zorgautoriteit 2011c; Nederlandse Zorgautoriteit 2012e; Nederlandse Zorgautoriteit 2013). A detailed overview is provided in the Appendix Table A2 - 3. Due to substantial changes in procedure codes, it was not possible to harmonize all services. Besides preventive services, three additional treatment/ diagnostic items were selected to enable comparisons to be made. Additionally, the changes in the fee schedule made it impossible to analyse changes in overall dental care service utilization.

Table 4: Service baskets and associated procedure codes

Service basket	Procedure codes
Preventive examinations and oral hygiene advice	C11, C12, M31, M70; A111, C112, C114, C124; C11, C13, M01, M02
Scaling and polishing	M50, M55, M59; C212, C214; M03
Fissure sealants (only for children/ adolescents)	V30, V35; C511; V30, V35
Fluoride applications (only for children/ adolescents)	M10, M20, M21; C611, C811; M05, M10, M20
Direct restorations	V10, V11, V12, V13, V14 (V20, V21, V50, V60, V70, V80, V85); E111, E112, E113, E114, E131, E411; V11, V12, V13, V14 (V20, V21, V50, V60, V70, V80, V85)
Extractions	H10, H15, H30, H35 (H20, H21, H25, H90); J311, J315; H35, H11, H16 (H21, H90)
Radiographs	X10, X21, X22, X24; A311, A321, A324, A327; X10, X21, X22, X24, X25, X26

For each of these groups of services, a binary variable was set to 1 for a particular treatment session if at least one corresponding code was remunerated in that session. Otherwise, it was set to 0. On a session level, payment information per service basket were totalled to obtain one value for every payment variable of interest for each basket. Provider fees as well as patients' OOP expenditures were calculated.

3.3.3 Empirical strategy

3.3.3.1 Utilization

In order to identify the experiment's impact on utilization of preventive services, utilization of services in the pre-experiment year and in the year of the experiment were compared. The analyses estimated the likelihood that a treatment session included the treatment item of interest. Analysis did not allow statements of changes in overall dental care use but evaluated shifts in the composition of utilization. On an individual treatment session level, pooled panel logistic regression was applied. By restricting the analysis to two calendar years with one pre-introduction and one post-introduction calendar year and by pooling data in the pre- and post-introduction period in order to reduce variance, substantial volatility of utilization over

the calendar year was considered. In order to address unobserved but fixed individual patient characteristics, the longitudinal character of the underlying data was exploited and patient level fixed effects were included in the analyses (Angrist and Pischke 2008).

$$Y_{it} = \alpha_i + \beta(Post_{it}) + \varepsilon_{it} \qquad (1)$$

Regression analyses were performed according to equation (1) for each service basket. Y_{it} - the variable of interest - is a dummy variable for each treatment session of patient i at time t indicating whether it includes at least one procedure of the particular service basket or not. $Post_{it}$ denotes a dummy variable indicating the post-introduction period. Hereby, β is the estimator of interest. ε_{it} represents the error term. Following previous analyses, indicating that reactions in utilization may considerably differ between children and adults, the analyses were stratified for children and adolescents up to the age of 18 and adults.

3.3.3.2 **OOP price elasticity of demand**

In order to combine information about OOP prices and service utilization, OOP price elasticities of demand for every service under evaluation were calculated. This reflects the reaction of demand on price changes in the short-run. Hereby, the variability in prices and utilization induced by the reform was exploited. In the context of this short-run perspective under evaluation, the price information constitutes an exogenous variable. It is assumed that in the short time horizon of the experiment, dental care providers used their pricing power in an environment with fixed and limited supply. Observed utilization of the specific service was used as a proxy for demand (Yule and Parkin 1985). Data was aggregated on an annual provider level to provide the number of services and average prices per provider per year for every service basket. To obtain a wider range of price and utilization information, observations from 2011-2013 were included in the analysis. Poisson regression was performed due to the count data character of the outcome variable. Provider-level fixed effects were included to control for unobserved characteristics of the provider, such as practice size, etc.. Again, the analysis was stratified for two age groups.

$$Y_{pt} = \alpha_p + \beta(C_{pt}) + \gamma(X_{pt}) + \varepsilon_{pt} \qquad (2)$$

The outcome variable Y_{pt} counts the number of treatment sessions with the respective treatment provided by provider p at time t. C_{pt} represents average patients OOP contribution for this service for dentist p at time t. X_{pt} is a vector of control variables containing information

about the patient's age, sex and additional insurance coverage. ε_{dt} denotes the error term. Based on the regression results from equation (2), margins at mean were calculated to obtain elasticity estimates. It denotes the proportionate change in demand given a proportionate change in price. All analyses were performed using Stata 13.1 analytical software (StataCorp. 2013. College Station, TX: StataCorp LP.). Statistically significant results are denoted by *** for $p<0.01$.

3.4 Results

Table 5 shows summary statistics for dependent and independent variables for the whole sample stratified by age groups and years. The mean of patients' age was 10 years for children and adolescents and 46 years for adults. Preventive services were utilized in most sessions in both age groups. Hereby, preventive examinations and oral hygiene advice were most prevalent followed by dental cleanings for adults. Fissure sealants were placed in 5.9% of treatment sessions for children and adolescents. Turning to the non-preventive items: Direct restorations were performed in one quarter of adult treatment sessions, followed by X-rays. Direct restorations were also the most prevalent service in the younger age group followed by X-rays. Extractions played only a minor role with around 3% in both age groups. Descriptive statistics show variations between the year of the experiment and the pre- and post-experiment years. The fraction of sessions including any preventive service dropped in the intervention year. This development was also observable for most preventive items except for dental cleanings in adults and fluoride applications for children and adolescents. Regarding restorative items and X-rays, descriptive statistics show mixed developments. The share of session including X-rays for the younger age group slightly increased in the year of the intervention and so did the share of extractions for the adult population. Relative utilization of the remaining items increased in the year of the experiment.

Table 5: Summary statistics: dependent and independent variables

	age group 0-17 Mean (SD)			age group 18-95+ Mean (SD)		
	2011	2012 (intervention)	2013	1011	2012 (intervention)	2013
Patient's age	10.05 (4.083)	10.08 (4.083)	10.08 (4.094)	46.17 (16.00)	46.44 (16.18)	46.75 (16.27)
Women/ Girls (% of all patients)	0.490 (0.500)	0.489 (0.500)	0.489 (0.499)	0.540 (0.498)	0.540 (0.498)	0.539 (0.498)
Fraction of session including the following intervention						
Prev. exams & oral hygiene advice	0.516 (0.500)	0.481 (0.500)	0.520 (0.500)	0.556 (0.497)	0.516 (0.500)	0.563 (0.496)
Dental cleanings	0.178 (0.382)	0.149 (0.356)	0.179 (0.383)	0.361 (0.480)	0.368 (0.482)	0.392 (0.488)
Fissure sealants	0.062 (0.240)	0.058 (0.234)	0.057 (0.231)	NA	NA	NA
Fluoride applications	0.222 (0.416)	0.225 (0.417)	0.228 (0.420)	NA	NA	NA
Any preventive service	0.569 (0.495)	0.536 (0.499)	0.573 (0.495)	0.621 (0.485)	0.591 (0.492)	0.660 (0.474)
Direct restorations	0.110 (0.313)	0.099 (0.299)	0.104 (0.305)	0.259 (0.438)	0.248 (0.432)	0.257 (0.437)
Extractions	0.027 (0.160)	0.026 (0.159)	0.026 (0.158)	0.030 (0.172)	0.032 (0.175)	0.026 (0.159)
X-rays	0.079 (0.270)	0.083 (0.276)	0.079 (0.270)	0.211 (0.408)	0.204 (0.403)	0.212 (0.408)
***N* (number of sessions)**	2,027,500	2,032,386	2,179,415	4,503,781	4,395,245	4,404,548

Average service fee increases were observed in the reform year for nearly all treatment items under investigation; except for fluoride applications for adult patients (see Appendix Table A2 - 1 Table A2 - 2). However, the magnitudes of increases differed substantially and range from 1,5% for X-rays for adults to 45% for tooth extractions for children and adolescents. In general, increases in service fees for children and adolescents were higher than for adult care. After the reform was abolished, most service fees dropped but were still above the pre-reform level. Patients' OOP expenditures were a multiple of the pre-reform expenditures in 2012 for most of the service items (Table 6 and Table 7). Services for children and adolescents came along with substantial co-payments in the year of the experiment, whereas OOP expenditures for these services were previously 0. In 2013, average OOP expenditures nearly returned to the pre-reform baseline values. Regarding first-stage and follow-on services, larger increases in service fees and OOP expenditures for restorative services were observed, such as extractions, than for regular services, such as preventive exams and oral hygiene advices.

Table 6: Descriptive statistics: patients' OOP expenditures for age groups 18-95+

Intervention	Average OOP expenditures (SD (standard deviation))			Absolute change in OOP expenditures	
	2011	2012	2013	2012	2013
Prev. exams & oral hygiene advice	0.06 € (0.85)	0.89 € (2.37)	0.06 € (0.99)	+0.83 €	-0.83 €
Dental cleanings	0.19 € (2.20)	3.00 € (4.45)	0.43 € (4.29)	+2.81 €	-2.57 €
Direct restorations	5.89 € (12.74)	12.93 € (21.25)	5.89 € (12.83)	+7.04 €	-7.04 €
Extractions	4.40 € (10.92)	12.75 € (23.96)	4.64 € (10.75)	+8.35 €	-8.11 €
X-rays	7.40 € (5.95)	8.48 € (6.81)	7.74 € (6.08)	+1.08 €	-0.74 €

Table 7: Descriptive statistics: patients' OOP expenditures for age groups 0-17

Intervention	Average OOP expenditures (SD)			Absolute change in OOP expenditures	
	2011	2012	2013	2012	2013
Prev. exams & oral hygiene advice	0.00 € (0.10)	0.25 € (1.42)	0.02 € (19.32)	+0.25 €	-0.23 €
Dental cleanings	0.01 € (0.27)	0.85 € (2.32)	0.02 € (0.60)	+0.84 €	-0.83€
Fissure sealants	0.01 € (0.67)	2.46 € (8.15)	0.01 € (0.26)	+2.45 €	-2.45 €
Fluoride applications	0.00 € (0.11)	0.46 € (1.07)	0.00 € (0.06)	+0.46 €	-0.46 €
Direct restorations	0.01 € (0.45)	2.01 € (7.88)	0.01 € (0.72)	+2.00 €	-2.00 €
Extractions	0.00 € (0.09)	2.38 € (8.17)	0.01 € (0.30)	+2.38 €	-2.37 €
X-rays	0.00 € (0.26)	0.97 € (4.24)	0.01 € (0.63)	+0.97 €	-0.96 €

Table 8 and Table 9 provide logistic regression results with patient fixed effects for utilization changes following the introduction of the experiment. Results are presented as odds ratios and associated percentage changes in utilization. Odds ratios (OR) indicate a decrease in utilization following the reform (OR<1) or an increase following the reform (OR>1). All estimates are statistically significant under α=0.01. For patients aged 18 and older, results indicate a significant relative decrease in utilization of preventive services in comparison to overall dental care use: The share of sessions including any preventive service decreased by 3.39% (OR: 0.873 (SE (standard error): 0.002)). However, for specific preventive items, the results were heterogeneous: Large decreases were observed for preventive exams and oral hygiene advice (-4.14 %; OR: 0.847 (SE: 0.001)), while sessions were more likely to include dental cleanings (0.48%; OR: 1.019 (SE: 0.002)). Results also show significant decreases in the share of direct restorations and X-rays. The fraction of sessions containing extractions increased in the adult population by 1.80% (OR: 1.075 (SE: 0.002)) following the reform. For children and adolescents, logistic regression results show a larger relative decrease in utilization of preventive items compared to the adult population. The fraction of sessions containing any preventive service decreased by 5.29% (OR: 0.809 (SE: 0.002)) following the

reform. Except for fluoride applications (2.07%, OR: 1.086 (SE: 0.004)), the likelihood that treatment sessions include preventive services decreased. The largest decrease was observed for preventive exams and oral hygiene instructions with -5.30% (OR: 0.808 (SE: 0.003)). In comparison to overalls dental care use, dental cleanings and fissure sealants declined by 2.27% (OR: 0.913 (SE: 0.004)) and 2.00% (OR: 0.923 (SE: 0.005)) respectively. For non-preventive items, sessions were less likely to include direct restorations (-1.71%; OR: 0.934 (SE: 0.004)) and extractions (-5.4%; OR: 0.804 (SE: 0.006)) in the age group under 18 but more likely to include X-rays (4.08%; OR: 1.178 (SE: 0.005)).

Table 8: Logistic regression with patient fixed effects for age group 18-95+

Intervention	Odds ratio after vs. before reform (SE)	Associated percentage change	Observations
Prev. exams & oral hygiene advice	0.847*** (0.001)	-4.14 %	7,171,833
Dental cleanings	1.019*** (0.002)	0.48 %	5,781,013
Any preventive service	0.873*** (0.002)	-3.39 %	6,693,394
Direct restorations	0.921*** (0.002)	-2.06 %	6,095,415
Extractions	1.075*** (0.005)	1.80 %	1,287,825
X-rays	0.887*** (0.002)	-3.00 %	6,102,535

Note. Dependent variable: dummy variable for each treatment session of patient *i* at time *t* indicating whether it includes at least one procedure of the particular service basket or not. Model includes patient-level fixed effects. Statistically significant results are denoted by *** for p<0.01.

Table 9: Logistic regression with patient fixed effects for age group 0-17

Intervention	Odds ratio after vs. before reform (SE)	Associated percentage change	Observations
Prev. exams & oral hygiene advice	0.808*** (0.003)	-5.3 %	3,174,717
Dental cleanings	0.913*** (0.004)	-2.27 %	2,073,063
Fissure sealants	0.923*** (0.005)	-2.00 %	1,286,610
Fluoride applications	1.086*** (0.004)	2.07 %	2,319,682
Any preventive service	0.809*** (0.002)	-5.29 %	2,934,764
Direct restorations	0.934*** (0.004)	-1.71 %	1,593,950
Extractions	0.804*** (0.006)	-5.4 %	682,989
X-rays	1.178*** (0.005)	4.08 %	1,735,041

Note. Dependent variable: dummy variable for each treatment session of patient *i* at time *t* indicating whether it includes at least one procedure of the particular service basket or not. Model includes patient-level fixed effects. Statistically significant results are denoted by *** for p<0.01.

Estimates for short-run OOP price elasticities of demand on a population level are depicted in Table 10. Under α=0.01, all estimates are statistically significant and point towards a relatively inelastic demand near to 0 for preventive oral healthcare services. This is shown for both age groups under evaluation. The most elastic preventive service were preventive exams and oral hygiene advice for adults with an OOP price elasticity of demand of -0.022 (SE:

0.001). A price elasticity of -0.022 means that a 1% increase in prices is associated with a 0.022% decrease in demand. Relatively higher elasticities were also observed for extractions and X-rays in the adult population with 0.061 (SE: 0.008) and 0.099 (SE: 0.004), respectively. Note that these elasticities show a positive sign, suggesting an increase in demand with an increase in price. In general, estimates point towards more inelastic demand for children and adolescents than for adults. This is especially reflected in estimates for preventive exams and oral hygiene advice: Whereas the elasticity for children and adolescents was -0.002 (SE: 0.000), demand in the adult population was -0.022 (SE: 0.001). In the younger age group, results also show slightly positive short-run price elasticities of demand for fissure sealants (0.001 (SE: 0.000)), extractions (0.004 (SE: 0.001)) and X-rays (0.012 (SE: 0.001)).

Table 10: OOP price elasticity of demand with provider fixed effects

Intervention	OOP price elasticity of demand (SE)	
	age group 0-17	age group 18-95+
Prev. exams & oral hygiene advice	-0.002*** (0.000)	-0.022*** (0.001)
Dental cleanings	-0.008*** (0.000)	-0.002*** (0.000)
Fissure sealants	0,001*** (0.000)	NA
Fluoride applications	-0.001*** (0.000)	NA
Direct restorations	-0.009*** (0.001)	0,001*** (0.001)
Extractions	0.004*** (0.001)	0.061*** (0.008)
X-rays	0.012*** (0.001)	0.099*** (0.004)

Note. Dependent variable: number of treatment sessions including the respective treatment provided by provider p at time t. Model includes dentist-level fixed effects. Statistically significant results are denoted by *** for p<0.01.

3.5 Discussion

Little is known about how price liberalization in dental care affects prices of different services and utilization patterns. Exploiting unique claims-level insurance data, the present study evaluated the 2012 Dutch free market experiment and analysed the distortive effects of the experiment on price and service utilization. Results indicate substantial increases in patient's OOP contributions for dental services following the liberalization with differences in increases between services. This supports the hypothesis of different levels of asymmetric information for first-stage and follow-on services. Estimates of short-run price elasticities of demand for different services that point towards differences in price sensitivity endorse these findings. Price liberalization affects the composition of treatment sessions leading to a decreased use of preventive services. This suggests a shift in the reason for seeing a dental care provider from a regular-preventive perspective to a symptom-based restorative approach. This study

is the first to show how price liberalization changes OOP prices in the dental care market and affects utilization patterns, especially with regard to preventive services.

Descriptive results show price increases for all services under evaluation following the experiment's introduction. A general price increase is in line with official evaluations by the NZa and supports the findings of Ketel and colleagues regarding providers' market power due to a limitation in supply (Ketel et al. 2018; Nederlandse Zorgautoriteit 2012b; Nederlandse Zorgautoriteit 2012c). Service fees for preventive services increased by up to 20% following the reform and 45% for extractions, respectively. Different price increases, especially regarding examinations and extractions, are in line with the findings of Chirico 2013 based on the Swedish dental care market and support Pauly 1978's concept of different levels of asymmetric information for first-stage and follow-on services. Chirico's evaluation took a 3-year horizon into account. Based on the present results, her findings can be extended to a short-run perspective where price liberalization was limited to one year and market forces have not settled, yet.

Due to maximum reimbursement rates, increasing service prices are also reflected in the OOP prices patients face. For an insured population, this is the actual price of interest in the short-run. Consistent OOP price increases following the introduction of the FME were found for all service baskets under evaluation with substantial differences between services. This shows that the effect of different levels of information asymmetries for first-stage and follow-on services is not only reflected in service prices but also in the OOP prices an insured population faces. Especially for preventive care and care for children and adolescents, a shift from full insurance coverage to a system with substantial patient co-payments is observed.

Higher OOP expenditures are expected to lead to lower utilization of healthcare, all other things considered equal. Due to the differences in fee schedules, it wasn't possible to assess the impact of the FME on overall dental care utilization. Nevertheless, substantial alterations were found in the composition of care utilized on an individual patient level following the introduction of the FME. For both age groups, the likelihood of a treatment session to include any preventive service decreased by 5.3% for children and adolescents and by 3.4% for adults respectively. This was mainly driven by decreases in the share of sessions including preventive examination and oral hygiene advice. Results also indicate slight increases for dental cleanings in adults and fluoride applications in the younger age group. This could be explained by

patients choosing clinical procedures instead of educative health promoting approaches, such as the provision of oral hygiene advices, when confronted with rising OOP costs for preventive services.

The effects observed for non-preventive items were heterogeneous. Utilization of extractions for adults increased relatively to overall utilization as well as the share of sessions including X-rays for children and adolescents. Due to substantial changes in treatment codes by a concurrent change of the fee schedule at the time of the experiment, evaluation of diagnostic and restorative items was limited to a set of comparable measures in order to avoid bias through inaccuracies in procedure harmonization. However, since it was possible to harmonize all possible preventive service items, distortions in utilization patterns away from preventive service use could be identified. As hypothesized, this suggests that price effects of the FME induced a shift in the reason for seeing a dental care provider from a regular-preventive perspective to a symptom-based restorative approach. The shift away from preventive service use is in accordance with the evidence on unintended offsets in general care for chronically ill patients (Chandra et al. 2010; Hsu et al. 2006; Trivedi et al. 2010). This is remarkable, since OOP price increases for all kind of services were observable, with even greater increases in restorative services under evaluation. These findings extend the evidence on undesired offsets for chronically ill to the general population in the context of dental care. Preventive services, such as fluoride varnish or sealants are effective measures to prevent oral disease (Ahovuo-Saloranta et al. 2017; Marinho et al. 2013). Therefore, decreasing utilization of practice-based prevention due to higher prices may affect population's oral health and treatment needs over the whole life cycle. Eventually, resulting dental diseases increase the cost burden through restorative care such as direct restorations, endodontic treatments and replacements.

In addition to an isolated analysis of price and utilization changes, short-run OOP price elasticities of demand were examined for different services and age groups to evaluate patients' OOP price sensitivity in the context of the experiment. In the absence of comprehensive claims-level individual data, previous analyses of demand's reaction on price changes had to apply surrogate outcome measures, such as expenditures per dental visit, which may suffer from a lack in accuracy and granularity (Sintonen and Linnosmaa 2000; Yule and Parkin 1985). In general, results show relatively inelastic OOP price elasticities of demand

close to zero. Especially with regard to prevention-oriented items of care, estimates are largely compatible to other estimates on oral healthcare services from insured populations evaluating long-term elasticities (Beazoglou et al. 1993; Grembowski et al. 1988; Meyerhoefer et al. 2014; Sintonen and Maljanen 1995). This contrasts with results from the RAND Health Insurance Experiment, which suggest that elasticity may be much higher shortly after changes in prices (Manning et al. 1985). Small differences in elasticities for children and adults are also found but without a clear direction. Therefore, findings suggesting less elastic demand for children's oral healthcare can't be confirmed (Conrad et al. 1987; Grembowski et al. 1987).

As suggested by Pauly (1978) and in contrast to Meyerhoefer et al. (2014), results show varying price elasticities for different services especially with regard to preventive check-ups and restorative services. In addition to the observation on service price development, this finding supports the existence of different price sensitivities for first-contact and follow-on services due to different levels of asymmetric information. Most remarkably, small but positive price elasticities of demand were observed for some non-preventive services, which means that demand increases in price for those items. Since actual utilization as a proxy for demand was used, these observations emphasize short-term market distortions following the experiment's introduction that led to a shift in the composition of utilization towards non-preventive services.

The present analysis was solely based on data from an insured population. It can be assumed, that the observed effects are even stronger in the population without dental insurance, which represented a minority at the time of the experiment. Patients without insurance for dental care had to pay the complete dentist fee out-of-pocket and therefore faced a higher increase in cost burden. Moreover, literature suggests that demand for oral healthcare services is more elastic in uninsured populations (Grembowski et al. 1988).

Originally, the intention of the experiment on price liberalization was to improve quality, contain cost, promote entrepreneurship in order to lower regional scarcities and improve market-dissemination of product innovations (Nederlandse Zorgautoriteit 2011b). A liberal market can serve as an instrument to reach these goals. However, several criteria must be met. Among these are equal bargaining power of supply and demand, no market access barriers and transparency about price, content and quality of the product.

The present results show that price liberalization of dental care came along with increasing service prices and substantial distortions in the composition of dental care demanded. This led to an unintended relative decrease in utilization of preventive services in comparison to overall dental care use and an increased financial burden of seeking oral healthcare. Observed patterns in price developments following the experiment's introduction suggest that the FME was not capable to induce competition among suppliers. In fact, providers were able to raise prices due to specific market characteristics that avert equal bargaining power between supply and demand. Varying price sensitivities of patients for different services (expressed through OPP price elasticities of demand) point towards information asymmetries between patients and providers. Providers of dental care were able to exploit these asymmetries since patients were not capable of assessing the quality and necessity of service to a sufficient extend due to insufficient transparency and knowledge.

Second, supply of dentists was fixed in the short-run since considerable market access barriers existed, starting with a limited number of students that was admitted to study dentistry. This shortage in supply provided dentists with a bargaining power that hampered a smooth functioning of a deregulated market and enabled the extraction of a monopoly rent (Ketel et al. 2018). The fact that dental care providers were not willing to engage in competition is confirmed by a report of the Dutch Consumer Association: During the experiment, a majority of the dentists evaluated was not willing to accept a new patient for one specific treatment (Dutch Consumer Organisation 2012). This fact made it impossible for patients to compare price and quality and chose a preferred provider.

These results show that careful analysis and monitoring is warranted to adequately weigh the intended and unintended consequences of changes in the design of dental reimbursement systems.

Altogether, the Dutch oral healthcare market at the time of the experiment did not meet the requirements necessary for a well-functioning oral healthcare market, which serves as an instrument to lower cost, improve quality and promote dissemination of innovations. However, alternative approaches to target these goals exist.

First, policy options that increase demand-sided bargaining power should be considered in this context. This can constitute an effective tool as shown by third party payers'

reimbursement rates. In the U.S., the general level and increases over time of third-party payers' reimbursement rates are substantially lower than the fees set by dentists themselves (Gupta et al. 2017). Promoting supply-sided bargaining power may be able to reduce the price effects induced through the presence of asymmetric information.

Second, to reach sustainable improvements of populations' oral health, reimbursement of dental professionals should be tied to health outcomes instead of number and kind of procedures provided, hereby establishing a value-based healthcare system (Niederman et al. 2017; Pitts et al. 2017). Those approaches focus on increasing the actual value for patients and aim at improving the health outcomes achieved per monetary unit spent (Porter 2009). Such performance-based financing models are able to lower cost through the avoidance of unnecessary treatments, provide incentives to improve quality and apply innovations that improve patient's oral health in a sustainable manner. At the same time this approach does not leave the judgement about quality to the consumer alone.

The following sections address the concept of performance-based financing models in oral healthcare. Section 4 examines to what extent performance-oriented reimbursement structures are able to achieve changes in dentists' behaviour. Section 5 aims at defining relevant measures of oral healthcare delivery and oral health outcomes which are feasible in comparing dentists with their peers. These can form the basis of a performance-based payment system that incentivizes the provision of prevention-oriented and patient-centred oral healthcare.

4 Linking salary with bonus payments: effects on service utilization

4.1 Background

There is continuing debate about the pros and cons of more performance-oriented payment of oral healthcare providers. Experts have long been proposing innovations in dental remuneration systems to face increasing expenditures without concomitant increases in population's oral health (Edelstein 2018; Voinea-Griffin et al. 2010a), However, it is largely unknown whether these new payment structures achieve their intended outcomes and to what extent they induce unintended consequences (Kao 2015). To date, such payment instruments are more broadly being used in general medicine, with dissemination in dental care still being scarce and impacts on dental health and dental healthcare being largely unknown (Brocklehurst et al. 2013b; Chenot 2017; Grytten 2017; Voinea-Griffin et al. 2010b).

In combination with Section 5, this chapter provides evidence about potential content and effect of performance-oriented payment systems in dental care. In this section, the impact of combining salary payments with performance-oriented financial bonuses on the utilization of dental care is examined. Hereby, natural variation in financial incentives in a large ambulatory care setting was exploited in which dental health professionals receive salary payments but only one subgroup of dental care providers was exposed to the introduction of performance-oriented bonus payments. These bonuses were related to the provision of a set of specific predefined dental services.

As outlined in Section 1, experiences and empirical evidence of such arrangements in dental care are still very limited due to the lack in evidence-based performance measures (Campbell and Tickle 2013b). In order to overcome this lack of quality indicators, surrogate measures have been applied to assess dentist's performance in a performance-oriented payment system. However, previous experiences show that careful evaluation of payment reforms is needed that focuses on both targeted parameters as well as potential unintended side effects of these payment arrangements.

The present analysis concentrated on the question how the implementation of the bonus framework affects providers' performance. To assess how accurate the strategy of financial incentives is able to enhance performance, three different aspects of utilization are examined to observe intended and unintended effects of additional performance-based payments:

utilization at the extensive margin and utilization at the intensive margin. For the latter, analysis distinguished between utilization of incentivized items, and utilization of non-incentivized items.

Establishing a causal link between payment structure and utilization of care requires suitable natural experiments when conducting randomized controlled trials is not possible. Exploiting a clearly defined reform in a university-based ambulatory care setting with different departments provided ideal conditions since a suitable comparison group is available within an isolated clinical setting. Based on routinely collected data, this quasi-experimental setting allowed the application of a DiD approach.

4.2 Institutional setting

In Germany, dental care is provided by around 69,000 dentists. These are mainly working in private practices, receiving fee-for-service remuneration. Additionally, oral healthcare is provided in academic ambulatory care-settings by around 1,900 dentists who work in universities (Ziller et al. 2015). This analysis focused on a reimbursement reform established in the Department of Prosthetic Dentistry at Heidelberg University. It is one of four dental departments at Heidelberg University, the other departments being Conservative Dentistry, Orthodontics, and Maxillofacial Surgery. In terms of treatment focus, the departments of Prosthetic Dentistry and Conservative Dentistry share substantial overlap in terms of types of care which are provided in both of these departments but by far less often in the other dental departments of Heidelberg University.

The majority of dentists who work in academic ambulatory care settings receives salary payments. The extent of salary payments is thereby often determined by seniority and organizational position and may be supplemented by bonuses for additional (non-regular) working hours such as night and weekend shifts or working overtime (Blum et al. 2011; Tarifgemeinschaft deutscher Länder and Marburger Bund 2017). Moreover, salaried dentists can receive an additional income component resulting from the treatment of privately insured patients in their department (Spengler and Jámbor 2006). Often, the head of the department is entitled to bill privately insured patients directly for services rendered in their respective department. At the discretion of the head of department, part of the revenue gained by such treatment is redistributed and shared with other dental professionals in the respective

department. Thereby, the share each practitioner receives is usually determined at the discretion of the department's head; often it is divided according to a predefined scheme that includes organizational position, productivity, or the like (Bruns 2003).

This analysis focused on a change of this allocation scheme for revenues gained from treating privately insured patients which took place in the year 2007 (see next section for further details). In 2007, the year of the intervention, the dental clinics provided about 76,000 treatment sessions. The Department of Prosthetic Dentistry treated approximately 1,700 patients in 9,000 mostly outpatient treatment session in 2007, focusing mainly on the provision of prosthetic services such as crowns, bridges and removable dentures. Other dental services such as conservative and periodontal treatments are also provided when directly linked to prosthetic care.

4.3 Description of the intervention

This study examined a shift from purely salary-based reimbursement of dentists to a novel payment scheme which consisted of salary payments combined with bonus payments for specific items of care provision. Hereby this predefined set of items of care serves as surrogate measure to determine performance (see Table 11 for an overview of the incentivized items of care). The intervention incentivized specific treatments and the treatment of specific patient groups and was established in April 2007 in the Department of Prosthetic Dentistry at Heidelberg University.

Table 11: Overview of incentivized items of care and associated point values.

Incentivized items of care	Associated point values
Prosthetic treatments (e.g. full dentures, prosthetic treatment of implants, interim dentures, denture relines)	0.5 - 3 points per treatment
Surgical implant services (e.g. placing implants, sinus lifts, bone block transplantation, placing membranes)	0.5 - 1 points per treatment
Endodontic treatments/ Root canal treatments	0.25 points per canal treated
Direct restorations	0.2 points per surface
Periodontal treatment request	2 points per treatment request†
Clinical documentation, study recalls, providing guidance to colleagues	0.25-0.5 points
Treatment of person with disability, patients suffering from infectious diseases or somatoform disorders	point values are doubled

† In advance of a periodontal treatment, the dentist has to submit a treatment request to the health insurance including detailed diagnosis as well as a treatment and cost schedule.

The intervention attributed point values to a number of specific items of dental care delivery (see Table 11). These point values were summed up for each dentist at the end of each quarter and determined the dentist's share of the so called "pool"- the revenues gained from treating privately insured patients in their department. The scheme applied to the treatment of all patients, independent of their insurance status (private insurance, statutory health insurance, exempt from charges because participating in a clinical study). All practitioners employed in the Department of Prosthetic Dentistry were entitled to participate in the incentive program except for dentists in their first year in practice. Participation in the program was voluntary.

4.4 Data and empirical strategy

4.4.1 Routinely reported administrative data

Information about all inpatient and outpatient treatments performed within Heidelberg University is routinely collected by the Hospital Information System, which primarily serves administrative and claiming purposes. Panel data for analysis were provided in an anonymized form, covering all claims made by the Department of Prosthetic Dentistry and the Department of Conservative Dentistry between January 1st, 2005 and December 31st, 2009. The dataset included 402,499 treatment claims provided in 79,132 treatment sessions to 14,805 patients from both departments under observation. Besides procedure codes and number of procedures performed, the dataset provided unique patient identifiers, patient's age and sex, treatment date, patient's insurance status, and information about the practitioner who performed the treatment. In Germany, dental services in inpatient and outpatient care are

reimbursed fee-for-service according to two specific fee schedules, one for services provided under a statutory health insurance scheme (Bewertungsmaßstab für zahnärztliche Leistungen – BEMA-Z) and one for the treatment of privately insured patients or self-payers (Gebührenordnung für Zahnärzte – GOZ) (Bundeszahnärztekammer 2011; Kassenzahnärztliche Bundesvereinigung 2016). Hence, claims data for dental services solely contain treatment codes and no clinical information, such as diagnoses or disease severity as it would be necessary for a reimbursement system based on diagnosis-related groups.

For the purpose of this analysis, the sample was restricted to patients aged between 18 and 80 years. Moreover, the evaluation concentrated on patients insured under a statutory insurance scheme to avoid bias from different patient-sided financial incentives. Statutory health insurance provides a standardized package of oral healthcare, covering costs for diagnostics, direct restorations, oral surgery, periodontology and endodontic treatments completely. Private insurance schemes vary in the reimbursement of oral treatment costs as their members can choose among different schemes with different levels of coverage. Additionally, to avoid distortions through the interaction of different dental departments within Heidelberg University, the analysis focused on treatment sessions that were limited to one department on that day.

4.4.2 Dependent and control variables

The unique university setting with different dental departments and the availability of comprehensive data allowed the exploitation of natural variation induced through the intervention. Hereby, the Department of Conservative Dentistry served as a suitable control group. As in terms of treatment focus, the departments of Prosthetic Dentistry and Conservative Dentistry have the broadest similarity in comparison with the other departments. Using a DiD design, dental service provision with and without additional performance-oriented bonuses was compared. To ensure comparability of interventions among both departments, the analysis focused on a common set of dental services. Thereby, three different categories of dependent variables were considered:

A) Utilization at the extensive margin, expressed as the number of patients treated per provider per week;
B) Utilization at the intensive margin:

B.1) Utilization of incentivized items, expressed as the number of patients per week who receive the respective treatment which is incentivized by the bonus scheme

- Direct restorations
- Periodontal treatment requests
- Root canal treatments

B.2) Utilization of non-incentivized items, expressed as the number of patients per week who receive the respective treatment which is not incentivized by the bonus scheme

- X-Rays
- Dental check-ups
- Assessment of the
- Tooth sensitivity tests
- Anaesthesia

Table 12 shows the number of treatments performed in terms of BEMA-Z treatment codes which were used to establish the dependent variables of interest from available administrative data. The most prevalent claims are diagnostic procedures such as dental check-up examinations, tooth sensitivity tests and X-rays but also infiltration anaesthesia as a service complementary to dental treatments.

Table 12: Descriptive statistics: overall statistics, dependent variables and associated treatment codes

Procedure	BEMA-Z code and description	Total
Direct restorations	**13a** (direct restoration, one surface)	5,990
	13b (direct restoration, two surfaces)	6,719
	13c (direct restoration, three surfaces)	2,389
	13d (direct restoration, > three surfaces)	1,812
	13e (composite direct restoration, one surface, posterior tooth)	8
	13f (composite direct restoration, two surfaces, posterior tooth)	13
	13g (composite direct restoration, three surfaces, posterior tooth)	1,198
Periodontal treatment requests	**4** (clinical assessment and preparation of treatment and cost schedule for diseases of the oral mucosa and the periodontium)	991
Root canal treatments	**28** (extirpation of the vital pulp, per canal)	2,229
	32 (root canal treatment, per canal)	5,859
	35 (root canal filling, per canal)	3,356
X-rays	**Ä925a** (radiographic assessment of the teeth, up to two images)	14,838
	Ä925b (radiographic assessment of the teeth, up to five images)	1,019
	Ä925c (radiographic assessment of the teeth, up to eight images)	96
	Ä925d (radiographic assessment of the teeth, > eight images)	258
	Ä934a (radiographic assessment of the skull, one image)	24
	Ä934b (radiographic assessment of the skull, two images)	1
	Ä934c (radiographic assessment of the skull, > two images))	0
	Ä935a (partial radiographic assessment of the skull, one image)	86
	Ä935b (partial radiographic assessment of the skull, two image)	2
	Ä935c (partial radiographic assessment of the skull, > two images)	0
	Ä935d (panoramic radiographs)	4,477
Dental check-ups	**01** (clinical investigation)	20,178
PSI assessment	**04** (assessment of the Periodontal-Screening-Index)	2,633
Tooth sensitivity tests	**8** (tooth sensitivity testing)	15,935
Anaesthesia	**40** (infiltration anaesthesia)	17,547
	41a (local anaesthesia, intraoral)	4,782
	41b (local anaesthesia, extraoral)	3
Total number of claims		402,499
Total number of treatment session		79,132
Total number of patients		14,805
Total number of dentists		105

In addition, Table 13 provides summary statistics for the sample stratified for treatment and control group. It includes descriptive statistics for the dependent and explanatory variables. The treatment and control group were similar with respect to the number of patients per practitioner and the proportion of women but differ slightly with respect to average patients' age, department's workforce (number of dentists), and the number of patients treated per week. Descriptive statistics for the dependent variables "utilization of incentivized" and "utilization of non-incentivized items" show that all services were provided in both departments on a regular basis. As most of the analysed treatment items belong primarily to the domain of conservative dentistry, a higher prevalence of respective treatment items is observed for the Department of Conservative Dentistry. To form a valid control group in DiD estimation, the outcomes don't necessarily have to be observed on the same level in both

the treatment and control group but need to fulfil the "parallel trend assumption" (Angrist and Pischke 2008). Robustness checks were used to test this assumption.

Table 13: Summary statistics: dependent and control variables, stratified by intervention and control group

Variable	Department of Prosthetic Dentistry (Intervention)		Department of Conservative Dentistry (Control)	
	Mean	SD	Mean	SD
Dependent variables				
Number of patients per practitioner per week	8.72	41.04	8.63	45.84
Number of patients per week receiving…				
Direct restorations (incentivized)	16.62	7.26	24.92	18.73
Periodontal treatment requests (incentivized)	0.47	1.00	3.33	4.57
Root canal treatments (incentivized)	6.49	3.20	11.40	5.77
X-rays	30.08	9.43	41.73	14.40
Dental check-ups	37.87	10.65	39.73	12.99
PSI assessment	3.22	2.88	6.90	4.46
Tooth sensitivity tests	16.39	6.62	44.86	13.38
Anaesthesia	28.25	11.22	27.71	14.73
Control variables				
Women (% of all patients)	0.58	0.06	0.57	0.06
Patient's age	55.45	2.09	48.16	2.27
Dental workforce (number of dentists)	18.70	1.11	17.13	1.05
Number of patients per week	162,71	2,24	147,28	2,73

4.4.3 Estimation strategy

The DiD approach enables identification of causal relationships through exploitation of natural variation in longitudinal data by comparing the treatment group to a suitable comparison group (Angrist and Pischke 2008). To investigate the impact of additional performance-oriented bonuses on the three different aspects of utilization, repeated cross section ordinary least squares DiD regression was estimated according to equation (3) (Imbens and Wooldridge 2009):

$$Y_i = \alpha + \beta(Prosth_i) + \gamma(Post_i) + \delta(Prosth_i * Post_i) + \theta X_i + \varepsilon_i. \qquad (3)$$

Hereby, Y_i denotes the respective outcome. This is the number of patients treated per practitioner per week for A): Utilization at the extensive margin and the number of patients per week receiving the respective treatment, for (B): Utilization at the intensive margin of both (B.1) incentivized items and (B.2) non-incentivized items. These outcomes are observed for the two departments indicated by the dummy variable $Prosth_i$ (where $Prosth_i$ equals one for

treatments provided in the Department of Prosthetic Dentistry) in two time periods. The latter is indicated by the dummy variable $Post_i$ which is equal to one in the post-introduction period. $Prosth_i * Post_i$ is the interaction term between services provided in the Department for Prosthetic Dentistry and the post-introduction period. It equals 1 for observations in the treatment group in the second period. The coefficient of this interaction δ, is the DiD estimate of interest. It depicts the change in the outcome variable of interest that can be attributed to the introduction of a payment system with additional performance-oriented bonuses. X_i represents a vector of control variables that may impact utilization of dental care. This vector includes patients' sex, patients' age as well as the combined number of patients per week and the workforce of the other department to account for potential interactions between departments such as changes in referrals between departments. Moreover, X_i also includes department's workforce for the outcome groups (B.1) and (B.2). ε_i denotes the error term. To account for potential serial correlation, clustered standard errors were calculated (Bertrand et al. 2004) .

In order to assess the robustness of the underlying identification strategy, a series of placebo intervention DiD estimations for the pre- and post-intervention period were performed. This served two aims: First, the parallel trend assumption required for a DiD estimation and therefore the validity of the intervention strategy was examined (Jones 2007). Second, placebo interventions enable the evaluation of potential anticipation effects or implementation lags. Equation (4) specifies these placebo interventions. Hereby, the time point of the intervention is postponed or antedated. These effects were calculated for three pre-introduction quarters (Q3 of 2006 – Q1 of 2007; denoted as 2006Q3-2007Q1) and four post-introduction quarters (Q3 of 2007 – Q2 of 2008; denoted as 2007Q3-2008Q2).

$$Y_i = \alpha + \beta(Prosth_i) + \gamma \sum_{i=2006Q3}^{i=2008Q2}(Quarter_i) + \delta\left(Prosth_i * \sum_{i=2006Q3}^{i=2008Q2}(Quarter_i)\right) + \theta X_i + \varepsilon_i \qquad (4)$$

Repeated cross section DiD aggregates input variables to the pre- and post-introduction period. Hence, assessment of changes in output levels within these periods is not possible from the standard DiD estimation. To account for this fact, a DiD with restricted longitudinal data was applied. This provides information about long-run persistency of potential effects of the payment reform. Hereby, the first post-introduction year data was excluded in the estimation to observe levels of service provision one year after implementation in comparison to the pre-introduction period. Estimation was performed according to equation 1. All

analyses were performed using Stata 13.1 analytical software (StataCorp. 2013. College Station, TX: StataCorp LP.). Statistically significant results are denoted by *** for p<0.01, ** for p<0.05 and * for p<0.10. This study has received ethical approval from Heidelberg University Medical Faculty's ethical review committee (S-500-2011).

4.5 Results

Table 14 presents DiD estimates for the changes in the number of patients treated per practitioner per week. It shows that this outcome – as a measure for changes in utilization at the extensive margin – increased significantly by 1.1 (standard error (SE): 0.09) in the intervention group following the reform. The difference in the outcome measure between both departments, denoted by the parameter estimate of the "Prosthetic Dentistry" dummy, is not significant and confirms comparability of treatment and control group. The parameter estimate for the post-introduction-dummy is also found to be non-significant.

Table 14: DiD estimates: intervention effect on the number of patients per practitioner per week

Parameter	**Number of patients per practitioner**
	Coefficient (SE)
Prosthetic Dentistry	-0.9 (0.19)
Post-Introduction	-0.8 (0.16)
Prosth x Post (DiD estimator)	**1.1* (0.09)**
Observations (*N*)	520

Note. Dependent variable: number of patients treated per practitioner per week. Model controls for patients' age, patient's sex, the total number of patients of both departments, and the workforce (number of dentists) of the other department. Standard errors are clustered at the department level. Statistically significant results are denoted by *** for p<0.01, ** for p<0.05 and * for p<0.10.

The results from regression analysis on "utilization of incentivized treatment items" are shown in Table 15. The DiD parameters are positive and significant showing increased utilization at the intensive margin for incentivized services. The largest increase was found for direct restorations with 13.1 (SE: 0.67) additional patients receiving a direct restoration in the Department of Prosthetic Dentistry following the reform. Periodontal treatments increased by 1.1 (SE: 0.08) patients per week after the intervention. In the treatment group, 4.1 (SE: 0.12) additional patients per week received a root canal treatment following the reform. The negative and significant parameter estimates for the "Prosthetic Dentistry" dummy show that these treatments were generally more prevalent in the Department of Conservative Dentistry.

Table 15: DiD estimates: intervention effect on the number of patients per week receiving the respective incentivized treatments

Parameter	Direct restorations	Periodontal treatment requests	Root canal treatments
	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
Prosthetic Dentistry	-19.0*** (0.05)	-3.9** (0.18)	-8.2** (0.56)
Post-Introduction	-10.3 (2.98)	-0.7* (0.04)	-2.7 (0.6)
Prosth x Post (DiD estimator)	**13.1** (0.67)**	**1.1** (0.08)**	**4.1** (0.12)**
Observations (*N*)	520	520	520

Note. Dependent variable: number of patients per week receiving the respective incentivized treatment. Model controls for patients' age, patient's sex, the combined number of patients of both departments and the workforce (number of dentists) in both departments. Standard errors are clustered at the department level. Statistically significant results are denoted by *** for p<0.01, ** for p<0.05 and * for p<0.10.

Table 16 presents DiD estimates for utilization at the intensive margin for non-incentivized items. DiD parameter estimates are positive and significant for all five non-incentivized treatments. The highest impact was observable for the number of patients per week who received infiltration and local anaesthesia following the reform (8.8 (SE: 0.13)). Utilization of diagnostic instruments under observation, which are X-rays, assessment of the PSI, dental check-ups and tooth sensitivity tests increased by 5.5 (SE: 0.77), 6.9 (SE: 0.10), 5.5 (SE: 0.39), and 4.5 (SE: 0.2) respectively.

Table 16: DiD estimates: intervention effect on the number of patients per week receiving the respective non-incentivized treatments

Parameter	X-rays	Dental check-ups	PSI assessment	Tooth sensitivity tests	Anesthesia
	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
Prosthetic Dentistry	-19.5** (0.63)	-9.0** (0.61)	-8.4** (0.41)	-35.2**(1.74)	-5.7** (0.32)
Post-Introduction	-3.8 (1.86)	-2.9 (0.58)	-3.5* (0.35)	-4.6 (1.41)	-5.9 (1.77)
Prosth x Post (DiD estimator)	**5.5* (0.77)**	**5.5** (0.39)**	**6.9*** (0.10)**	**4.5** (0.22)**	**8.8*** (0.13)**
Observations (*N*)	520	520	520	520	520

Note. Dependent variable: number of patients per week receiving the respective non-incentivized treatment. Model controls for patients' age, patient's sex, the combined number of patients of both departments and the workforce (number of dentists) in both departments. Standard errors are clustered at the department level. Statistically significant results are denoted by *** for p<0.01, ** for p<0.05 and * for p<0.10.

Table 17 shows results from placebo DiD regressions. For utilization at the extensive margin, the largest effect was observed two quarters after the intervention, pointing towards an implementation lag. An implementation lag was also observable for the incentivized outcomes "direct restorations" and "root canal treatments". While the DiD coefficient for "root canal treatments" is largest two quarters after the reimbursement reform, the

coefficient's peak for "direct restorations" is observable for the third post-introduction quarter. For "periodontal treatment request", the largest DiD parameter estimate is observed two quarters in advance of the intervention. Except for "dental check-ups", placebo DiD estimators for non-incentivized items are highest for the second post-introduction placebos and therefore show an implementation lag of two quarters. Although robustness checks show implementation lags of two quarters for most of the outcome measures, there was no generally uniform time point for intervention-related peaks in the utilization of various treatment items. Note that the placebo DiD estimators show relatively high variation. Ideally, placebo coefficients should be u-shaped over time with the coefficient of the actual intervention being its peak value. This variation manifests especially in the DiD estimation for "periodontal treatment requests" and "dental check-ups".

Table 17: DiD placebo intervention estimates for all outcome dimensions in comparison to DiD estimates

Parameter	Number of patients per practitioner	Direct restorations	Periodontal treatment requests	Root canal treatments	X-rays	Dental check-ups	PSI assessment	Tooth sensitivity tests	Anesthesia
	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
Prosth x Post (DiD estimator)	**1.1* (0.09)**	**13.1** (0.67)**	**1.1** (0.08)**	**4.1** (0.12)**	**5.5* (0.77)**	**5.5** (0.39)**	**6.9*** (0.1)**	**4.5** (0.2)**	**8.8*** (0.13)**
Placebo interventions pre-introduction									
Prosth x 2006Q3	0.7** (0.03)	7.3** (0.18)	0.9** (0.05)	3.4** (0.07)	3.8** (0.19)	6.2*** (0.05)	6.0*** (0.053)	1.2** (0.07)	2.9*** (0.01)
Prosth x 2006Q4	0.957** (0.07)	11.1** (0.45)	1.6** (0.08)	4.2** (0.10)	5.1* (0.52)	6.8** (0.12)	6.4*** (0.063)	2.3** (0.14)	5.8*** (0.09)
Prosth x 2007Q1	1.042* (0.1)	13.7** (0.60)	1.0* (0.09)	4.2** (0.11)	5.8* (0.86)	7.2** (0.37)	6.5*** (0.090)	4.2** (0.28)	7.3** (0.17)
Placebo interventions post-introduction									
Prosth x 2007Q3	1.184* (0.11)	14.5** (0.70)	0.9* (0.10)	4.5** (0.13)	6.6* (1.04)	5.4* (0.52)	7.4*** (0.096)	5.2** (0.30)	9.8*** (0.15)
Prosth x 2007Q4	1.395** (0.09)	17.1** (0.60)	1.2* (0.15)	4.6** (0.19)	7.9* (1.12)	6.1* (0.59)	7.4** (0.163)	5.9** (0.23)	11.5** (0.34)
Prosth x 2008Q1	1.036* (0.16)	17.8*** (0.28)	1.2* (0.14)	3.7* (0.31)	6.1 (1.44)	4.2 (0.77)	7.1** (0.147)	5.1** (0.31)	9.5** (0.60)
Prosth x 2008Q2	0.624 (0.27)	16.0*** (0.03)	1.4 (0.26)	3.2* (0.46)	3.2 (1.44)	3.0* (0.34)	6.7** (0.261)	2.2 (0.54)	8.5* (1.26)
Observations (*N*)	520	520	520	520	520	520	520	520	520

Note. Dependent variable: number of patients per practitioner per week and the number of patients per week receiving the respective service. Model controls for patients' age, patient's sex, the combined number of patients of both departments and the workforce of the other department (number of dentists). Moreover, controls include department's workforce for all outcomes except for "Number of patients per practitioner". Placebo interventions vary the time of the intervention to check for robustness and inform about pre-introduction and post-introduction trends. Standard errors are clustered at the department level. Statistically significant results are denoted by *** for p<0.01, ** for p<0.05 and * for p<0.10.

Beneath the question for an initial intervention effect and potential implementation lags, success of a change in payment structure is also determined by its sustainability. Table 18 provides DiD estimates for all dependent variables as estimated on basis of a restricted sample, which excluded data from the first post-introduction year. DiD coefficients are positive for all dependent variables. Positive parameter estimates were found for all outcomes measuring utilization of incentivized items and the non-incentivized items "dental check-up" as well as "PSI assessment".

Table 18: DiD estimates with restricted sample: one-year post-introduction effect on the number of weekly patients per practitioner per week and on the number of patients per week receiving the respective treatments

Outcome	**1-year post-introduction**
	DiD estimator (SE)
Number of patients per practitioner	1.0 (0.16)
Direct restorations	17.0** (0.51)
Periodontal treatment requests	1.4** (0.08)
Root canal treatments	4.0* (0.58)
X-rays	4.3 (1.10)
Dental check-ups	4.5* (0.44)
PSI assessment	7.8** (0.28)
Tooth sensitivity tests	3.4 (0.64)
Anaesthesia	9.7 (1.64)
Observations (N)	416

Note. Dependent variable: number of patients per practitioner per week and the number of patients per week receiving the respective service. Model controls for patients' age, patient's sex, the combined number of patients of both departments and workforce of the other department (number of dentists). Moreover, controls include department's workforce for all outcomes except for "Number of patients per practitioner". The model excludes the first post- introduction year data to observe levels of service provision one year after the introduction. Standard errors are clustered at the department level. Statistically significant results are denoted by *** for $p<0.01$, ** for $p<0.05$ and * for $p<0.10$.

4.6 Discussion

The impacts of introducing performance-oriented payment schemes are a frequent matter of debate in both general medicine and dental care. To date, there is a dearth of empirical insights into the impact of such incentives on providers' behaviour and utilization of care. The present study is the first to analyse both intended and unintended effects of performance-oriented bonus payments on utilization of dental care. Hereby, provider's performance was assessed by a surrogate measure that builds upon the provision of specific "desired" service items. Exploiting a natural experiment enables to conclude that an additional financial bonus which targets the provision of specific services increased utilization of dental services in different directions. Beneath intended positive effects on the utilization of incentivized

services, unintended consequences are shown with regard to utilization of non-incentivized items. Besides these increases at the intensive margin, the incentive also enhanced utilization at the extensive margin since the number of patients treated per practitioner increased. Moreover, results suggest that increases in utilization, especially with regard to directly incentivized items, were persistent over time. Robustness checks point towards an implementation lag of half a year after introduction for most of the examined outcomes.

Earlier research has demonstrated that enhancing the provision of specific services through performance-oriented payment may in fact result in more utilization of incentivized treatments (Clarkson et al. 2008; Woods et al. 2010). The present results confirm these findings and show that this effect is not only observable when one single intervention is addressed by direct incentives but also when an incentive system targets multiple items of care. Findings are also in line with earlier research by Decker 2011, who showed that additional payments enhance utilization at the extensive margin – although this was not explicitly intended by the intervention.

In addition, the present paper adds to the extant literature with regard to potential side effects of financial incentive systems. The analysis examined the reform's impact on parameters that weren't targeted directly by the reform and increases in the provision of diagnostic items and treatment supporting services were observed. Although none of the selected items were directly incentivized through the payment reform, increases in the supply of these non-incentivized services are explained by their complementary character to incentivized items of care. Whereas anaesthesia is a necessary treatment supporting service, dental check-ups, X-rays, PSI assessment, and tooth sensitivity tests are diagnostic interventions. Here, the assessment of the PSI is directly linked to the incentivized item "periodontal treatment request" as it is necessary for defining the need for periodontal treatments. The same is true for tooth sensitivity tests which are connected to various endodontic and prosthetic treatments as well as X-rays, representing a frequently used diagnostic technique. Whereas increased utilization of dental check-ups, tooth sensitivity tests and the assessment of PSI don't pose considerable health risks for patients, increased utilization of potentially harmful X-rays were also observed. This provides complementary evidence to the findings of Chalkley & Listl 2018, who observed significant increases in X-rays when dentists switch from fixed salary to fee-for-service remuneration.

A limitation of the present study is that the intervention was focused on one dental department. In contrast to evaluations of national interventions which are able to draw conclusions about utilization changes on a population level, the findings of the present study may not be directly transferrable to other settings. Results suggest that increases in services provided by the Prosthodontic Department following the reform might indicate a change away from "referral to the Conservative Dentistry colleagues" towards more of a "do-it-yourself-strategy" within the Department of Prosthetic Dentistry. While the regulatory changes examined may not be directly applicable on the broader population level, results may still provide evidence of broader relevance in the sense that financial incentives can impact scope of practice and referral decisions. For example, additional financial incentives for periodontal treatments could imply more provision of this type of services in general dental practices and less referrals to practices specialized in periodontal care.

Moreover, a sharp onset of the treatment effects for all outcomes can't be postulated. This constitutes a second limitation of the present analysis. Performed robustness checks revealed a high volatility in the dependent variables over time, which manifests in the variation of placebo DiD coefficients. This is especially true for the outcome variables "periodontal treatment requests" and "dental check-ups" where a clear trend in placebo estimates wasn't observable. This raises the question whether the parallel trend assumption holds for these two specific outcome measures. By including a suitable comparison group, the DiD approach reduces bias as it accounts for common volatility and common time trends not caused by the intervention. Thus, DiD is a suitable approach when the underlying longitudinal data is highly volatile.

At the same time, this represents a major strength of the methodological approach applied. The unique study environment with comparable treatment and control groups in an isolated clinical setting allowed to exploit natural variation by applying a quasi-experimental design. This reduces several forms of potential bias, enabling to establish a causal link between the intervention and utilization of care.

Results show that implementing performance-oriented financial incentives also affects non-targeted aspects of utilization. Consequently, the design of such interventions should put specific emphasize on fine-tuning of financial incentives especially with regard to services where increased utilization isn't intended. Moreover, careful design of such interventions is

advisable concerning the monetary amount of the incentive. Large financial incentives are at risk to induce crowding-out of intrinsic motivation (Himmelstein et al. 2014). The intervention examined here connects the incentive to variation in bonus payments which warrants the incentive to be a rather small fraction of overall income. It has been recommended that pay-for-performance schemes should not exceed 10% of income (Campbell and Tickle 2013a).

The present analysis relied on administrative data based on procedure codes. Therefore, effects on patient's health outcomes could not be examined. While standardized diagnostic codes are routinely available and implemented in many other areas of healthcare, similarly standardized diagnostic codes are not yet routinely available for dental care. Availability of these diagnostic codes in oral healthcare should be promoted in order to enable enhanced analysis of the impact of performance-based financial incentives and their bearing on patients' wellbeing.

This analysis provides novel evidence for the effect of performance-oriented provider payment on utilization of dental care as well as associated side effects. However, the definition of target parameters of the underlying intervention followed a rather pragmatic approach. Here, number and type of procedures claimed mainly served as the basis for incentives. Hence, incentivization was not explicitly directed at a prevention-focused and patient-centred provision of oral care. In order to achieve sustainable improvements in populations' oral health, it is necessary to establish a system where value for patients forms the basis of reimbursement and therefore incentivises achieving and maintaining good oral health (Niederman et al. 2017; Pitts et al. 2017; Porter 2009). Since quality measures for a reimbursement system of that kind are widely missing, the question remains how a meaningful and structured approach can be designed to define a set of suitable performance measures. These should be able to serve as target parameters for implementing value-based payment structures that incentivize a prevention-focused and patient-centred provision of oral care. Section 5 addresses this issue and focuses on defining relevant target parameters based on a structured approach involving relevant stakeholders.

5 Performance-oriented payment: a set of measures for oral healthcare delivery

5.1 Background

Whereas the previous section focused on the effects of performance-oriented payment on utilization of dental services, this section aims at defining relevant measures of oral healthcare delivery and oral health outcomes which are feasible in comparing dentists with their peers. Hereby, resulting measures are able to serve as a basis for target parameters of a performance-based payment system that incentivizes the provision of prevention-oriented and patient-centred oral healthcare. In combination with the previous section, this chapter provides evidence about potential content and effects of performance-oriented payment systems in dental care.

The purpose of this section is to establish measures of oral health for transparent and explicit reporting of routine data to facilitate more patient-centred and prevention-oriented oral healthcare. Eventually, these measures are able to constitute the basis for target parameters for implementing value-based payment structures. To accomplish this, an intermediate objective was to develop a comprehensive list of topics that a range of stakeholders perceive as valid, important, and relevant for describing oral health and oral healthcare. More specifically, those topics should 1) measure the quality of care, 2) describe aspects of oral health in patients and populations and 3) identify and describe the factors that potentially affect delivery of care or oral health and may therefore explain warranted, as opposed to unwarranted, variation (Baâdoudi et al. 2016; Navathe and Emanuel 2016).

A qualitative 4-stage approach was used to develop the list of topics: 1) scoping of literature and its appraisal, 2) an expert meeting, 3) a 2-stage Delphi process (online), and 4) a World Café discussion. The aim was to create consensus through structured conversations with a wide range of oral healthcare stakeholders (general dental practitioners, patients, insurers, and policy makers) from the Netherlands, Germany, the United Kingdom, Ireland, Hungary, and Denmark.

This study is the first to establish a comprehensive and multiple- stakeholder consented topic list designed for guiding the implementation of transparent and explicit measurement of routine data of oral health and oral healthcare. Successful measurement within oral healthcare

systems is essential to facilitate implementation of performance-based remuneration systems that aim at sustainable improvements in populations' oral health by promoting patient-centred and prevention-oriented oral healthcare.

5.2 Methods

In order to establish a set of oral health topics, a 4-stage approach was used: 1) scoping of literature and appraisal, 2) an expert meeting, 3) an online 2-stage Delphi process and 4) a World Café discussion (Figure 9). This approach was used to create a broad list of potential topics and then have structured conversations with a range of stakeholder groups in oral healthcare (general dental practitioners, patients, insurers, and policy makers) to refine that list and create consensus. Structured conversations enabled group communication while minimizing "group think". These methods gave stakeholders the opportunity to contribute to the development of core oral health topics and measures by providing their views and opinions.

Figure 9: Timeline of the 4-stage approach

5.2.1 Literature search and appraisal

Literature scoping was performed to explore already existing measures in oral healthcare. A PubMed and Google Scholar literature search was conducted during July 2015 and supplemented with governmental reports, based on the following search terms: 1) (performance OR process OR outcome OR quality OR indicator OR measure OR outcome OR comparator) AND (oral OR dental) AND (health OR healthcare) and 2) ("process assessment" OR "outcome assessment" OR "oral health") [MeSH]. Title and abstract reviews identified 12 relevant publications (Bourgeois et al. 2008; Buorgeois and Llodra 2004; Gezondheidsraad 2012; Herndon et al. 2015; Ireland et al. 2001; Nihtilä 2010; Nutbeam 1998; Osta et al. 2012; Ottolenghi et al. 2007; Petersen et al. 1994; Rodríguez et al. 2005; Tsichlaki and O'Brien 2014). These mentioned 625 potential topics in total. 147 of these were actually described.

Since most of these 147 measures did not define a clear numerator or denominator they were considered as topics. Based on these oral healthcare topics, a long list was created.

Initial appraisal of the relevance, validity, and importance of the retrieved topics was performed through "sense check" conversations with a sample of general dental practitioners at ACTA Amsterdam and Heidelberg Dental School (n = 6). Duplicate topics were removed or merged, and the remaining topics were pragmatically split into two groups: the A- and B-lists. Topics were placed in the A-list if they met the following criteria:

- Topic is measurable with data from available sources, such as health insurance claims data, dental practice records, or patient questionnaires.
- Topic is considered important, useful, and relevant by the dentists for comparison purposes.
- Topic is not a disease-severity index.

Indices were excluded since the information on them is usually not routinely available and different practices will use different indices according to their preferences. The B-list consisted of topics that were identified but failed to meet ≥1 of the criteria. A second sense check was performed with other general dental practitioners from the same localities (n = 8) to see whether the division into A- and B-lists was sensible and whether any missing topics could be identified.

5.2.2 Expert meeting

To initiate the process of creating measures from the long list of topics an expert meeting was held in Frankfurt/ Main in October 2015. From six participating EU countries (Germany, Netherlands, United Kingdom, Scotland, Denmark and Hungary), representatives were invited to the expert meeting. Representatives from Germany (n=5), the Netherlands (n=4), from the UK (n=2), Scotland (n=2), Denmark (n=1) and Hungary (n=1) participated in the meeting. All participants are usually involved in dental practice or research, represent the payer perspective or the patient side.

During the expert meeting, the A- and B-lists were discussed in two rounds with two randomly created groups separated in two rooms. Each discussion was facilitated by a moderator and two note-keepers. The discussions of both rounds were tape-recorded. The moderator made sure that the conversations did not go into full detail on how to measure a specific topic, but

focused on defining all important topics and categorizing them. The note-keepers wrote the content of the conversation down on paper tablecloths in order to support a structural discussion. In the first round of discussions, the topics were checked on whether they were rightfully placed in the A- or B-list and whether there were topics missing. After 30 minutes the groups switched rooms. The moderators of each table gave a summary of the first discussion. Participants could comment on the input given in the first round by the previous table and add topics or comments, when necessary details were missing at that table. After the expert meeting, two note-keepers adjusted the A- and B-list based on the conversations during the expert meeting. The tape-recordings were used to cross-check the notes and to make sure that all relevant information from the discussion was incorporated and nothing was missed that had been discussed during the meeting. The adjusted list was double checked by the other note-keepers and by the moderators of the expert meeting.

5.2.3 Delphi process

To create consensus on important oral healthcare topics among stakeholders involved in oral healthcare delivery, a Delphi process was performed which consisted of two rounds. The Delphi method enables a structured group communication and allows judgements on specific topics which reflect the views and opinions of a specified group (Goodman 1987). This method overcomes geographic challenges and time boundaries as it does not require face-to-face meetings and therefore allow all participants from different European countries to have equal opportunity to engage in the process (Geist 2010).

The Delphi process was designed as an online questionnaire with a discussion process. The Synmind software and platform (http://www.synmind.com/) was used for the Delphi process. This allowed to conduct a real-time (RT) Delphi, where respondents can get immediate feedback as the online platform updates the scores and comments automatically. Participants can revisit the platform at any time during the Delphi process which makes the multiple iterations of a traditional paper-pencil version redundant (Gordon and Pease 2006).

The stakeholders who attended the expert meeting recruited participants from their own countries for the Delphi. Stakeholders who were general dental practitioners, patients, insurers, and policy makers with backgrounds in the public and private sectors were invited to participate (n = 57). Of those, 46 (81%) participated in the first round of Delphi, of whom

27 were men and 19 were women (Table 19). From the first round, 61% also participated in the second round (n = 28).

Table 19: Characteristics of the Delphi participants (n=46)

Characteristics	n (%)
Sex	
Male	27 (59)
Female	19 (41)
Occupation	
Dentist	11 (24)
Dental specialist	6 (13)
Hygienist/ therapist	2 (4)
Dental policy sector	2 (4)
Insurance sector	2 (4)
Patients	3 (7)
Unknown	20 (43)
Practice	
Public	10 (22)
Private	3 (7)
Part public/ private	6 (13)
Other	7 (15)
Unknown	20 (43)
Mean age: 44y (range: 26-69)	

The first round of Delphi ran for three weeks in December 2015, and the second round ran for two weeks in February 2016. In the first week of each round, the participants were asked to score their levels of agreement on the inclusion or exclusion of the topics for the development of oral health measures (strongly disagree, 0; disagree, 1; agree, 2; strongly agree, 3) and to comment on the topics to explain their decision. For the remainder of each round, the Synmind platform was open for discussion among participants and moderators; participants could see comments and ratings of others and were able to give and receive comments. The comments and individual ratings were presented per topic and per participant. The ratings of all participants on a topic were visualized in a spider diagram (Figure 10). Participants stayed anonymous to both the researchers as well as to the other participants. The conversations were moderated by five anonymous moderators which provided controlled feedback; each moderator was assigned to one or two groups.

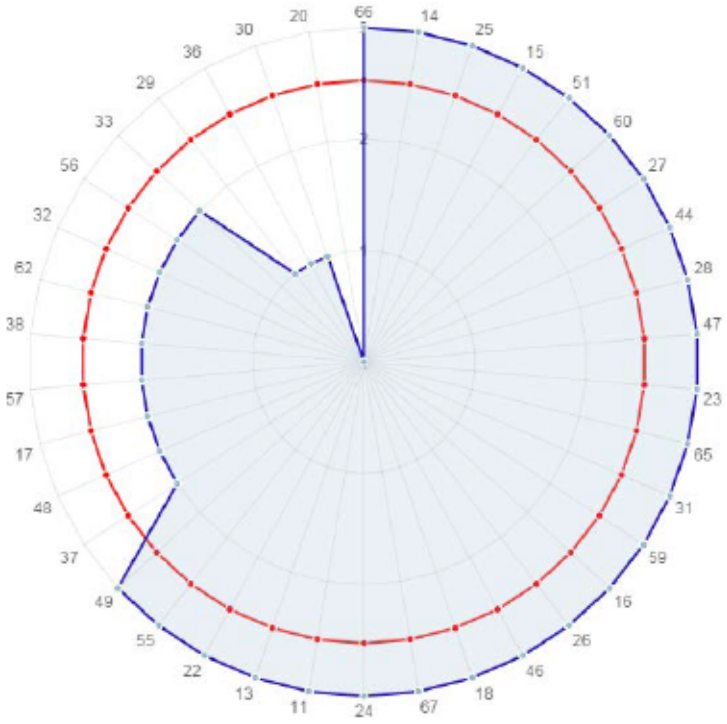

Figure 10: Spider diagram for Delphi visualization

The analysis of the first round of Delphi included three steps:

- Reviewing the level of agreement for each topic through percentage of agreement (i.e., the sum percentage of the scores for agree and strongly agree), mean, and mode.
- Reviewing the comments to gain an understanding of why the responses tended toward agreement or disagreement.
- Decide on removing, including, or amending the topic, which depended on consensus within the research team based on steps 1 and 2, with any disagreements resolved by discussion.

After the first round, the topics were revised and included into a second round of Delphi. In this round, the participants received more information about the reasons expressed why that topic was being considered, and a descriptor was provided to indicate how information on that topic could be obtained from available data sources (Appendix Table A3 - 2). Analysis of the second round of Delphi was based on the following criteria:

- If the score mean was >2, the topic remained in the list.
- If the score mean was ≤2, the comments were used to gain an understanding why the topic should be included.

- The decision on removing, including, or amending the topic and the adjustments within and among clusters were based on consensus within the research team on the basis of steps 1 and 2 and consideration of all comments and suggestions made by participants.

5.2.4 World Café

The World Café method enables large group dialogue and can reveal the collective intelligence of a group through multiple rounds of conversation (Brown and Isaacs 2005; Holman et al. 2007). Important for the World Café to be successful and create consensus is to: 1.) set the context were it is clear to the participants what the purpose is of the meeting, 2.) create an open and warm environment to stimulate thinking and conversation, 3.) create open questions on relevant pressing concerns related to the measures and 4.) encourage everyone to speak, think and listen (Ritch and Brennan 2010). These four rules served as guideline throughout the World Café.

A World Café meeting was held in June 2016 in Amsterdam to finalize the list of oral health topics by creating consensus between and within different groups of stakeholders. Participants were recruited purposefully from the network of the ADVOCATE project partners (n = 19). Criteria were that all groups of relevant stakeholders were involved and that all participating countries were represented. Every participant was allocated into six table discussions based on a random sequence so that each discussion was conducted with a unique group of participants. Each table discussed a cluster of topics in groups of five or six participants for six rounds, with participants changing tables after each round. Every participant therefore discussed each group of topics once. During the discussions, the moderators made sure that the following three questions were discussed: 1) whether topics were important, relevant, and valid; 2) whether there were any topics missing; and 3) whether the topics needed amendment. Participants were encouraged to write, draw, or doodle points from their conversation on the tablecloth, creating a record of incremental discussions as rounds progressed. The moderators' role was to summarize the previous, accumulating discussions on the cluster of topics and to ensure all topics were considered in each round.

At the end of the sixth round of discussions, the moderators discussed the main findings of the conversations and made preliminary adjustments to the topics. The participants were given the opportunity to endorse the revised topics via an anonymous voting system

(SOCRATIVE; http://www.socrative.com/). The results of the voting were displayed live, providing the opportunity for clarification of any remaining issues for each topic.

Following the meeting, a review was undertaken by the moderators to ensure that all revisions to the topic list had been captured. Final revisions were agreed per the following nonexclusive criteria to guide judgments:

- Topics with <50% agreement during the voting were excluded from the topic list.
- For topics that scored 50-75% agreement, decisions for inclusion depended on the arguments made by participants during the discussions.
- Topics with an agreement >75% were included in the final topic list.

5.2.5 Measures development

The 4-stage approach of creating consensus on oral healthcare topics resulted in a list of 48 relevant and important topics for stakeholders in oral healthcare (Figure 11, Table 20). The research team then developed measures; through discussion, numerators and denominators were defined for the topics. The definition of numerators and denominators was guided by the characteristics of data likely to be available from health insurance claims data or data obtainable from a patient questionnaire deployed in dental practices.

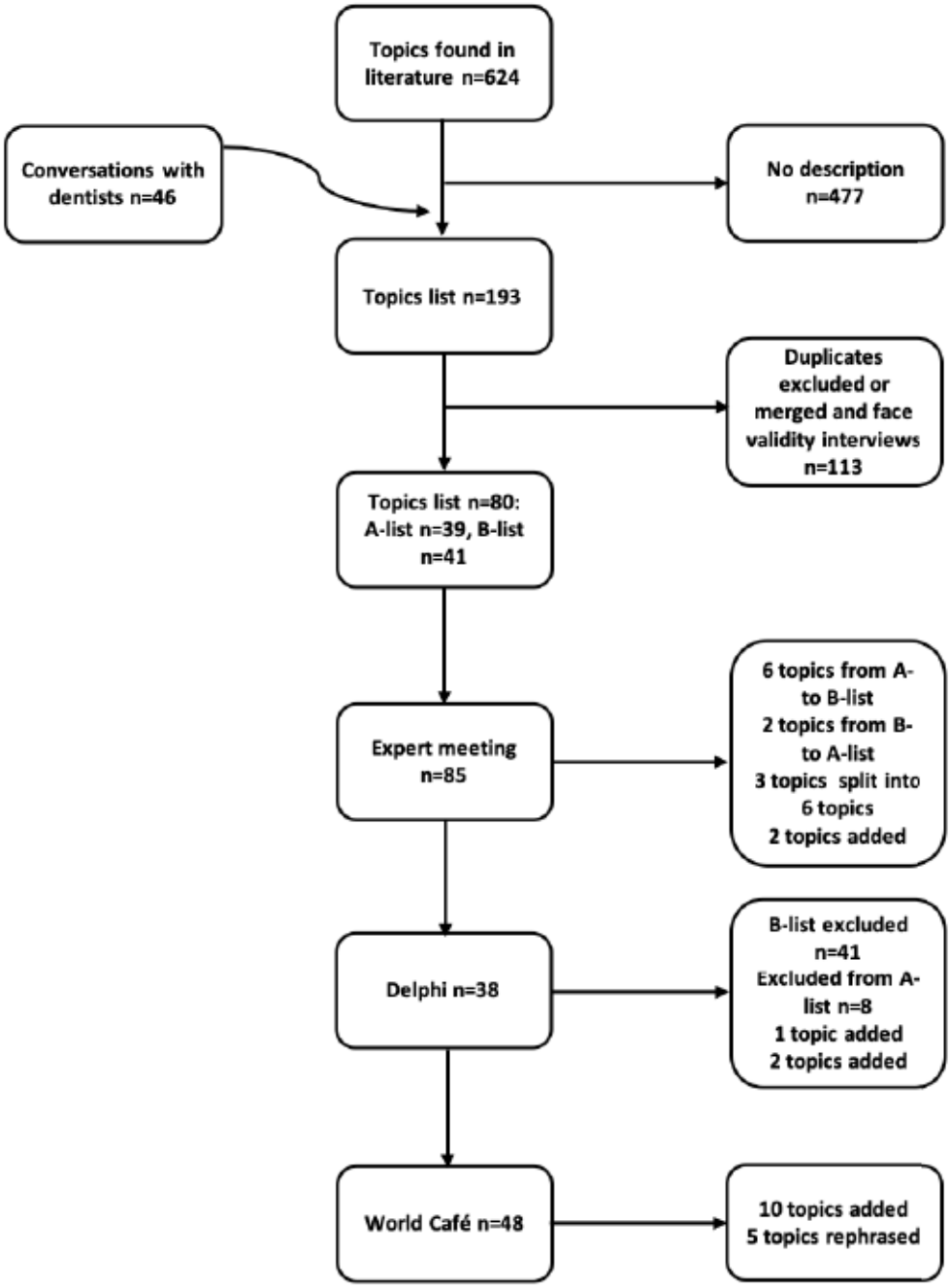

Figure 11: Flowchart of 4-stage process for developing oral healthcare topics

5.3 Results

Figure 11 depicts a flowchart of the 4-stage approach providing an overview of the inclusion and exclusion of topics over the whole development process. Literature search on measures in oral healthcare showed thousands of hits that were mostly unrelated to concrete measures. Further refinements of the search criteria showed not to be of use in determining relevant articles. The scope of the literature yielded inconsistent and incomplete results for addressing

the task of creating measures for oral healthcare. A total of 625 potential measures were identified from the literature search. From these, only 147 were described in sufficient detail to be potentially useable, and most did not describe a clear numerator or denominator. For this reason, they were considered as potential topics that might be developed into measures. The initial sense-check conversations added 46 topics to the long list of topics. After removal of duplicates and the second sense check, the A-list consisted of 39 topics and the B-list of41 topics.

During the expert meeting, six topics were moved from the A- to the B-list, and two topics were moved from the B- to the A-list. Two topics were added to the A-list, and three topics were divided, each forming two separate topics. The expert meeting resulted in a total of 85 potential topics (45 in the A-list and 40 in the B-list), which were grouped into nine clusters: A1- general dental practice and attendance, A2- oral symptoms and diagnosis, A3- health behaviours, A4- oral treatments, A5-preventive treatment and surveillance, A6- patient's perception, B7- signs and symptoms, B8- preventive and B9- dental practice. Moreover, the participants indicated that the topics were imprecise. Therefore, the topics were rephrased to clarify the meaning.

The Delphi process started with 85 topics, which were scored by the participants on their agreement to include or exclude from the list of oral healthcare measures. After the first round of Delphi, 39 topics remained in the A-list, grouped into six clusters, and 41 topics were excluded. Of these 41 topics, 40 were in the B-list at the start of the Delphi. From the initial B-list, two topics were combined into one topic, which was added to the A-list. Twelve topics in the original A-list were rephrased, and two new topics were added. The topics were reordered to make the transitions within and between the topic groups more logical. (Appendix Table A3 - 1)

After the second round of Delphi, 38 potential topics remained (Appendix Table A3 - 2). In this round, agreement on the topics was, as expected, higher. Only one topic was removed and no new topic was added; in addition, two topics were merged to one topic. The mean agreement for the remaining topics after the second round of Delphi on the 3-point ordinal scale was 2.5, and the mean percentage of agreement was 89%.

During the World Café, the participants identified ten missing topics, and these were added to the topic list. Five topics were rephrased from the list of topics. There were four topics where agreement was 50% to 75% and one topic with <50% agreement (Appendix Table A3 - 3).

Table 20: Topics list after 4-stage process

Group 1: Access to dental care
Reason for dental visit†
Funding of dental care provided†
Interval of dental check-ups by a dentist†, ‡
Referrals†
Decision not to proceed with recommended dental care solely due to costs†
Decision not to proceed with recommended dental care for other reasons than costs†
Access to dental care (affordability, availability and acceptability) †
Group 2: Symptoms and diagnosis
Current symptoms†
Communication about symptoms and wishes†
Medical history†
Social history†
Number of teeth†
Radiographs †, ‡
Periodontal examination†, ‡
Oral mucosa and cancer screening†
Examination for new caries lesions†
Group 3: Health behaviours
Tooth brushing†
Use of fluoride toothpaste†
Interdental cleaning†
Smoking†
Alcohol consumption†
Diet†
Group 4: Oral treatments
Fillings†, ‡
Root canal treatment†, ‡
Crowns and bridges†, ‡
Retreatment†, ‡
Periodontal treatment†, ‡
Extraction†, ‡
Partial removable dentures†, ‡
Full removable dentures†, ‡
Dental implants†, ‡
Aesthetic treatment (veneers, facings, whitening) †, ‡
Complications as a result of treatment†
Antibiotics prescribing†
Group 5: Oral prevention
Fissure sealants†, ‡
Fluoride application†, ‡
Professional cleaning (clean and polish) †, ‡
Oral hygiene advice†, ‡

Dietary advice†
Smoking advice†
Caries under surveillance†
Risk assessment for tailored prevention§
Group 6: Patient perception
Oral function (chewing, speaking, etc.)†
Appearance of teeth†
Dental anxiety†
Shared decision making (active patient involvement in treatment planning)†
Patients' satisfaction with received treatment†
Patients' perception on dental care†

†Measure available through patient questionnaire data
‡Measure available through claims data
§Measure not available through patient questionnaire data or claims data

Table 20 shows the final list of 48 topics for oral healthcare categorized into six clusters: 1) access to dental care, 2) symptoms and diagnosis, 3) health behaviours, 4) oral treatments, 5) oral prevention and 6) patient perception. Potential numerators and denominators based on claims data or patient questionnaires are presented in Table 21.

Table 21: Oral health measures: numerators/ denominators

	Data from Claims Data Sources	**Data from Patient Questionnaires Deployed in a Dental Practice**
Definition	Number of patients with a specific treatment or diagnostic test performed /Total number of claimed services per year	Number of people responding to the question with a specific answer/ Total number of people responding to the question
Example	*Extraction:* Total number of extractions in a given age group/ Total number of patients with at least 1 service claimed per year	*Medical history:* Number of people responding "yes" to the question "Does your dentist ask you in every visit about your medical history and medicines you use?"/ Total number of people responding to the question

The final list of topics covers different aspects of dental care on a system level, an individual patient level and on the level of provision of dental care. Aspects of the system level contain topics like "funding of dental care provided" and "access to dental care", for which high levels of agreement on inclusion were observed (95-100%). The individual patient level includes symptoms, habits and patients' perception of care and oral function. The high agreement rates for topics on patients' perception, like "shared decision making" and "patients' satisfaction with received treatment", emphasize the importance stakeholders' attribute to patient-centeredness. Even though agreement to include the topics on patient perception during both the Delphi and the World Café was high among stakeholders, further conversation revealed different views on these topics. Parts of the participants said that these

topics are important, others stated that this is "only relevant when the expectations of the patient are realistic". These views are important issues that should be discussed when striving for empowerment of patients and when discussing shared decision making.

Large agreement (100%) among stakeholders was observed for specific items of prevention and oral health-related behaviours, such as "fissure sealants", "fluoride application", "tooth brushing" and "smoking". Less agreement was found for dietary and smoking advice given by the dentist (80%), which reflects stakeholders' concerns about effectiveness but also the discussion on the core remit of a dentist.

During the course of the study, large agreement (100%) could also be observed for including the core set of oral treatments, for example "periodontal treatments", "fillings" and "extractions". This is due to the fact that information on symptoms and diagnosis can hardly be obtained from insurance claims data in Europe as oral healthcare financing and reimbursement is still mainly organized around procedures rather than around diseases. Therefore, information on oral treatments serve as an information source about the dentist's work but also as a surrogate measure for oral diseases that the population under treatment suffers from.

5.4 Discussion

Using a 4-staged approach to determine valid, important, and relevant topics created a strong base for the development of measures for oral healthcare. The six clusters cover all aspects of oral healthcare that were important to the stakeholders. Measures can be adjusted according to the available data source, allowing them to be utilized for comparisons at local, regional, and national levels. These newly established measures are anticipated to allow a robust comparability of oral healthcare delivery and may therefore serve as target parameters for a performance-based remuneration system that promotes a value-based oral healthcare delivery.

Previous approaches to establish measures have been limited in number and methodological rigor (Ireland et al. 2001; Nihtilä 2010; Osta et al. 2012; Ottolenghi et al. 2007). By using an extensive approach for development, these measures are more robust. The four approaches worked synergistically in creating consensus among relevant groups of stakeholders. Moreover, including stakeholders from six European countries allowed for the incorporation

of experiences from different systems of healthcare provision, financing and education. Therefore, the set of topics developed may be applicable in different countries. As this project was restricted to six European countries, further research may focus on whether any refinements are required for other health systems.

The methods used in the present study have some limitations. The literature search was necessarily pragmatic because research into the development of measures was limited, but at the same time the terms "measure," "topic," or "indicator" are widely used. By this pragmatic approach it is possible but unlikely that any relevant topics could have been missed, since an extensive approach was used. At each stage, the stakeholders were asked to provide input about any potentially missing topics. Earlier experiences with the Delphi methodology showed limitations in participants not returning to the web application to read and comment on other participants and perhaps change their own ratings and views (Freedman et al. 1980; Geist 2010). This study mitigated these risks by providing clear instructions to the participants before starting the Delphi, reminders to join the discussion, and information about comments from other participants. The majority (61%) of the participants responded in both rounds.

Another potential limitation is that there might be items in the topic list that were defined by stakeholders as valid, important, and relevant but which had evidence demonstrating limited effectiveness. The evidence was not formally checked for all proposed topics since this research was based on a stakeholder-centred approach. Some topics were included where current practice is subject to continuing debate about its effectiveness at the population level and, similarly, for topics where provision might be considered appropriate for some individuals but would probably not be best practice for a population.

The measures developed by this study were focused on two data sources—namely, insurance claims data and patient-sourced data from different countries. It is feasible that the same measures could be applied with limited modifications to different data sources, such as dental practice records.

This study is the first to establish a set of core items for strengthening patient-centred and prevention- oriented oral healthcare by means of broad stakeholder consensus. As this study was based on international stakeholder involvement, it provides insight from the perspectives

of a broad spectrum of stakeholder groups on important and relevant aspects within oral healthcare. The method adopted allowed the stakeholders to select and endorse the topics. The topics form a well-established basis that can be developed and further refined into measures. These measures are able to serve as a starting point for target parameters of a performance-based remuneration system focusing on patient-centred and prevention-oriented oral healthcare delivery. Aspects that explain variation caused by other reasons than oral care serve as control variables. This ensures that performance-based remuneration targets the intended aspects of oral healthcare delivery.

6 Conclusion

Oral diseases seriously affect people's quality of life and impose a considerable economic burden to society. Although largely preventable, they remain highly prevalent among European societies. Hereby, a social gradient is observable, which shows that populations have not benefited equally from oral health improvements over the last decades. Instead of a narrow approach focusing on the aetiological factors causing oral diseases, the wider social determinants of oral health need to be considered to reach sustainable improvements in populations' oral health. A multi-layered oral health-promotional approach intends to improve patients' risk behaviours and utilization of prevention-focused services by tackling their underlying drivers located in health system determinants and the wider socio-environmental milieu.

For both aspects, interventions building upon the steering mechanism of economic incentives have been increasingly proposed and have already proven effectiveness in various settings related to general healthcare. Those may address fiscal policies discouraging oral health-related risk behaviour as well as financial incentives affecting utilization of oral healthcare services on both patient and provider side. Evidence regarding the effects of those policy interventions on oral health and oral care is scarce and it is unclear how economic incentives should be designed to promote oral health and a prevention-focused oral healthcare utilization. The purpose of this dissertation was to provide useful evidence to policy makers about how policy interventions based on economic incentives may serve as a helpful tool for preventing oral diseases. Therefore, a series of qualitative and quantitative approaches were exploited to analyse policy options in the context of different European systems.

Under the premise of a common risk factor approach, taxes on SSBs have frequently been proposed to reduce non-communicable diseases like obesity and type 2 diabetes. However, relatively little is known about the caries-related impacts of SSB taxation. By means of a simulation-based cost-effectiveness analysis, Section 2 demonstrated that a 20% ad valorem tax on SSBs may substantially improve oral health and reduce the caries-related economic burden in terms of treatment costs avoided. Using the Dutch population as a reference case, a 20% SSB taxation would result in an average of 2.13 caries-free tooth years per person and, on a population level, prevention of 1,030,163 caries lesions. The intervention was found to

save a total of 159.01 million euros in terms of dental care expenditures. The estimated lifetime tax revenues (3.49 billion euros) are larger than the administrative costs of taxation (37.3 million euros). Benefits would be the greatest for younger age groups and reduced sugar consumption through taxation postpones caries onset to a later point in life. Hence, people enter the restorative cycle later and hereby reduce their treatment needs over the life course. Fiscal policies influencing oral health-related risk behaviour are effective in reducing populations' caries burden, although substitution to non-taxed but unhealthy products needs to be considered. Since taxation of unhealthy products applies to all consumers, oral health improvements can be expected to occur over the whole socio-economic continuum. Therefore, in the context of risk behaviour, demand-sided interventions building upon economic incentives to steer consumption of unhealthy products are able to improve populations' oral health.

A sensible integrated approach to the prevention of oral diseases ties to both determinants of risk behaviour by means of a common risk factor approach as well as access to and utilization of oral healthcare services. In the latter case, market-oriented reforms in healthcare systems are discussed among health policy makers. These are intended to improve the quality of care and to contribute to cost containment by meeting consumer preferences more efficiently. Since increasing health expenditures for citizens have been observed in this context, it is questionable whether such interventions can improve prevention-oriented utilization of oral healthcare services. In 2012, the Netherlands established the so called "free market experiment", which allowed providers of dental care to set the prices for their dental services themselves. Using large-volume health insurance claims data and exploiting this experiment in Dutch dental care, Section 3 identified the effects of a liberalization of service prices with regard to changes in utilization patterns of prevention-oriented dental services. To analyse the quasi-experimental setting, pooled regression with individual fixed effects was applied.

Analysis showed substantial increases in prices and patients' OOP contributions for dental services following the liberalization with differences in increases between types of services. Variations in price and OOP price increases support the hypothesis of different levels of asymmetric information for first-stage and follow-on services. Estimates of short-run price elasticities of demand for different services that point towards differences in price sensitivity

endorse these findings. In the presence of this market failure, a liberalized market cannot reach an efficient equilibrium

In response to the experiment, the proportion of treatment sessions containing preventive-oriented services decreased significantly by 3.4% among adults and by 5.3% for children and adolescents. Although price liberalizations are intended to form a market that meets consumer preferences more efficiently, price liberalization affects the composition of treatment sessions towards a decreasing use of preventive services, suggesting a shift in the reason for seeing a dental care provider from a regular-preventive perspective to a symptom-based restorative approach.

Market-oriented reforms involve the danger of providing economic disincentives to patients regarding prevention-focused utilization of oral care. This emphasizes that specific market requirements must be met to avoid unintended side effects of price liberalizations and secure a proper functioning of the market. The presence of asymmetric information implies that patients are not capable of assessing the quality and necessity of service to a sufficient extend. This highlights that incentives to promote high value oral care should tie to the supply-side directly, since those approaches don't leave the judgement about quality to the consumer alone.

In this context, performance-oriented provider payment systems are considered a sensible strategy to optimize healthcare. Yet, there is still relatively little empirical evidence with respect to their implementation. On basis of routinely collected administrative data and using difference-in-differences analysis, Section 4 evaluated the impact of adding performance-oriented bonus payments to salary on the utilization of dental care. For this purpose, natural variation in financial incentives in a large ambulatory care setting was exploited in which dental professionals receive salary payments but only one subgroup of dental care providers was exposed to the introduction of performance-oriented bonus payments. These bonuses were related to the provision of a set of specific predefined dental services. A significant increase was observed in utilization for directly and indirectly incentivized treatment items. An increase in overall utilization in response to introducing bonus incentives was also identified. These findings suggest that combining salary with bonus payments has the potential to extract improved performance in oral healthcare. However, given the evidence regarding unintended

side-effects, careful monitoring seems advisable when designing and implementing performance-oriented financial incentives.

Since the definition of target parameters for performance-based remuneration as evaluated in Section 4 followed a rather pragmatic approach, the question remains how suitable target parameters for performance-oriented payment systems in oral healthcare can be designed. Section 5 established a set of core items for strengthening patient-centred and prevention-oriented oral healthcare by means of broad stakeholder consensus. The topics form a well-established basis that can be developed and further refined into measures. These measures are able to serve as a starting point for target parameters of a performance-based remuneration system focusing on patient-centred and prevention-oriented oral healthcare delivery. Included aspects that explain variation caused by other reasons than oral care serve as control variables. This ensures that performance-based remuneration targets the intended aspects of oral healthcare delivery.

The overall picture shows that policy interventions aiming to improve oral health and oral healthcare delivery require careful design and monitoring in order to control for intended and unintended consequences. At the same time, joint efforts of several stakeholders are needed. Hence, the results of the present evaluations imply several recommendations for relevant stakeholder groups.

From a dental research perspective, more applications of methodological approaches apart from RCTs are desirable, such as quasi-experimental designs based on observational data or simulation-based analyses, to provide the evidence needed to make statements about effects of health policies and long-run cost and effects of oral healthcare interventions (Listl et al. 2016).

Although only oral health-related effects were considered in the present analysis of SSB taxation, the intervention appeared to be cost-saving. Besides caries reduction, SSB taxation is also able to reduce the incidence of further non-communicable diseases (Briggs et al. 2017). Hence, a single fiscal policy can improve public health by tackling a range of different diseases in a cost-effective manner. This emphasizes that population-based interventions following a common risk factor approach are an effective strategy for improving populations general and oral health. However, policy makers face considerable barriers to fiscal policy implementation,

especially from the food and beverage industry (World Health Organization 2016). In order to overcome those barriers, a comprehensive information campaign in advance of tax implementation should involve a broad coalition of supporters, including the civil society, health professionals and health organizations.

Integration of dental and NCD prevention strategies requires further efforts from different stakeholders. In order to generate useful and robust empirical evidence about the joint effects on different diseases from those interventions, an integration of dental and general health data is required. This implies that health insurance databases or other health databases need to integrate oral health (care) and general health (care) data in order to enable a concomitant analysis of oral and general health effects. At the same time, comprehensive oral health outcome measures are needed that allow comparison of oral health and general health effects and enable a more precise evaluation of policy interventions building upon a common risk factor approach.

The latter is also relevant when it comes to the question of competing alternatives for resource use. Whereas taxation of sugary drinks saves cost and improves oral health and general health at the same time, it is likely that public funding of oral health interventions displaces general healthcare spending. Under the premise of an efficient use of scarce resources it is necessary to enable the comparison of different healthcare interventions, including those targeting oral health, regarding associated costs and impact on quality of life (Karnon 2017).

A successful movement towards an integrated health promotional strategy, which addresses the common risks to general and oral health, requires a departure of the dental profession from an isolated and compartmentalized approach to oral health (Sheiham 2005). Clinicians may widen their perception of dentistry from a disease treatment focus towards a concept of providing care and support for oral health. Considering the common risk factor approach in dental practice may for example involve the integration of smoking cessation programs or nutrition counselling that go beyond a narrow knowledge-based approach (Warnakulasuriya 2002; Watt 2005). Moreover, future education and training of oral health professionals should not only focus on educating technical experts but also impart socio-cultural competencies and knowledge to foster a health-promoting environment (Preet 2013).

Change in the perception of dentistry is an ongoing process as illustrated by the development of consensus-based oral healthcare measures in Section 5. In comparison to other measures, less agreement was found for dietary and smoking advice given by the dentist. This might reflect two different aspects: Stakeholders' concerns about effectiveness of conventional approaches to those interventions but also the discussion on the core remit of the dental profession. This view is not restricted to the dental profession alone, but is also taken by the general public, policy makers and insurers.

With regard to prevention-focused utilization of oral healthcare services, results emphasize several peculiarities in the oral healthcare market that need to be considered in oral healthcare policy making. Among these are market access barriers and asymmetric information which increase supply-sided market power. The consequences of underestimating these specific conditions of healthcare markets and their implications for policy making are outlined in Section 3. However, other market players can also contribute to reduce the impact of those market failures.

The public can advocate for a more patient-centred oral healthcare system that encourages patient empowerment and health literacy and promotes the ability of the public to judge the quality of care provided. Advocacy can be organised by means of patient organisations or patient involvement in public agencies (Carman et al. 2013).

Insurers can increase demand-sided bargaining since these organizations are more powerful than single patients and therefore have a dominant effect on provider prices. Hereby, several options exist that exploit insurers market power and account for the fact that patients are usually unable to shop around or bargain (Pauly 2000). These include the prohibition of "balance billing", provider fees in excess of a predefined reimbursement rate, or direct contracts with dentists or dentist networks. Furthermore, insurers can include certain additional requirements within those contracts that ensure prevention-focused delivery of care.

In this context, performance-based payment structures as exploited in Section 4 constitute an option for insurers. Measures for a prevention-focused and patient-centred delivery of care as developed in Section 5 provide a basis for incentivisation. Whereas the present analysis evaluates an intervention in one dental department, increasing availability of data and

capacities for analysis enable large-scale implementations of comprehensive incentive structures on a system level. A starting point for those interventions is examined by the British NHS, which explored quality incentives in a pilot program (Hulme et al. 2016).

DeCare Dental, a large Irish dental insurance provider, designed a dashboard analysing provider's performance based on claims data to monitor and compare different providers regarding adequate delivery of care (written communication with Gerard Gavin, Chief Dental Officer Decare, December 2016). This provides an example how insurance claims data can be processed and presented on individual level and in comparison to peers.

Those measures developed in Section 5 may also serve as basis for peer comparison, which constitute a non-financial strategy of transforming dental practice and stimulate value of care (Emanuel et al. 2016). Peer comparison builds upon the principle of relative social ranking which postulates that individuals care about their performance in comparison to their social peers (Navathe and Emanuel 2016). Hence, it promotes motivation through social interaction. Those measures can either be applied internally within professional improvement groups or made available to the public as a version of public reporting cards. Providing the information about relative performance of providers to a public audience reacts to the growing public demand for transparency and explicit demonstration of competence by care providers (Moses et al. 2013). Those unblinded peer comparisons, which are available to the public, may be powerful in eliciting social pressure but unintended side effects, such as reduced access to care for patients with complex conditions, must be considered (Waldo et al. 2015).

However, dental care providers can also set up those quality improvement groups as a measure of ongoing professional education to engage in discussions with their peers. Based on comprehensive measures of a prevention-focused and patient-centred oral care, those groups facilitate learning from variations in practice within systems and potentiate increasing value of care provided. Applying the measures developed in Section 5, field studies are currently under way to test the feasibility of those professional group discussions by means of academic detailing (Leggett et al. 2017). These field studies bring dentists together for open discussions about their oral care service delivery and patient's oral health outcomes.

This dissertation provides novel evidence to policy makers about how policy interventions based on economic incentives may serve as a helpful tool for preventing oral diseases. The

overall picture shows that careful analysis and monitoring is warranted to adequately weigh the intended and unintended consequences of those policies. At the same time, improving populations oral health in a sustainable manner requires efforts of all stakeholder groups involved.

7 Summary

Oral diseases seriously affect people's quality of life and impose a considerable economic burden to society. Although largely preventable, they remain highly prevalent among European societies. A multi-layered oral health-promotional approach intends to improve patients risk behaviours and utilization of prevention-focused services by tackling their underlying drivers located in health system determinants and the wider socio-environmental milieu. For both aspects, interventions building upon the steering mechanism of economic incentives have been increasingly proposed. The aim of this dissertation is to provide useful evidence to policy makers about how policy interventions based on economic incentives may serve as a helpful tool for preventing oral diseases.

By means of a simulation-based cost-effectiveness analysis, it was shown that a 20% ad valorem tax on sugar-sweetened beverages may substantially improve oral health and reduce the caries-related economic burden in terms of treatment costs avoided. Using the Dutch population as a reference case, taxation would result in an average of 2.13 caries-free tooth years per person and, on a population level, prevention of 1,030,163 caries lesions. The intervention was found to save a total of 159.01 million euros of dental care expenditures. Benefits would be the greatest for younger age groups and reduced sugar consumption through taxation postpones caries onset to a later point in life.

Market-oriented reforms in healthcare systems are intended to improve the quality of care and to contribute to cost containment by meeting consumer preferences more efficiently. Since increasing health expenditures for citizens have been observed in this context, it is questionable whether such interventions can improve prevention-oriented utilization of oral healthcare services. In 2012, the Netherlands established the so called "free market experiment", which allowed providers of dental care to set the prices for their dental services themselves. Using large-volume health insurance claims data and exploiting this natural experiment in Dutch dental care, the effects of a liberalization of service prices were identified with regard to changes in utilization patterns of prevention-oriented dental services. Hereby, pooled regression with individual fixed effects was applied. Analysis showed substantial increases in prices and patients' out-of-pocket contributions for dental services following the liberalization with differences in increases between types of services. Variations in price and

out-of-pocket price increases support the hypothesis of different levels of asymmetric information for first-stage and follow-on services. In response to the experiment, the proportion of treatment sessions containing prevention-oriented services decreased significantly by 3.4% among adults and by 5.3% for children and adolescents. Price liberalization affects the composition of treatment sessions towards a decreasing use of preventive services, suggesting a shift in the reason for seeing a dentist from a regular-preventive perspective to a symptom-based restorative approach.

The presence of asymmetric information implies that patients are not capable of assessing the quality and necessity of service to a sufficient extend. This highlights that incentives to promote high value oral care should tie to the supply-side directly, since those approaches don't leave the judgement about quality to the consumer alone. In this context, performance-oriented provider payment systems are considered a sensible strategy to optimize healthcare. On basis of routinely collected administrative data and using difference-in-differences analysis, the impact of adding performance-oriented bonus payments to salary on the utilization of dental care was evaluated. For this purpose, natural variation in financial incentives in a large ambulatory care setting was exploited. A significant increase was observed in utilization for directly and indirectly incentivized treatment items. An increase in overall utilization in response to introducing bonus incentives was also found. These findings suggest that combining salary with bonus payments has the potential to extract improved performance in oral healthcare.

Since the definition of target parameters for performance-based remuneration followed a rather pragmatic approach, the question remains how suitable target parameters for performance-oriented payment systems in oral healthcare can be designed. A set of core items for strengthening patient-centred and prevention-oriented oral healthcare was established by means of broad stakeholder consensus. These measures are able to serve as a starting point for target parameters of a performance-based remuneration system focusing on patient-centred and prevention-oriented oral healthcare delivery.

This dissertation provides novel evidence about how policy interventions based on economic incentives may serve as a helpful tool for preventing oral diseases. However, careful analysis and monitoring is warranted to adequately weigh the intended and unintended consequences of those policies.

8 Zusammenfassung

Orale Erkrankungen beeinträchtigen die Lebensqualität der Menschen erheblich und stellen eine wirtschaftliche Belastung für die Gesellschaft dar. Denn obwohl weitgehend vermeidbar, sind sie nach wie vor weit verbreitet. Ein mehrschichtiger Ansatz zur Förderung der Mundgesundheit zielt darauf ab, das Risikoverhalten der Patienten und die Nutzung präventionsorientierter Leistungen zu verbessern, indem zugrunde liegende Gesundheitssystemvariablen und Faktoren des sozio-ökologischen Umfelds angegangen werden. Für beide Aspekte wurden zunehmend Maßnahmen in Betracht gezogen, die auf dem Steuerungsmechanismus finanzieller Anreize aufbauen. Ziel dieser Dissertation ist die Bereitstellung von Evidenz, inwiefern Maßnahmen, die auf finanziellem Anreizen beruhen, ein hilfreiches Instrument zur Prävention oraler Erkrankungen darstellen können.

Durch eine simulationsbasierte Kosten-Effektivitäts-Analyse wurde gezeigt, dass eine 20%ige Wertsteuer auf zuckergesüßte Getränke die Mundgesundheit erheblich verbessern und kariesbedingte Behandlungskosten reduzieren kann. Ausgehend von der niederländischen Bevölkerung als Referenzfall würde die Besteuerung zu durchschnittlich 2,13 kariesfreien Zahnjahren pro Person und auf Bevölkerungsebene zur Prävention von 1.030.163 Kariesläsionen führen. Durch die Intervention könnten insgesamt 159,01 Mio. EUR an Mundgesundheitsausgaben eingespart werden. Die Vorteile wären für jüngere Altersgruppen am größten. Zudem verschiebt ein durch Steuern verringerter Zuckerkonsum den Kariesbeginn auf einen späteren Zeitpunkt im Leben.

Marktorientierte Reformen in Gesundheitssystemen sollen die Qualität der Versorgung verbessern und zur Kostendämpfung beitragen, indem Verbraucherpräferenzen effizienter entsprochen wird. Da in diesem Zusammenhang steigende Gesundheitsausgaben für die Bürger zu beobachten sind, ist es fraglich, ob solche Interventionen die präventionsorientierte Nutzung zahnmedizinischer Leistungen verbessern können. Im Jahr 2012 führten die Niederlande das so genannte "marktwirtschaftliche Experiment" durch, das es Zahnärzten ermöglichte, die Preise für ihre Leistungen selbst festzulegen. Anhand von Krankenversicherungsdaten wurden die Auswirkungen einer Preisliberalisierung im Hinblick auf veränderte Muster in der Inanspruchnahme präventionsorientierter Mundgesundheitsleistungen identifiziert. Hierbei wurde eine gepoolte Panelregression mit

fixen Effekten auf Individualebene angewendet. Die Analyse zeigte erhebliche Preiserhöhungen und gestiegene Zuzahlungen für zahnmedizinische Leistungen nach der Liberalisierung mit unterschiedlichen Steigerungen zwischen den Leistungsarten. Diese Schwankungen stützen die Hypothese, dass asymmetrischen Informationen für verschiedene Leistungen unterschiedlich hoch sind. Als Reaktion auf das Experiment sank der Anteil der Behandlungen mit präventionsorientierten Leistungen deutlich um 3,4% bei Erwachsenen und bei Kindern und Jugendlichen um 5,3%. Eine Preisliberalisierung verändert die Zusammensetzung der Behandlungssitzungen hin zu einer abnehmenden Inanspruchnahme von Präventionsleistungen. Dies deutet auf eine Verschiebung in den Gründen für einen Zahnarztbesuch hin: von einer routinemäßigen präventiven Perspektive hin zu einem symptombasierten restaurativen Ansatz.

Das Vorhandensein asymmetrischer Informationen bedeutet, dass Patienten nicht in der Lage sind, die Qualität und Notwendigkeit der Dienstleistung in ausreichendem Maße zu beurteilen. Dies zeigt, dass Anreize zur Förderung präventionsorientierter Mundgesundheitsleistungen direkt an die Angebotsseite anknüpfen sollten. Leistungsorientierte Vergütungssysteme gelten in diesem Zusammenhang als sinnvolle Strategie zur Optimierung der Gesundheitsversorgung. Auf der Grundlage routinemäßig erhobener administrativer Daten und mittels des Differenzen-in-Differenzen-Ansatzes wurde der Einfluss leistungsorientierter Bonuszahlungen auf die Inanspruchnahme zahnärztlicher Leistungen bewertet. Eine signifikante Zunahme der Auslastung für direkt und indirekt inzentivierte Prozeduren ist zu beobachten. Darüber hinaus zeigt sich eine Erhöhung der Gesamtnutzung als Reaktion auf die Einführung leistungsorientierter Boni. Diese Ergebnisse deuten darauf hin, dass die Kombination von Gehalt und leistungsorientierten Boni das Potenzial hat, Veränderungen in der zahnmedizinischen Versorgung zu erzielen.

Da die Definition der Zielparameter für die leistungsorientierte Vergütung einem pragmatischen Ansatz folgte, bleibt die Frage, wie geeignete Zielparameter für solche Vergütungssysteme in der Zahnmedizin gestaltet werden können. Durch einen breiten Stakeholder-Konsens wurde eine Reihe von Kernpunkten zur Stärkung der patienten- und präventionsorientierten Zahnheilkunde definiert. Diese Indikatoren können als Ausgangspunkt für Zielparameter eines leistungsorientierten Vergütungssystems dienen, das

sich auf eine patienten- und präventionsorientierte Mundgesundheitsversorgung konzentriert.

Diese Dissertation liefert neue Erkenntnisse darüber, inwiefern Interventionen, die auf finanziellen Anreizen basieren, ein hilfreiches Instrument zur Prävention oraler Erkrankungen darstellen können. Eine sorgfältige Analyse und Überwachung sind jedoch unabdingbar, um die beabsichtigten und unbeabsichtigten Folgen dieser Reformen angemessen abzuwägen.

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10 Eigenanteil an Datenerhebung und -auswertung und eigene Veröffentlichungen

Die Kapitel 3 und 5 dieser Arbeit entstanden im Rahmen des Horizon 2020 EU-Projekts ADVOCATE (Added Value for Oral Care).

Die Datenauswertung und -interpretation für Kapitel 3 wurde vollständig von mir durchgeführt.

Die qualitative Forschung in Kapitel 5 wurde gemeinsam von Fatiha Baâdoudi (ACTA Amsterdam) und mir durchgeführt und ausgewertet. Frau Baâdoudi führte die Literaturrecherche durch, welche kurz in Kapitel 5.2.1 ausgeführt wird. Gemeinsam führten wir die Einzelinterviews („sense check conversations") mit Zahnärzten durch, wobei Frau Baâdoudi diese mit Zahnärzten in Amsterdam durchführte und ich mit Zahnärzten in Heidelberg. Mein Beitrag zur Durchführung der Delphi-Methode lag in der Moderation des Prozesses und in der Mitwirkung in der Analyse. Das Treffen basierend auf der World Café Methode („World Café meeting") wurde ebenfalls von uns beiden gemeinsam zu gleichen Teilen geplant, durchgeführt und ausgewertet. Das Expertentreffen („expert meeting") wurde von mir geplant, durchgeführt und ausgewertet.

Kapitel 2 dieser Arbeit entstand in Zusammenarbeit mit Milica Jevdjevic (Radboud UMC Nijmegen). Das zugrundeliegende Markov-Modell entwickelten wir gemeinsam zu gleichen Teilen. Dies umfasste eine umfangreiche systematische Literaturrecherche, die Definition der Gesundheitszustände und die Parametrisierung des Modells. Hierbei lag der Fokus von Frau Jevdjevic (aufgrund Ihres zahnmedizinischen Hintergrunds) insbesondere auf der Definition der Gesundheitszustände. Mein Schwerpunkt lag in der Ableitung der Übergangswahrscheinlichkeiten aus der bestehenden zahnmedizinischen Literatur und somit in der Parametrisierung des Modells.

Bei der Anwendung des Modells auf die Einführung einer Zuckersteuer in den Niederlanden konzentrierte sich die Arbeit von Frau Jevdjevic auf die Recherche populationsspezifischer Daten im Hinblick auf Getränkekonsum, Kariesinzidenz und Demographie. Mein Beitrag lag in der Bestimmung ökonomischer Parameter, wie Preiselastizitäten und administrative Kosten der Besteuerung sowie in der Darstellung zugrundeliegender Wirkmechanismen finanzieller Anreize.

Kapitel 4 dieser Arbeit entstand gemeinsam mit Prof. Dr. Dr. Stefan Listl. Die Datenakquise wurde von Herrn Listl vorgenommen. Die Datenanalyse und -interpretation wurde vollständig von mir durchgeführt.

Teilergebnisse der vorliegenden Arbeit wurden in folgenden Aufsätzen vorab publiziert:

1. Jevdjevic, M., **Trescher, A.-L.**, Rovers, M. and Listl, S. (2019). The Caries-Related Cost and Effects of a Tax on Sugar-Sweetened Beverages. *Public Health*, 169, 125-132.

2. Baâdoudi, F., **Trescher, A.-L.**, Duijster, D., Maskrey, N., Gabel, F., ADVOCATE Consortium, van der Heijden, G.J. and Listl, S. (2017). A Consensus-Based Set of Measures for Oral Health Care. *Journal of Dental Research*, 96(8), 881–887.

Publikation 1 basiert auf dem 2. Kapitel dieser Dissertation. Das Manuskript habe ich gemeinsam mit Frau Jevdjevic verfasst. Das zugrundeliegende Markov-Modell entwickelten wir gemeinsam zu gleichen Teilen. Mein Schwerpunkt lag in der Ableitung der Übergangswahrscheinlichkeiten aus der bestehenden zahnmedizinischen Literatur und somit in der Parametrisierung des Modells. Bei der Anwendung des Modells auf die Einführung einer Zuckersteuer in den Niederlanden konzentrierte sich meine Arbeit auf die Bestimmung ökonomischer Parameter, wie Preiselastizitäten und administrative Kosten der Besteuerung sowie auf der Darstellung zugrundeliegender Wirkmechanismen finanzieller Anreize.

Publikation 2 basiert in Teilen auf dem 5. Kapitel dieser Dissertation, insbesondere dem Methoden- und Ergebnisteil. Das Manuskript habe ich gemeinsam mit Frau Baâdoudi und Frau Duijster erstellt. Hierbei lag mein Beitrag insbesondere in der Darstellung der zugrundeliegenden Methoden sowie der Überarbeitung des Manuskripts. Frau Baâdoudi und ich waren federführend im Design, der Durchführung, sowie der Analyse der Ergebnisse. Gemeinsam führten wir die Einzelinterviews („sense check conversations") mit Zahnärzten durch. Das Treffen basierend auf der World Café Methode („World Café meeting") wurde ebenfalls von uns beiden gemeinsam zu gleichen Teilen geplant, durchgeführt und ausgewertet. Mein Beitrag zur Durchführung der Delphi-Methode lag in der Moderation des

Prozesses und in der Mitwirkung in der Analyse. Das Expertentreffen („expert meeting") wurde von mir geplant, durchgeführt und ausgewertet.

Teilergebnisse der vorliegenden Arbeit wurden in folgenden Aufsätzen zur Publikation eingereicht:

3. **Trescher, A.-L.**, Listl, S., van der Galien, O., ADVOCATE Consortium, Gabel, F., and Kalmus, O.. Once Bitten, Twice Shy? Lessons Learned from an Experiment to Liberalize Price Regulations for Dental Care *(zur Überarbeitung und Wiedereinreichung bei European Journal of Health Economics).*

4. **Trescher, A.-L.**, and Listl, S.. Linking Salary with Bonus Payments: Evidence from a Natural Experiment in Dental Care (*eingereicht bei Implementation Science).*

Publikation 3 basiert auf Kapitel 3 dieser Arbeit. Sie entstand im Rahmen des Horizon 2020 EU-Projekts ADVOCATE. Die Datenauswertung und -interpretation für Kapitel 3 wurde vollständig von mir durchgeführt, das Manuskript habe ich verfasst. Die weiteren Autoren wirkten bei der Datenakquise und Studienkonzeption, sowie bei der Überarbeitung des Manuskripts mit.

Publikation 4 basiert auf Kapitel 4 dieser Arbeit. Es entstand gemeinsam mit Prof. Dr. Dr. Stefan Listl. Die Datenakquise wurde von Herrn Listl vorgenommen. Die Datenanalyse und -interpretation wurde vollständig von mir durchgeführt. Das Manuskript habe ich verfasst, Herr Listl wirkte bei dessen Überarbeitung mit.

Weitere eigene Veröffentlichungen:

Niederman, R., Huang, S. S., **Trescher, A.-L.**, and Listl, S. (2017). Getting the Incentives Right: Improving Oral Health Equity with Universal School-Based Caries Prevention. *American Journal of Public Health*, 107(10), S50–S55.

Gabel, F., O'Hanlon, K., Brankin, P., Bryce, R., **Trescher, A.-L.**, Haux, C., and Listl, S. (2017). Linkage of Health Care Claims Data and Apps Data: The ADVOCATE Oral Health Care Dashboard. *International Journal for Population Data Science*, *1*(1).

Haux, C., Kalmus, O., **Trescher, A.-L.**, Gabel, F., Listl, S., and Knaup, P. (2018). Detecting and Resolving Data Conflicts when Using International Claims Data for Research. *Studies in Health Technology and Informatics*, 247, 1–5.

Faggion, C. M., Málaga, L., Monje, A., **Trescher, A.-L.**, Listl, S., and Alarcón, M. A. (2017). The 300 most cited articles published in periodontology. *Clinical Oral Investigations*, 21(6), 2021–2028.

Ulrich, F., Maier, C., and **Trescher, A.-L.** (2014). Wie wird der Innovationsfonds innovativ? *Gesundheits- und Sozialpolitik*, 68 (2), 10-15.

Trescher, A.-L., Lohmann, J., and Klingel, T. (2014). Exchanges - Creating Health Insurance Marketplaces in: Andreas Schmid, Simone Singh (Ed.), Crossing Borders - Health Care in the U.S., Schriften zur Gesundheitsökonomie, P.C.O. Verlag, Bayreuth, 49-64.

11 Appendices

Contents

Appendix 1: Taxation of sugar-sweetened beverages and caries prevention

A1.1 Relationship between the amount of consumed sugar and caries incidence

According to Bernabé et al. 2016, DMFT increases by 0.1 (0.04 to 0.15) units over 11 years for every 10g of sugar additionally consumed per day

Assumption: linear caries development over the 11-year time horizon

Mean value for half-yearly increase: 0.1 /22= 0.00454546 DMFT

Lower value for half-yearly increase: 0.04 /22= 0.00181818 DMFT

Upper value for half-yearly increase: 0.15/22= 0.00681818 DMFT

Recalculation into transition probabilities:

Assumption from Global Burden of Untreated Caries (Kassebaum et al. 2015):

DMFT increment = incidence

Yearly net DMFT increment = incidence per person-year = x

6-month probability per individual: $1 - e^{(-x*0.5)} = x_{i\_6m}$

Calculation add-on for a 10g higher sugar consumption:

Mean value for 6-month probability per individual: 0.00453514

Lower value for 6-month probability per individual: 0.00181652

Upper value for 6-month probability per individual: 0.00679499

The uncertainty in relationship between the amount of sugar consumed and caries incidence was examined in deterministic sensitivity analysis by taking the lower and upper bound as an input value.

A1.2 Additional figures and tables

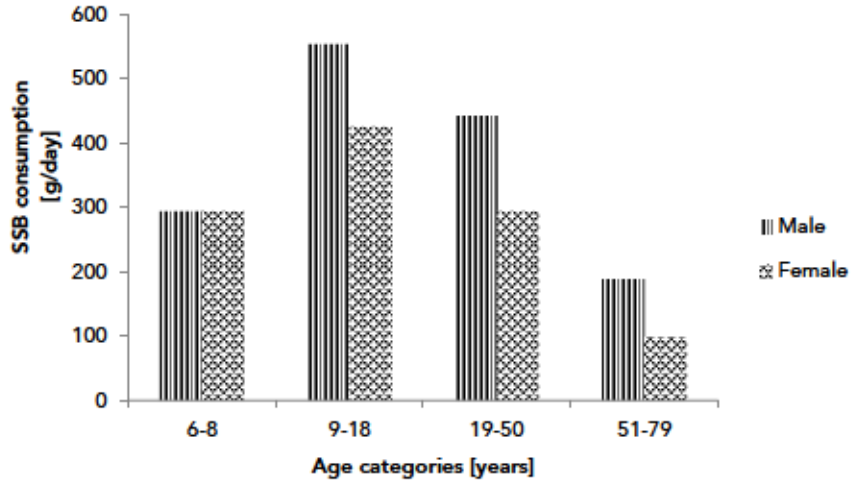

Figure A1 - 1: SSB consumption of the Dutch population stratified by gender and age groups (DNFCS 2012-2014) (van Rossum et al. 2016)

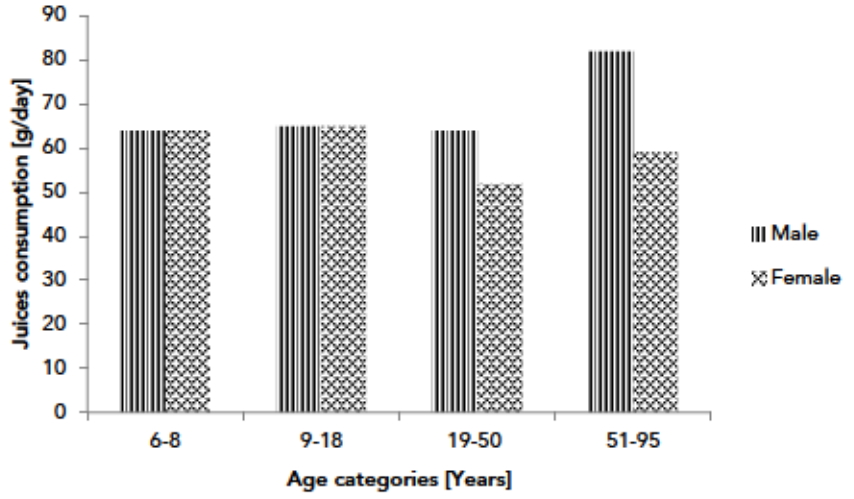

Figure A1 - 2: Juice consumption of the Dutch population stratified by age gender groups (DNFCS 2012-2014) (van Rossum et al. 2016)

Table A1 - 1: Oral health benefits and treatment costs avoided due to 20% SSB taxation, lifetime horizon, lower values for price and cross-price elasticity, mean value for caries incidence reduction

	Caries lesions prevented (total)	Caries-free tooth years (per person)	Caries-free tooth years (total, million)	Treatment costs avoided (million €)
Boys & men				
Boys aged 6-12	575,381 (571,388 to 579,374)	31.44 (31.28 to 31.59)	21.40 (21.29 to 21.50)	82.37 (82.03 to 82.71)
Men aged 13-18	363,944 (362,771 to 365,118)	19.74 (19.69 to 19.79)	12.36 (12.33 to 12.40)	54.84 (54.69 to 55.00)
Men aged 19-35	701,113 (698,848 to 703,378)	11.95 (11.90 to 12.00)	21.52 (21.43 to 21.62)	112.86 (112.46 to 113.26)
Men aged 36-55	493,294 (488,895 to 497,694)	4.83 (4.77 to 4.88)	11.44 (11.31 to 11.57)	72.99 (72.22 to 73.76)
Men aged 56-79	184,844 (183,765 to 185,923)	1.28 (1.26 to 1.29)	2.71 (2.68 to 2.74)	21.91 (21.74 to 22.09)
Girls & women				
Girls aged 6-12	360,251 (357,560 to 362,941)	22.47 (22.35 to 22.60)	14.59 (14.51 to 14.67)	56.31 (56.05 to 56.56)
Women aged 13-18	222,111 (221,390 to 222,833)	12.98 (12.94 to 13.01)	7.76 (7.74 to 7.78)	35.18 (35.08 to 35.29)
Women aged 19-35	443,107 (441,756 to 444,457)	7.85 (7.82 to 7.89)	13.84 (13.78 to 13.91)	72.03 (71.77 to 72.29)
Women aged 36-55	294,908 (291,810 to 298,006)	2.95 (2.91 to 2.99)	6.97 (6.88 to 7.06)	44.45 (43.91 to 44.99)
Women aged 56-79	455,040 (452,042 to 458,039)	0.67 (0.67 to 0.68)	1.48 (1.47 to 1.50)	50.23 (49.78 to 50.68)
Total	**4,093,992 (4,085,395 to 4,102,59)**	**7.52 (7.51 to 7.54)**	**114.08 (113.84 to 114.32)**	**603.17 (601.92 to 604.43)**

Table A1 - 2: Oral health benefits and treatment costs avoided due to 20% SSB taxation, lifetime horizon, upper values for price and cross-price elasticity, mean value for caries incidence reduction

	Caries lesions prevented (total)	Caries-free tooth years (per person)	Caries-free tooth years (total, million)	Treatment costs avoided (million €)
Boys & men				
Boys aged 6-12	66,173 (65,744 to 66,602)	3.93 (3.91 to 3.94)	2.67 (2.66 to 2.68)	10.43 (10.38 to 10.47)
Men aged 13-18	42,763 (42,631 to 42,895)	2.43 (2.42 to 2.44)	1.52 (1.52 to 1.53)	6.95 (6.93 to 6.97)
Men aged 19-35	79,189 (78,917 to 79,461)	1.42 (1.41 to 1.43)	2.56 (2.54 to 2.57)	13.71 (13.65 to 13.77)
Men aged 36-55	39,394 (38,692 to 40,096)	0.42 (0.41 to 0.43)	1.00 (0.98 to 1.02)	6.56 (6.44 to 6.69)
Men aged 56-79	4,953 (4,910 to 4,996)	0.03 (0.03 to 0.03)	0.07 (0.07 to 0.07)	0.59 (0.59 to 0.60)
Girls & women				
Girls aged 6-12	37,409 (37,155 to 37,662)	2.54 (2.52 to 2.55)	1.65 (1.64 to 1.65)	6.56 (6.53 to 6.58)
Women aged 13-18	23,462 (23,389 to 23,536)	1.47 (1.47 to 1.47)	0.88 (0.88 to 0.88)	4.07 (4.05 to 4.08)
Women aged 19-35	44,442 (44,273 to 44,610)	0.84 (0.83 to 0.84)	1.48 (1.47 to 1.48)	7.93 (7.89 to 7.96)
Women aged 36-55	15,882 (15,404 to 16,359)	0.19 (0.19 to 0.20)	0.45 (0.44 to 0.47)	3.00 (2.92 to 3.08)
Women aged 56-79	-2,973 (-3,000 to -2,945)†	-0.02 (-0.02 to -0.02)†	-0.04 (-0.04 to -0.04)*	-0.35 (-0.36 to -0.35)†
Total	**350,694 (349,658 to 351,730)**	**0.81 (0.80 to 0.81)**	**12.23 (12.20 to 12.26)**	**59.44 (59.27 to 59.61)**

†Due to low SSB consumption and substitution with juices, total amount of sugar consumed within this group is higher after SSB taxation

Table A1 - 3: Oral health benefits and treatment costs avoided due to 20% SSB taxation, lifetime horizon, mean values for price and cross-price elasticity, lower value for caries incidence reduction

	Caries lesions prevented (total)	Caries-free tooth years (per person)	Caries-free tooth years (total, million)	Treatment costs avoided (million €)
Boys & men				
Boys aged 6-12	42,054 (41,745 to 42,363)	3.62 (3.60 to 3.64)	2.47 (2.45 to 2.48)	6.76 (6.73 to 6.80)
Men aged 13-18	26,166 (26,083 to 26,250)	2.27 (2.26 to 2.28)	1.42 (1.42 to 1.43)	4.22 (4.21 to 4.24)
Men aged 19-35	50,691 (50,536 to 50,846)	1.38 (1.37 to 1.38)	2.48 (2.47 to 2.49)	8.41 (8.37 to 8.44)
Men aged 36-55	31,112 (30,733 to 31,490)	0.53 (0.52 to 0.54)	1.26 (1.24 to 1.27)	4.80 (4.73 to 4.87)
Men aged 56-79	8,689 (8,638 to 8,740)	0.128 (0.127 to 0.129)	0.27 (0.27 to 0.27)	1.04 (1.03 to 1.05)
Girls & women				
Girls aged 6-12	40,242 (39,949 to 40,536)	2.54 (2.53 to 2.56)	1.65 (1.64 to 1.66)	6.46 (6.43 to 6.49)
Women aged 13-18	24,909 (24,830 to 24,988)	1.48 (1.47 to 1.48)	0.88 (0.88 to 0.89)	4.02 (4.01 to 4.04)
Women aged 19-35	49,729 (49,577 to 49,881)	0.89 (0.88 to 0.89)	1.56 (1.56 to 1.57)	8.26 (8.23 to 8.29)
Women aged 36-55	30,819 (30,445 to 31,193)	0.31 (0.31 to 0.31)	0.73 (0.72 to 0.74)	4.77 (4.70 to 4.84)
Women aged 56-79	9,105 (9,052 to 9,158)	0.06 (0.06 to 0.06)	0.13 (0.13 to 0.14)	1.09 (1.08 to 1.10)
Total	**313,516 (312,784 to 314,248)**	**0.85 (0.85 to 0.85)**	**12.86 (12.83 to 12.88)**	**49.84 (49.72 to 49.96)**

Table A1 - 4: Oral health benefits and treatment costs avoided due to 20% SSB taxation, lifetime horizon, mean values for price and cross-price elasticity, upper value for caries incidence reduction

	Caries lesions prevented (total)	**Caries-free tooth years (per person)**	**Caries-free tooth years (total, million)**	**Treatment costs avoided (million €)**
Boys & men				
Boys aged 6-12	245,230 (243,555 to 246,906)	13.62 (13.56 to 13.69)	9.27 (9.23 to 9.32)	35.77 (35.63 to 35.92)
Men aged 13-18	155,683 (155,179 to 156,186)	8.49 (8.47 to 8.51)	5.32 (5.30 to 5.33)	23.84 (23.77 to 23.90)
Men aged 19-35	296,764 (295,809 to 297,720)	5.14 (5.12 to 5.16)	9.26 (9.22 to 9.30)	48.55 (48.38 to 48.73)
Men aged 36-55	202,688 (200,589 to 204,787)	1.98 (1.96 to 2.00)	4.69 (4.63 to 4.75)	30.65 (30.28 to 31.02)
Men aged 56-79	69,115 (68,716 to 69,514)	0.48 (0.48 to 0.49)	1.02 (1.01 to 1.03)	8.23 (8.17 to 8.30)
Girls & women				
Girls aged 6-12	150,480 (149,363 to 151,596)	9.56 (9.51 to 9.61)	6.21 (6.17 to 6.24)	24.07 (23.96 to 24.18)
Women aged 13-18	93,611 (93,311 to 93,912)	5.54 (5.53 to 5.56)	3.31 (3.30 to 3.32)	15.07 (15.02 to 15.12)
Women aged 19-35	186,214 (185,647 to 186,780)	3.32 (3.30 to 3.33)	5.85 (5.82 to 5.88)	30.75 (30.63 to 30.86)
Women aged 36-55	115,887 (114,479 to 117,295)	1.17 (1.15 to 1.18)	2.76 (2.72 to 2.80)	17.84(17.59 to 18.08)
Women aged 56-79	33,954 (33,755 to 34,154)	0.23 (0.23 to 0.23)	0.50 (0.49 to 0.51)	4.05 (4.02 to 4.09)
Total	**1,549,627 (1,546,164 to 1,553,089)**	**3.18 (3.17 to 3.18)**	**48.19 (49.08 to 48.29)**	**238.83 (238.30 to 239.36)**

Appendix 2: Utilization of preventive services in a market with free prices

A2.1 Additional tables

Table A2 - 1: Descriptive statistics: Service fees for age groups 18-95+

Intervention	Average (SD) service fees			Annual percentage change in service fees	
	2011	2012	2013	2012	2013
Prev. exams & oral hygiene advice	19.95 € (2.74)	21.65 € (6.09)	21.04 € (4.33)	+1.70 €	-0.61 €
Dental cleanings	28.87 € (13.07)	32.83 € (13.86)	36.27 € (22.27)	+3.96 €	+3.44 €
Direct restorations	84.54 € (57.59)	104.74 € (65.49)	87.62 € (57.51)	+20.2 €	-17.12 €
Extractions	52.19 € (44.36)	73.34 € (64.93)	58.61 € (50.74)	+21.15 €	-14.73 €
X-rays	31.80 € (21.10)	32.28 € (20.90)	32.28 € (20.51)	+0.48 €	0 €

Table A2 - 2 Descriptive statistics: Service fees for age groups 0-17

Intervention	Average (SD) service fees			Annual percentage change in service fees	
	2011	2012	2013	2012	2013
Prev. exams & oral hygiene advice	20.76 € (5.05)	23.84 € (9.72)	23.82 € (21.47)	+3.08 €	-0.02 €
Dental cleanings	22.20 € (11.23)	26.53 € (10.36)	23.54 € (15.92)	+4.33 €	-2.99 €
Fissure sealants	61.95 € (43.04)	69.66 € (55.63)	63.26 € (43.23)	+7.71 €	-6.40 €
Fluoride applications	23.27 € (2.68)	24.14 € (5.08)	24.80 € (5.36)	+0.87 €	+0.66 €
Direct restorations	81.62 € (63.12)	102.96 € (71.56)	84.19 € (64.25)	+21.34 €	-18.77 €
Extractions	40.09 € (28.64)	58.26 € (38.26)	55.34 € (30.51)	+18.17 €	-2.92 €
X-rays	35.15 € (20.05)	41.31 € (28.32)	35.94 € (19.96)	+6.16 €	-5.37 €

Table A2 - 3: Harmonization table

Treatment basket	2011		2012		2013	
	Code	Description	Code	Description	Code	Description
Preventive examination/ oral hygiene instructions	C11	**Periodic preventive examination (first one in the calendar year)** (Periodiek preventief onderzoek/ eerste in kalenderjaar)	A111	**Periodic check-up** (Periodieke controle)	C11	**Periodic check-up** (Periodieke controle)
	C12	**Periodic preventive examination (second and further in the calendar year)** Periodiek preventief onderzoek, tweede en volgende in hetzelfde kalenderjaar	C112	**Standard preventive information/ instruction** (Preventieve voorlichting en/of instructie standaard)	C13	**Problem-focused consultation** (Probleemgericht consult)
	M31	**determination of the plaque-score** (Plaque-score)	C114	**expanded preventive information/ instruction** (Preventieve voorlichting en/of instructie uitgebreid)	M01	**Preventive information/ intruction** (Preventieve voorlichting en/ of instructie)
	M70	**Comprehensive nutrition analysis** (Uitgebreide voedingsanalyse)	C124	**Consulation for evaluation of prevention** (Consult voor evaluatie van preventie)	M02	**Consulation for the evaluation of prevention** (Consult voor evaluatie van preventie)
Professional Cleaning	M50	**Limited dental cleaning** (Gebitsreiniging (beperkt))	C212	**Standard dental cleaning** (Gebitsreiniging standaard)	M03	**Dental cleaning** (Gebitsreiniging)
	M55	**Average dental cleaning** (Gebitsreiniging (gemiddeld))	C214	**Expanded dental cleaning** (Gebitsreiniging uitgebreid)		
	M59	**Expanded dental cleaning** (Gebitsreiniging (uitgebreid))				
Fissure Sealants	V30	**Sealant (including etching), first tooth** (Sealing (Inclusief etsen), eerste element)	C511	**Sealant per tooth** (Sealen per element)	V30	Sealant, first tooth **(Sealen eerste element)**
	V35	**Sealant (including etching) Other teeth during the same session** (Sealing (Inclusief etsen), volgende element in dezelfde zitting)			V35	**Sealant, any further teeth in the same session** (Sealen ieder volgend element in dezelfde zitting)
Fluoride application	M10	**Fluoride application (Including previous oral cleansing): Method I** (Fluoride applicatie (Inclusief voorafgaande mondreiniging): Methode I)	C611	**Fluoride application decidious teeth** (Beslijpen en/of fluorideren melkelement)	M05	**Fluoride application decidious teeth** (Beslijpen en/of fluorideren melkelement)

	M20	**Fluoride application (Including previous oral cleansing): Method II** (Fluoride applicatie (Inclusief voorafgaande mondreiniging): Methode II)	C811	**fluoride treatment upper and lower jaw** (Fluoridebehandeling boven- en ondergebit)	M10	**Fluoride treatment method I** (Fluoridebehandeling methode I)
	M21	**Fluoride application (Including previous oral cleansing): Method II, groupwise** (Fluoride applicatie (Inclusief voorafgaande mondreiniging): Methode II, groepsgewijs)			M20	**Fluoride treatment method I** (Fluoridebehandeling methode II)
X-Rays†	X10	**Intra-oral X-ray** (Intra-orale foto (Per opname))	A311	**Create and assess a small X-ray** (Maken en beoordelen kleine röntgenfoto)	X10	**Small X-ray** (Kleine röntgenfoto)
	X21	**Panoramic X-ray** (Orthopantomogram)	A321	**Create and assess a panoramic X-ray** (Maken en beoordelen kaakoverzichtsfoto)	X21	**Panoramic X-ray** (Kaakoverzichtsfoto)
	X22	**Panoramic X-ray for implant purposes in the edentulous jaw** (Orthopantomogram tb b. v. implantologie in the edentate kaak)	A324	**Create and assess an X-ray of the skull** (Maken en beoordelen schedelfoto)	X22	**Panoramic X-ray for implant purposes in the edentulous jaw** (Kaakoverzichtsfoto t.b.v. implantologie in de teandeloze kaak)
	X24	**X-ray of the skull** (Röntgenschedelprofielfoto)	A327	**Create and assess a multi-dimensional X-ray of the jaw** (Maken en beoordelen meer-dimensionale kaakfoto)	X24	**X-ray of the skull** (Schedelfoto)
					X25	**Create a multi-dimensional X-ray of the jaw** (Maken meerdimensionale kaakfoto)
					X26	**Assess a multi-dimensional X-ray of the jaw** (Beoordelen meerdimensionale kaakfoto)
Extractions†	H10	**Extraction** (Extractie)	J311	**Extraction** (Trekken tand of kies)	H35	**Complicated extraction with mucoperiostal folding** (Moeizaam trekken tand of kies, met mucoperiostale opklap)
	H15	**Any further extraction in the same session and the same quadrant** (Volgende extractie in dezelfde zitting en zelfde kwadrant)	J315	**Complicated extraction** (Moeizaam trekken tand of kies)	H11	**Extraction** (Trekken tand of kies)
	H30	**Complicated extraction without mucoperiostal folding** (Gecompliceerde extractie zonder mucoperiostale opklap)			H16	**Any further extraction in the same session and the same quadrant** (Trekken volgende tand of kies, in dezelfde zitting en hetzelfde kwadrant)

	H35	**Complicated extraction with mucoperiostal folding** (Gecompliceerde extractie met mucoperiostale opklap)			
	claimed in combination:			*claimed in combination:*	
	H20	**Suture, per aveolus** (Hechten, per alveole)		H21	**Cost of suture materials** (Kosten hechtmateriaal)
	H21	**Cost of suture materials** (Kosten hechtmateriaal)		H90	**Preparation of practice space for surgery** (Voorbereiding praktijkruimte ten behoeve van chirurgische verrichtingen)
	H25	**Comprehensive wound debridement** (Uitgebreid wondtoilet)			
	H90	**Preparation of practice space for surgery** (Voorbereiding praktijkruimte ten behoeve van chirurgische verrichtingen)			
Direct restorations	V10	**Pit filling** (Pitvulling)	E111	**One-surface restoration** (Eénvlaksvulling)	V11 **One-surface restoration** (Eenvlaksrestauratie)
	V11	**One-surface restoration** (Eenvlaksrestauratie)	E112	**Two-surface restoration** (Tweevlaksvulling)	V12 **Two-surface restoration** (Tweevlaksrestauratie)
	V12	**Two-surface restoration** (Tweevlaksrestauratie)	E113	**Three-surface restoration** (Drievlaksvulling)	V13 **Three-surface restoration** (Drievlaksrestauratie)
	V13	**Three-surface restoration** (Drievlaksrestauratie)	E114	**Four- or five-surface restoration** (Vier- of vijfvlaksvulling)	V14 **Crown of plastic (composite?) material** (Kroon van plastisch materiaal)
	V14	**Crown of plastic (composite?) material** (Kroon van plastisch materiaal)	E131	**Construction of plastic material for extreme tooth erosion per element** (Opbouw van plastisch materiaal bij extreme gebitsslijtage per element)	
			E411	**Placing a root-canal pin** (Plaatsen wortelkanaalpin)	
	claimed in combination:			*claimed in combination:*	
	V20	**Etching in advance of placing composite restoration** (Etsen ten behoeve van composiet)		V20	**Etching in advance of placing composite restoration** (Etsen ten behoeve van composietvulling)

V21	**Etching in combination with etchable underlay** (Etsen in combinatie met etsbare onderlaag)	V21	**Etching in combination with etchable underlay in advance of placing composite restoration** (Etsen in combinatie met etsbare onderlaag ten behoeve van composietvulling)
V50	**Drying of a tooth by means of a rubber dam** (Droogleggen van elementen door middel van cofferdam)	V50	**Drying of a tooth by means of a rubber dam** (Droogleggen van elementen door middel van cofferdam)
V60	**Indirect pulp-capping** (Indirecte pulpa-overkapping)	V60	**Indirect pulp-capping** (Indirecte pulpa-overkapping)
V70	**Para-pulp pin** (Parapulpaire stift)	V70	**Para-pulp pin** (Parapulpaire stift)
V80	**Root-canal pin** (Wortelkanaalstift)	V80	**Root-canal pin** (Wortelkanaalstift)
V85	**Further root-canal pins in the same tooth** (Elke volgende wortelkanaalstift in hetzelfde element)	V85	**Further root-canal pins in the same tooth** (Elke volgende wortelkanaalstift in hetzelfde element)

† without orthodontic code

Appendix 3: Performance-oriented payment: a set of measures for oral healthcare delivery

A3.1 Additional tables

Table A3 - 1: Analysis Delphi round I

Topics	Mean	Agreement in- and exclusion (%)†	Excluded/Included	Reason
List A -Group 1 – General dental practice and attendance				
1.1 Type of dental practice funding (public, private, both)	2.1	86%	Included	Funding may impact the treatment choices or show lack of resources; important for good comparison
1.2 Total number of dental visits in (time horizon to be specified)	2.0	76%	Excluded	Topic is covered by topic 1.3, 1.4 and 1.5.
1.3 Interval of regular dental check-ups	2.4	92%	Included (rephrased)	Important to know whether interval is patient-based and provides information on interest of patient in oral health – says something on preventive attitude
1.4 Number of acute dental visits	2.2	90%	Excluded	Replaced by topic 1.5
1.5 Reasons for dental visit (problem, treatment, check-up)	2.5	93%	Included (rephrased)	Topics, 1.2, 1.3 and 1.4 could be merged together into one topic
1.6 Reasons for non-attendance (costs, anxiety, etc.)	2.3	90%	Excluded	Not possible to measure non-attendance in people who attend. Part on anxiety included in group 6
1.7 Care continuity (duration of being registered at the same dentist)	1.8	68%	Excluded	Care continuity should be measured together with satisfaction, access and mobility. Care continuity cannot be retrieved appropriately.
1.8 Decision not to proceed with recommended dental treatment due to cost	1.9	75%	Included (rephrased)	Costs are important in treatment choice and non-attendance.
1.9 Referral to dental specialist	2.0	75%	Included (rephrased)	Gives insight into whether there is knowledge of the boundaries of care and might reflect the complexity of treatment undertaken within the practice
Additional topics on access:	-	-	Included (new)	

Distance to practice (km)				
Age of first attendance				
List A – Group 2 -Oral symptoms and diagnoses				
2.1 Current symptoms	2.5	92%	Included (rephrased)	Provides important information for treatment and prevention planning. Furthermore it reflects reasons for attendance
2.2 Medical history (co-morbidities and medication)	2.6	93%	Included (rephrased)	The mouth is part of the body and both interact, so information is essential for diagnosis, treatment and prevention.
2.3 X-rays (including bitewings, solo's and OPT's)	2.4	92%	Included (rephrase with comment)	Important and inevitable in daily practice. Remark: X-rays on indication cannot be measured, since patients won't remember and the information is not registered or claimed. Total number of x-rays reimbursed/claimed can be measured.
2.4 Periodontal examination (BPE, PI, BI, PSI, PD)	2.8	97%	Included (remark)	Gives basic information that is essential for the oral health status and it tells something about the awareness of the dentist. However information cannot be retrieved in all countries (e.g. Netherlands)
2.5 Bleeding gums (after/during tooth brushing)	2.2	76%	Excluded	Topic is covered in the topics 2.1 and 2.4
2.6 Pain/discomfort	2.5	87%	Excluded	Topic is covered in the topic 2.1.
2.7 Mirror/probe examination (general check-up)	2.5	91%	Excluded	It is part of the regular check-up/screening process, this topics would not provide additional information besides the topic on check-up
2.8 Number of teeth	2.5	95%	Included	Important topic on the oral health status, however the acquisition of this information is for discussion.
List A – Group3 -Health behaviours				
3.1 Tooth brushing (frequency, duration, method)	2.6	95%	Included	Important topic for oral health, hygiene and might be an indicator of compliance. However people give social desirable answers to this.
3.2 Use of fluoride toothpaste	2.4	95%	Included (add remark)	Might give information on how the dentists inform their patients. Remark added is that probably >99% of people use fluoride toothpaste, information collected through this topic will be an exception.
3.3 Interdental cleaning (tooth picks, floss, toothbrush)	2.6	97%	Included	Important topic, especially with increasing age. But compliance is often a problem and there is doubt on the true effectiveness of interdental cleaning.
3.4 Smoking	2.6	95%	Included (with remark)	Relevant for general health and oral health. You can even speak of a legal and ethical obligation for the dentists to inform patients on the consequences and dangers. However patients might not want to hear another expert-opinion.

3.5 Alcohol use	2.1	76%	Included (with remark)	Same reasons as topics 3.4, but with alcohol use it seems likely that even more social desirable answers occur.
3.6 Diet (sugary foods & drinks, fruits, bottle use, acids, etc.)	2.5	95%	Included (rephrased)	Important topic for caries and erosion. But also important for dietary habits that can lead to other oral and general health problems. Remark on how and what to measure, number of eating moments, sugary foods and drinks and/or acidic.
List A – Group 4 - Oral treatments				
4.1 Fillings	2.7	97%	Included (with remark)	An important topic where a lot of specific information can be retrieved from, for example, filling placed where decay has gone through enamel, type of filling, restorations etc. Remark: However many of these specific information on fillings cannot be retrieved from claims data or patients
4.2 Extractions	2.6	94%	Included (with remark)	Important for assessing dental health, more important is why the extraction is done, however this information cannot be retrieved.
4.3 Root canal treatment	2.6	95%	Included	Important in a dental practice. Not much discussion on this topic.
4.4 Periodontal treatment	2.6	92%	Included (rephrased)	Important topic that relates to retreatment. Rephrase to make it clearer.
4.5 Retreatment	1.9	64%	Included (rephrased)	Low retreatment rates are one of the best indicators for a high standard of initial care.
4.6 Crowns, bridges and veneers / facings	2.3	76%	Included	Aesthetics are an important component of oral health
4.7 Dental implants	2.3	84%	Included	Depends on availability and preference of the dentists. Questionable whether it improves oral health, but an important topic for comparison of dentists.
4.8 Full removable dentures	2.4	86%	Included	Large agreement and no counterarguments given for exclusion. Dentures are especially important with the ageing population.
4.9 Partial removable dentures	2.5	89%	Included	Large agreement. Important for quality of life.
4.10 Orthodontic treatment	1.9	68%	Excluded	Orthodontic treatments are usually not performed by the general dental practitioner.
4.11 Trauma-related treatment	2.1	78%	Excluded	Is included in topic 1.5
4.12 Sedation	1.2	35%	Excluded	Not essential in general dental practice- very specialised
List A – Group 5 - Preventive treatment and surveillance				
5.1 Fissure sealants	2.4	95%	Included	Prevention, especially important for children.
5.2 Fluoride application	2.6	95%	Included	Important, question that can be answered is whether its performed as a regular treatment (mainly in children) or only for high risk patients.
5.3 Health advice (dietary advice, oral hygiene instruction, smoking cessation, etc. and follow-up)	2.7	100%	Included (rephrased)	Full agreement, important for oral health and oral health policy. Topic separated into a topic on oral hygiene advice, dietary advice and smoking advice.

5.4 Professional cleaning (scale & polish, plaque removal)	2.4	85%	Included	The effectiveness is questioned but it is still considered an important topic.
5.5 Caries under surveillance	2.1	81%	Included (rephrased)	The topic means: whether there is shared knowledge about early caries, and not supervised neglect.
5.6 Time without restoration	1.8	65%	Excluded	Although it would be interesting to know, but almost impossible to collect this information. Even if collected through a questionnaire there would be a high risk of reporting bias.
List A – Group 6 – Patient's perception				
6.1 Patient satisfied with function (speaking, chewing, smiling, etc.)	2.5	92%	Included (rephrased)	Important topic, only smiling is already covered by topic 6.2.
6.2 Patient satisfied with appearance of teeth	2.3	95%	Included	Important topic, however only relevant when the expectation are realistic
6.3 Patient involved in decision making	2.5	90%	Included (rephrased)	"This is crucial and reflects the capability of the dentist as well as the healthcare/insurance system to offer time to educate and inform patients about risks, possibilities, alternatives and prognosis of several treatment options".
6.4 Patient recommends dentist to friends and family	1.7	57%	Excluded	Provides feedback for the dentists but is not a core topic.
Additional topic on: Anxiety				Topic 1.6 on dental anxiety is placed in group 6
List B – Group 7 – Signs and symptoms				
7.1 Teeth grinding	1.4	56%	Excluded	Not measurable and too specific.
7.2 Teeth wear	1.6	54%	Excluded	Not measurable, although many find this important especially since it is a growing problem.
7.3 Temporomandibular joint disorder (TMD)/jaw dysfunction.	1.3	46%	Included (rephrased and remark)	Mentioned as a comment at several topics, but there are difficulties accurately assessing whether patients have TMD problems. Remark: do you have suggestions for measuring TMD through patients (claims data won't give this information)
7.4 Halitosis (bad breath)	1.8	64%	Excluded	Majority agrees to exclude and partially it is covered in topic 2.1.
7.5 Bad taste	1.9	66%	Excluded	Majority agrees to exclude and partially it is covered in topic 2.1.
7.6 Saliva problems	1.1	40%	Excluded	Important part of oral health but not a core topic. Partially included in topic 2.1.
List B – Group 8 – Preventive				
8.1 Adverse habits (e.g. pen biting)	2.0	79%	Excluded	Not a core topic.

8.2 Bottle milk during the night	1.5	58%	Excluded	Partially covered in the topic on dietary advice in group 5. Furthermore, it concerns a specific group
8.3 Obesity	1.7	62%	Excluded	Controversy whether the dentists should give advice on this.
8.4 Exercise	3.1	90%	Excluded	Not the role of the dentist to give advice on this.
8.5 Compliance (following the preventive advice of the dentist)	1.0	22%	Excluded	Important in practice, however cannot be reliably measured.
8.6 Mother's knowledge of fluoride toothpaste	1.5	54%	Excluded	Specific topic and partially covered in topic 3.2.
8.7 Preventive care-seeking for pregnant women	1.6	57%	Excluded	Too specific – not core topic. But agreement that this is important for this specific group.
8.8 Fluoride exposure rates	1.5	52%	Excluded	Information cannot be retrieved from claims data or patients; other sources would not provide practice specific information.
8.9 Plaque improvement	1.3	43%	Excluded	Partially covered in periodontal examination and it is difficult to measure.
8.10 Prevention programs at school	1.4	44%	Excluded	Specific group and is not dental practice related
Additional topic: Elderly			Excluded	Not a core topic.
List B – Group 9 – Dental practice provided to patient				
9.1 Population per dentist	1.5	50%	Excluded	Partially measured by the social demographic characteristics.
9.2 Patients with special needs	1.5	57%	Excluded	Specific group and difficult to measure.
9.3 Training in motivational interviewing	1.8	69%	Excluded	Difficult to measure.
9.4 Orthodontic failures	2.2	78%	Excluded	Not a core topic and difficult to measure.
9.5 Orthodontic after care - retentions	1.9	75%	Excluded	Not a core topic.
9.6 Teeth with fracture	1.6	53%	Excluded	Partially covered by topic 1.6.
9.7 Complaints from patients	1.6	57%	Excluded	Access to this information is difficult to retrieve, however partially information for this topic is retrieved in topics 6.1 and 6.2.
9.8 All indexes (DMFT, DMFS, DPSI, etc.)	1.3	46%	Excluded	This information is usually not registered, so not measurable.
9.9 Replacement of restoration	1.6	59%	Excluded	Covered in topic 4.5.

9.10 Use of composite or amalgam	1.5	60%	Excluded	Not essential information.
9.11 Use of dental dam	1.8	76%	Excluded	Evidence is not strong- not a core topic
9.12 Number of teeth with a mobility >1mm	1.9	71%	Excluded	Covered by topic 2.4.
9.13 Pocket assessment	1.4	46%	Excluded	Covered by topic 2.4.
9.14 Surgical periodontal treatment	1.8	65%	Excluded	Evidence is not strong. Covered by topic 2.4.
9.15 Presence of infection (sepsis)	1.5	64%	Excluded	Not measurable- often not registered
9.16 Treatment of dental anxiety	1.7	62%	Excluded	Covered in group 6.
9.17 Treatment plan and costs	1.4	51%	Excluded	Covered in topic 6.3.
9.18 Cost of treatment acceptable to patient	1.7	64%	Excluded	Covered in topic 1.8.
9.19 Visiting hygienist for treatment or by referral	1.7	65%	Excluded	Not a core topic for all countries and is partially covered in topic 1.9.
9.20 Mouth guards	2.1	84%	Excluded	Not a core topic.
9.21 Oral mucosal lesions	1.0	40%	Excluded	Added to topic 9.23
9.22 Dental fluorosis	2.0	81%	Excluded	Not a core topic.
9.23 Oral cancer screening	0.7	27%	Included (rephrased)	Merged with oral mucosa screening.
9.24 Absence of plaque	1.8	70%	Excluded	Covered in topic 2.4.

†Topics in groups 1-6 were asked whether the topics should be included, the topics in the groups 7- 9 were asked whether the topics should be excluded

Table A3 - 2: Analysis Delphi round II

Topics	Descriptor	Source/Note	Mean	Agreement (%)	Included	Reason
Group 1 – Information about attendance						
1.1 Reason for dental visit	'I visited the dentist today, because…' • New symptoms/ unplanned treatment • Planned check-up • Planned treatment • Planned preventive treatment • Trauma/emergency treatment (more than one possible)	patient questionnaire	2.8	100	In	Basic information that gives insight in expectations and habits of the patient.
1.2 Travel time to dental practice	'How long does it take you to travel to your dental practice?' • < 15 min • 15 - 30 min • 30 - 60 min • > 60 min	patient questionnaire	1.3	38	Out	Not relevant for majority of patients to get the care they need and it is biased by the mode of transportation.
1.3 Funding of dental care provided	'How is your dental care for today funded'? • Public sector / public insurance scheme – fully funded • Public sector / public insurance scheme – with co-payment • Private insurance scheme • Self-payer	Patient questionnaire, some countries also from claims data	2.2	93	In	Important since there might be a perceived difference of care according to the type of funding.
1.4 Interval of dental check-ups	Time between dental check-ups AND / OR 'How often do you come to the dentist for a dental check-up?' • 3-4 times a year • 2 times a year • Once a year • Irregularly • Never	Patient questionnaire and/or claims data	2.5	93	In	Important for measuring and improving overall oral health
1.5 Referral by your dentist	'Have you ever been referred by your dentist to:' • Oral hygienists • Periodontist (gum disease) • Root canal specialists • Orthodontist • Other	Patient questionnaire	1.9	70	In	For some countries this will provide important information since a substantial part of care is provided by others.

	(none or more than one possible)					
1.6 Decision not to proceed with recommended dental care solely due to costs	'Have you ever decided not to proceed with dental care solely due to costs?' Yes / No	Patient questionnaire	2.2	90	In	Important since it might affect the decision for a treatment (plan).
Group 2 – Symptoms and diagnosis						
2.1 Current symptoms	'Do you currently suffer from:...?' • Pain • Discomfort • Bleeding • Dry mouth • Bad taste • Bad breath	Patient questionnaire	2.7	96	In (topic 2.7 merged together)	Important basic information that is vital for diagnosis and treatment planning.
2.2 Medical history	'My dentist asked me about my medical history and what medicines I am taking?' Yes/No	Patient questionnaire	2.5	92	In	Basic information that is needed for an appropriate treatment (plan). Note: some find only dental history important and not medical history.
2.3 Number of teeth	'Adults can have up to 32 natural teeth (that includes wisdom teeth), but over time people lose some of them. How many natural teeth have you got? .... (Count total number of teeth)'	Patient questionnaire	2.1	68	In	Important for oral health, however difficult as self-reported measure of patients.
2.4 X-rays	'Number of X-rays taken in the previous 12/24/36 months' AND/OR 'Have you had any x-rays taken by your dentist in the last 12/24/36 months?'	Patients questionnaire and/or claims data	2.1	79	In	Important for diagnosis and further treatment, but self-report by patients might be biased as they will not remember.
2.5 Periodontal examination	'Dentist performs formal periodontal disease scoring (bleeding score, plaque score, pocket depth, etc.)'	Claims data	2.5	92	In	Important for oral health status. Especially an important topic since in some countries there is no registration of this.
2.6 Oral mucosa and cancer screening	-	"Important topic, but how to retrieve this information accurately, completely and reliable?"	2.5	89	In	Important for a dentist to measure however question are raised on how this could be measured, since in most cases patients won't know because

						it is part of the dental examination.
2.7 Temporomandibular joint dysfunction (dysfunction of muscles, joints and/or jaw)	'My dentist asks me about any problems with my jaw muscles or joints' Yes/No	Patient questionnaire Note: Should this be added to topic 2.1?	1.9	64	Out (Merged with topic 2.1)	
Add new topic on dental caries examination	'Does your dentist usually examine your teeth for new cavities?' Yes/No	Patient questionnaire	-	-	In (added)	Rose to be a missing topic in the list while it is an important part of daily practice.
Group 3 – health behaviours						
3.1 Tooth brushing	'How often do you usually brush your teeth?' • Irregularly • Less than once a day • Once a day • Twice a day • More than twice day	Patient questionnaire	2.8	96	In	Important topic however might give social desirable answers.
3.2 Use of fluoride toothpaste	'Do you use fluoride toothpaste?' • Yes/No/Don't know	Patient questionnaire Note: Since most people use fluoride toothpaste (>95%) does this topic add any value?	2.2	77	In	Debated topic. Some people agree that it's not relevant because >95% use fluoride toothpaste. Others are still interested in capturing the percentage that does not use fluoride (nature trend) as this might affect oral health.
3.3 Interdental cleaning	'How often do you use tooth picks, floss or interdental brushes?' • Never • Once a month or less • Several times a month • Several times a week • Daily	Patient questionnaire	2.5	89	In	Found important however evidence is not clear on this.
3.4 Smoking	'Do you smoke tobacco?' • Yes, I am a current smoker • No, but I have been a smoker in the past • No, I have never been a smoker	Patient questionnaire	2.6	93	In	Important topic for general and oral health.
3.5 Alcohol consumption	'How often do you drink alcohol?' • Never • Once a month or less	Patient questionnaire	2.0	74	In	Important topic for health however debate on the effectiveness of advice on

	• 2-4 times a month • 2-3 times a week • 4-5 times a week • More than 5 times a week	Note: Alcohol is a risk factor for oral cancer, but the absolute increase in risk is very small.				alcohol intake is part of the role of a dentist.
3.6 Diet	'How often do you eat something between meals? • Never • Less than once a day • 1-2 times a day • 3-5 times a day • More than 5 times a day – 'How often do you drink acidic drinks during the day (fruit juices, fizzy drinks, energy drinks or squash)?' • Never • Less than once a day • 1-2 times a day • 3-5 times a day • More than 5 times a day	Patient questionnaire Note: Dietary information is prone to reporting bias. The provision of dietary advice by dentists is covered in group 5.	2.3	81	In	Basic information especially important in relation to caries.
Group 4 – Oral treatments						
4.1 Fillings	Number of fillings in the past 12/24/36 months, AND/OR 'Have you had any new fillings in the last 12/24/36 months?'' • Yes/No	Claims data and perhaps patient questionnaire	2.6	100	In	Important basic information, but patients might not remember or know this.
4.2 Root canal treatment	Number of root canal treatment in the past 12/24/36 months, AND/OR 'Have you had any root canal treatment done in the last 12/24/36 months?'' • Yes/No	Claims data and perhaps patient questionnaire	2.3	96	In	High agreement on including this topic
4.3 Crowns, bridges and veneers/facings	Number of crowns, bridges or veneers/facings in the past 12/24/36 months, AND/OR 'Have you had any crowns, bridges or veneers/facings in the last 12/24/36 months?'' • Yes/No	Claims data and perhaps patient questionnaire Note: veneers and facing kept in the topics list because aesthetics	2.2	88	In	Majority agrees to include the topic, but comments are made on this topic being an aesthetic topic and not an oral health measure.

		was found an important issue in oral healthcare				
4.4 Retreatment	'In the last 12/24/36 months, have you had any filling, root canal treatment, crown or bridges that had to be redone within 12 months of the original treatment?' • Yes • No • Unsure/can't remember	Claims data and perhaps patient questionnaire	2.1	78	In	Suggestion to use 24 months. Some doubts on the reliability of the gathered information
4.5 Periodontal treatment	Number of patients with claims for periodontal treatment in the past 12/24/36 months, AND/OR 'Did you receive any treatment from a dental healthcare provider for gum disease in the last 12/24/36 months?'' • Yes/No	Claims data and perhaps patient questionnaire	2.4	100	In	Part of basic oral healthcare.
4.6 Extractions	Number of extractions in the past 12/24/36 months, AND/OR 'Have you had any teeth removed in the last 12/24/36 months?'' • Yes/No	Claims data and perhaps patient questionnaire	2.6	96	In	Useful information and can validate the topic on how many teeth do you have.
4.7 Partial removable dentures	Number of partial removable dentures placed in the past 12/24/36 months, AND/OR 'Did you get a new partial removable denture in the last 12/24/36 months?'' • Yes/No	Claims data and perhaps patient questionnaire	2.2	89	In	Majority agrees this is important information for the dentist and patients will be able to answer this.
4.8 Full removable dentures	Number of full removable dentures placed in the past 12/24/36 months, AND/OR 'Did you get a new full removable denture in the last 12/24/36 months?'' • Yes/No	Claims data and perhaps patient questionnaire	2.3	93	In	Majority agrees this is important information for the dentist and patients will be able to answer this.
4.9 Dental implants	Number of dental implants in the past 12/24/36 months, AND/OR 'Have you had any dental implants placed in the last 12/24/36 months?'' • Yes/No	Claims data and perhaps patient questionnaire	2.3	93	In	Majority agrees this is important information for the dentist and patients will be able to answer this.
Group 5 – Oral prevention						
5.1 Fissure sealants	Number of fissure sealants in the past 12/24/36 months.	Claims data and patient questionnaire	2.3	89	In	Important prevention topic. Note that the cases where it

						has fallen out are probably not included
5.2 Fluoride application	Number of fluoride application in the past 12/24/36 months.	Claims data and perhaps patient questionnaire	2.4	89	In	Important prevention topic. Note: how to measure over and under use.
5.3 Professional cleaning (scale, polish and plaque removal)	Number of claims for professional cleaning in the past 12/24/36 months, AND/OR 'Have you had a 'clean and polish' done in the dental practice in the last 12/24/36 months?'' • Yes/No	Claims data and perhaps patient questionnaire	2.4	100	In (rephrase)	Important part of daily practice. Clean and polish instead of scale and polish.
5.4 Oral hygiene advice	'My dentist advises me on tooth brushing and other aspects of oral hygiene' • Yes/No	Patient questionnaire	2.6	100	In	Essential advice
5.5 Dietary advice	'My dentist gives me dietary advice to prevent dental caries and/or erosion. • Yes/No	Patient questionnaire	2.4	93	In	Important information in relation to caries and erosion which are important factors in oral health
5.6 Smoking advice	'My dentist advises me about the effects of smoking on my health' • Yes/No	Patient questionnaire	2.3	89	In	Question only for adults (not children)
5.7 Caries under surveillance	'Has your dentist talked to you about an early caries lesion in the last 12/24/36 months that only required observation?'	Patient questionnaire	2.0	73	In	Informative but difficult to get this data from patients and dentists might provide social desirable answers.
Group 6 – Patient perception						
6.1 Oral function (chewing, speaking, etc.)	'I am satisfied with my ability to chew, eat and speak.' • Strongly agree • Agree • Disagree • Strongly disagree	Patient questionnaire	2.4	93	In	Important feedback information (quality of life)
6.2 Appearance of teeth	'I am satisfied with the appearance of my teeth.' • Strongly agree • Agree • Disagree • Strongly disagree	Patient questionnaire	2.0	77	In	Important factor for patients, aesthetics increasingly important to people (quality of life).
6.3 Dental anxiety	'I was anxious before attending the dentist today' • Strongly agree	Patient questionnaire	2.1	81	In	Important from patient management perspective.

	• Agree • Neutral • Disagree • Strongly disagree					
6.4 Shared decision making	'Does your dentist involve you in making clinical decisions as much you want to be?' • Always • Sometimes • Rarely • Never	Patient questionnaire	2.4	92	In	It is an obligation for the dentist to involve their patient in the decision making.

Table A3 - 3: Voting of oral healthcare topics during the World Café

Topics of oral healthcare	Agreed (%)	Disagreed (%)	Abstained(%)
Group 1: Access to dental care			
Reason for dental visit	100	0	0
Funding of dental care provided	95	0	5
Interval of dental check-ups by a dentist	95	5	0
Referrals	50	30	20
Decision not to proceed with recommended dental care solely due to costs	95	0	5
(Decision not to proceed with recommended dental care for other reasons than costs)	100	0	0
Access to dental care	100	0	0
Group 2: Symptoms and diagnosis			
Current symptoms	100	0	0
Communication (prompting questions) about symptoms and wishes	90	5	5
Medical history	95	0	5
Social history	85	10	5
Number of teeth	60	30	10
X-rays	65	15	20
Periodontal examination	90	0	10
Oral mucosa and cancer screening	65	5	30
Examination for new caries lesions	85	5	10
Group 3: Health behaviours			
Tooth brushing	100	0	0
Use of fluoride toothpaste	100	0	0
Interdental cleaning	90	10	0
Smoking	95	0	5
Alcohol consumption	75	10	15
Diet	85	10	5
Recreational drug use	35	35	30
Group 4: Oral treatments			
Periodontal treatment	100	0	0
Fillings	100	0	0
Root canal treatment	100	0	0

Crowns, bridges and veneers/facings	95	0	5
Retreatment	75	15	10
Extraction	100	0	0
Partial removable dentures	95%	5	0
Full removable dentures	100	0	0
Dental implants	95	0	5
Complications as a result of treatment	85	10	5
Antibiotics prescribing	95	5	0
Group 5: Oral prevention			
Fissure sealants	100	0	0
Fluoride application	100	0	0
Professional cleaning (clean and polish)	85	15	0
Oral hygiene advice	100	0	0
Dietary advice	80	10	10
Smoking advice	80	10	10
Caries lesions under surveillance	90	0	10
Risk assessment for tailored prevention	90	0	10
Group 6: Patient perception			
Oral function (chewing, speaking, etc.)	100	0	0
Appearance of teeth	90	5	5
Dental anxiety	95	0	5
Shared decision making (active patient involvement)	100	0	0
Patients' satisfaction with received treatment	95	0	5
Patients' perceptions on dental care	100	0	0

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13 Eidesstattliche Versicherung

Bei der eingereichten Dissertation zum Thema *Towards More Evidence-Informed Policy Making for Preventing Oral Diseases* handelt es sich um meine eigenständig erbrachte Leistung.

Ich habe nur die angegebenen Quellen und Hilfsmittel benutzt und mich keiner unzulässigen Hilfe Dritter bedient. Insbesondere habe ich wörtlich oder sinngemäß aus anderen Werken übernommene Inhalte als solche kenntlich gemacht.

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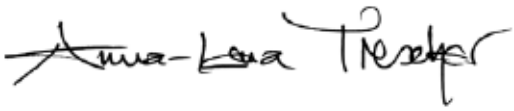

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