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Comparison of the oral health status and costs of the provision of dental care in ten high-income countries

Abstract

Objective: Comparison of different types of oral health systems in relation to outcome and cost figures with the aim of evaluating system efficiency by using quantifiable results.

Method: A composite indicator -the Dental Health Index -was used as the overall value for measuring a population´s dental status. The DHI is linked to the total dental costs as a percentage of the gross domestic product (GDP), in order to create an index of system efficiency, which subsequently facilitates comparisons with other high-income countries.

Results: In general, good oral health can be achieved in each of the different types of advanced dental care. However, the national health system of Sweden (SE) and the social security system of Korea (KR) performed better than the systems of all other countries. Superior in terms of system efficiency is the national health systems of the United Kingdom (UK) and Sweden (SE) and a social security model (KR). Overall, the Swedish system can be considered as best-practice-model for dental care.

Conclusion: Across the systems, models that foster a preventive and tooth-retaining approach -also for their adult population – make faster and better progress in improving oral health status, are more cost-effective and demonstrate superior system efficiency. A range of 5% to 6% of GDP turns out to be a good benchmark for cost-efficacy in countries with elevated oral health status. Moreover, countries that implement an active oral health policy perform better.

Keywords: measuring population´s oral health status, performance of different dental care systems, overall dental health indicator, oral health care system efficiency, macro-level country comparisons of oral health

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Introduction

Over the last decade, we have seen the publication of numerous cross-country comparisons in the field of oral care, focusing on special aspects of oral care provision and behaviours.[1–4] Most of these analyse the dental status of subgroups or aspects of specific characteristics of dental care provision. Macro-level international comparisons which examine oral health status and its development from a population perspective are very rare and even more so are cost considerations in cross-country comparisons. This is astonishing as only population-oriented comparisons, including total cost reflections, enable deeper insights into other systems and their specific advantages or disadvantages. For instance, by systematically evaluating the experiences of advanced countries in the field of dental provision, Germany achieved a paradigm-shift in dental treatment and provision (from a prosthetic to a preventive and tooth- retaining approach) thereby saving substantial amounts of financial resources.[5,6]

In most high-income countries the lifetime-prevalence of caries experience decreased substantially over the last three decades, unlike in low- and lower-middle-income countries, where oral diseases increased. Surprisingly, the highest burden of total tooth loss is found in the economically well-developed countries.[6,7] The decreasing prevalence of caries in high-income countries led to dramatic improvements in the oral health conditions of the entire population in many of these countries.[8–12]

On the other hand, as oral health is an integral part of general health, it constitutes a substantial economic burden for societies and health care systems. The direct costs for dental treatment in EU-countries rank third behind the costs for diabetes and heart diseases and are higher than for cancer treatment.[8] These direct oral health care costs are compounded by the social costs of oral diseases in terms of negative effects on work productivity. According to a study that provides evidence on this topic, these indirect costs amount to half of the yearly direct treatment costs worldwide.[13]

One of the problems involved in investigating the efficiency of dental care systems arises when attempting to measure the health benefit side of dental care. In cross-national comparisons, the oral health status of a society is often only measured by a certain age class, mostly 12 year old. Conclusions are then drawn for the entire population based on this indicator. However, this approach is incorrect, as these results are only reliable for the investigated subgroup and cannot be generalised for the whole population, since caries experience does not develop steadily over a lifetime. Moreover, the major dental decay problems occur in adults, not in children.[2] Consequently, a single indicator that corresponds to a certain age or age-bracket is unable to characterise the dental health of a country´s population. Therefore, in this work, we use an overall indicator developed by Bauer et al.,[5] to measure the dental status of the entire population.

To the authors knowledge, there are only very few studies that have investigated the efficiency of different dental care systems in the world. However, such studies are necessary to better understand other dental care systems and their performance as far as outcomes, costs and efficiency are concerned. Steps towards filling this gap have been made by two recent publications. The study of Foote et

al.[14] uses mean oral health values for 12 and 18-year olds as proxy variables for measuring a population´s dental health. This is, in principle, questionable. As many countries, including Germany, have no figures for 18-year olds, the study often has to resort to values for 12-year olds. Apart from this, the approach is also methodologically questionable, as only dental costs for youngsters should be compared with health data for youngsters. The share of costs, required for the young generation, is unknown. Nevertheless, the study design is an innovative and promising approach to analysing system efficiency questions. A second approach is to be found in the comprehensive publication by Winkelmann et al.[8] on oral health care and costs in Europe. It is a treasure trove, offering a huge data-set of useful information on this topic. However, the abundance of data provided by this publication is so overwhelming that it requires a systematic analytical framework which concentrates on a set of decisive indicators to be able to draw conclusions from it. This is the weakness of this approach from our specific perspective. Nevertheless, the publication constitutes a preliminary stepping stone to facilitate international comparisons of dental system effectiveness and efficiency.

Our study intends to integrate the relevant special knowledge available on certain aspects and connections into our macro-level data system, so as to enlarge possibilities of explaining the improvements achieved. This will furnish us with a full picture enabling systematic analysis of different advanced dental care systems and allowing conclusions on health policy influences. Our study is based upon proven standardised existing data on outcomes and costs facilitating the conduct of evaluations on the performance of oral health care systems. In this study, we apply such an approach, using new analytical tools[15] that have been implemented in several studies,[5,16,17] to selected advanced dental care systems worldwide. The objections voiced by Klingenberger et al.[18] to this concept are not convincing as the authors generally argue that first and foremost substantially more data would be required (e.g. single disease cost calculations). However, these data do not exist, are costly to acquire and their collection poses methodological challenges, not least that of comparing them with data from foreign countries.

We assess and compare how different oral health systems perform with the currently available possibilities, which are adequate in our judgement, to enable us to draw conclusions on the effectiveness and efficiency of dental care systems. This might help policy makers when designing appropriate oral health policies and in selecting public health interventions to bring about improvements. Furthermore, our results could furnish hints for developing countries seeking tested paths towards enhancing their dental care systems.

The aim of this article is to determine which dental care systems perform best and can serve as best-practice models. Furthermore, it reviews the hypothesis, according to which countries that regularly investigate and monitor the performance and quality of treatment and care, are more innovative and perform better in terms of the efficacy (oral health outcomes) and the efficiency of their dental care systems.

Material and methods

The cost of dental decay and its implications (tooth loss) account for 95% of total dental expenditures worldwide.[19] In Germany the current share is 85% (2021).[20] That is why we focus on dental decay while measuring oral health status. This approach indirectly includes periodontal and endodontic treatments in the measurement of oral health status, as the success or failure of these treatments results in tooth loss or tooth retention and is documented in the DMF-T (Decayed, Missing, Filled permanent Teeth) surveys. This must be kept in mind as severe periodontitis plays a major role in tooth loss in higher age groups.

The DMF-T index has been widely used as a proven and reliable measure for caries experience in dental epidemiology for over 75 years.[2] Generally, it measures caries on a dentine level (manifest caries) and does not document initial caries (enamel caries) which is reversible. For our purpose, this differentiation is not necessary because the difference in adolescents is marginal[21] and, more importantly, most countries to date collect data only on a dentine basis, except Sweden, where initial lesions are included.[22] In recent years, other countries like Denmark (DK) and Germany (DE) have also started to include initial lesions in their monitoring systems.

The overall indicator for measuring the oral health of the whole population, the Dental Health Index (DHI), is composed of the single indicators for the corresponding World Health Organization (WHO) standard reference age classes and, additionally, includes the indicator *missing teeth* (M-T) in the senior group (65-74).[16] To ensure that the comparatively high absolute values of the M-T in seniors are not over accentuated in the composite DHI, the values are converted into index points. To avoid repetition the construction of the DHI index is explained in detail elsewhere.[15,16] The formula for the DHI is:

DHI = (Caries-free Index 5/6 + DMF-T 12 + DMF-T 35/44 + M-T Index 65/74 + Edentulism Index 65/74): 5

A population´s better dental status and a more effective system of dental care are expressed by a lower DHI. Linking the DHI and the Dental Care Cost Index (DCCI), defined as a proportion of total outpatient dental care costs in relation to GDP, gives rise to the Efficiency Index (EI).[16] Total dental care costs comprise spending by government, health insurance, voluntary health insurance and private spending. Thus, the cost-levels of different care systems can be compared independently of the type of system. To ensure that both indices indicate improvements in the same manner and direction, the two values are added. Thus, superior oral health status of the entire population and lower macroeconomic expenditure for dental care are reflected in decreasing indices. Consequently, a lower efficiency index signals a more favourable benefit/cost ratio within the dental system. Mathematically, the formula reads as follows:

Efficiency Index (EI) = Dental Health Index (DHI) + Dental Care Cost Index (DCCI)

For the epidemiological data we used the data base of WHO/Malmö University[23] and supplemented them by data from national representative surveys in the countries under observation. Until recently, no national representative surveys on adults´ dental health existed in Sweden. However, for the past 50 years, every ten years, the University of Jönköping has published a representative survey on the adult population of the county of Jönköping (the latest survey is currently in the process of evaluation),[24] which is meant to be typical for the Swedish adult population. Various studies from different regions and at different periods support that assessment.[22] In 2008, the Swedish Dental Health Register was introduced. It provides nearly complete national data on the oral health of Swedish adults.[25] Whether these data, evaluated for 2014, support the above assessment, will be examined later.

The data on total dental expenditure per year in percentage of GDP were taken from the OECD Statistics. Data on further details of dental care in Europe are collected by the data-bases provided by Winkelmann et al,[8] and Kravitz et al.[26] The year 2019 was chosen as the most actual year for cost comparisons because data from the following years might be biased owing to the corona crisis.

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The overall indicators for measuring the benefits and costs of a dental care system are applied to selected high-income countries. The criteria for inclusion are: different types of dental care systems, the existence of a regular monitoring framework and differing living conditions, measured by population density per sq km. In order to ensure that the comparison is not biased by including only countries with comfortable living conditions, the selection is worldwide and includes countries with geographically challenging living conditions (e.g. indigenous people in remote areas with a different cultural background) and varying access to fluoridated drinking water (Table 1).

Table 1 Characteristics of the selected countries

Country[1]	System type	GDP/capita[1] PPP in US $ in thous. (2019)	Population density People /sq km	Access to fluoridated drinking water in % (2020)
DE		46.8	238	0
KR[2]	Social security model	31.9	531	6
JP		40.4	346	0
UK		42.7	277	11
SE	National health model	51.9	25	0
DK		59,6	146	0
CH		84.1	219	0
CA	Private insurance model	46.4	4	44
US		65.1	36	77
AU	Mixed private/public model	54.9	3	89

1. ISO country codes; 2. South Korea, hereafter Korea[27–29]

Although Switzerland and Canada generally have a social security system, they are assigned here to the private insurance model, as the health legislator in both countries explicitly decided not to include dental provision in the general health care system (except when it relates to children, expectant mothers and public assistance recipients.[30] In Switzerland, costs for dental care are only included in the medical insurance system if such costs were 'generated by serious and unavoidable diseases of the masticatory system or by another serious illness or its aftermath'.[31] As only 10% of the Swiss population have chosen private insurance,[26] in reality, most dental treatments are paid for privately.

Geographical living conditions differ specifically between countries with a high population density (KR, JP), and the USA, Canada and Australia (low population density). That might have consequences for the provision of care and the performance of dental care systems. Also access to fluoridated drinking water differs largely (Table 1) and is highest in the large-scale countries (AU, US, CA).

This study is a descriptive and cross-national investigation, based on existing data. The fact, that the time-points of the survey data in the single countries vary, unfortunately, is unavoidable in cross-country comparisons. While it is able to demonstrate evidence of relationships and influencing factors, conclusions on cause and effect are limited.

Results

The Swedish population, with its national health system and a DHI of 2.6 enjoys by far the best oral health status of the countries under observation (Table 2). Additionally, it should be borne in mind that the Swedish findings based on clinical-radiographic examinations and the caries figures are the sum of initial and dentine caries.[22] Rank two goes to a country with a young social security system, Korea, with a DHI of 3.5. The USA (DHI of 3.8) comes in third. The oral health levels of the British, Australian, Japanese, Canadian, Swiss and Danish populations are rather similar. Germany ranks last with a DHI of 4.8. The difference in DHI between the first and the last country amounts to 85% (Sweden=100), which means the oral health status of the German population is 85% lower than that of Sweden. At any rate, the Swedish (state-oriented) and Korean (social security-oriented) dental care systems outperform the other countries in terms of system effectiveness.

Table 2 Dental Health Index of the population (DHI) in selected high-income countries for the period around 2019 or nearest

Country	Survey year	Caries-free 5/6		DMFT 12 (2)	DMFT 35/44 (3)	M-T 65/74		Edentulism 65/74		DHI[14](6)	Rank
		in %	Index (1)			abs.	Index[15] (4)	in %	Index (5)		
DK	2006/08/17/22	76	2.4	0,38	13.5	8	7	5.7	0,6	4.4	8
DE	2016	>50	5.0	0,44	11.2	11,1	6	12.4	1,2	4.8	9
SE	2005/20/21	73	2.7	0,65	6.2	5,5[4]	3	2.2	0,2	2.6	1
UK	2009/17/22	<76.3[7]	2.4	0,5	11.1	6,8[5]	4	15[6]	1,5	3.9	4
CH	1999/00/12	51[13]	4.9	0.9	11.2	7	4	6.5	0,7	4.3	7
US	2004/11/16	62.3[9]	3.8	1,2	9.4	5.6	3	13.7	1.4	3.8	3
CA	2008/09/15	66	3.4	1,0	12.3[10]	5,6[11]	3	15	1.5	4.2	6
JP	2016/21	61	3.9	0,6	12	6.7	4	4.1	0,4	4.2	6
KR	2011/12-13/18	38	6.2	1,8	5.5	5,6[1]	3	9.7[8]	1,0	3.5	2
AU	2014/17-18	65.7	3.4	0.9[12]	10.3[2]	8,8[3]	5	11.1	1,1	4.1	5

1) Mean of 65-69/70-74; 2) 35-54; 3) 55-74; 4) 70; 5) England, 55+; 6) 65; 7) 5 y, only England; 8) 65+; 9) Mean of 2-5/6-8; 10) 40-59; 11) 60-79; 12) 12-14; 13. 16 Zürich districts; 14) DHI: (6)=[(1)+(2)+(3)+(4)+(5)]: 5; 15) Index for M-T conversion: 0-<2=1point, 2-<4= 2pts, 4-<6=3 pts, 6-<8=4pts, 8-<10=5 pts, 10-<12=6 pts, 12-<14=7 pts, 14-<16=8 pts, 16-<18=9 pts, >18=10pts. [9–12, 21–23, 32–46]

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A look at the single indicator for twelve-year olds reveals that this value alone cannot express the oral health level of an entire population. The ranking below produces a result that diverges greatly from the ranking according to the DHI (Table 2). Although it is important to lay the best possible foundation for lifelong natural teeth in the young generation, tooth diseases develop differently in middle-aged adults and in seniors. Moreover, as our comparison proves, the sole comparison of edentulism in seniors, sometimes proposed as a possible single indicator for measuring overall dental health, delivers no reliable results. Only Sweden leads in most of the single indicators (Table 2).

When looking at the countries´ ranking, it stands out that large-scale countries with challenging living conditions and a share of indigenous people living in remote areas are performing relatively well (US: 3, AU: 5, CA: 6), although the oral health of the indigenous populations in these countries is substantially lower than in the non-indigenous populations.[47–49] As a large proportion of the drinking water in all three countries is fluoridated, unlike in the other countries, this might partially explain the good outcome figures. Moreover, countries operating a private insurance or a mixed private/public model (US, AU, CA, CH) perform rather well as far as the efficacy of oral health outcomes is concerned.

An earlier survey, using the same method, and examining some of the same countries, revealed different rankings (Table 3) which shows that the country rankings have only limited validity. Only Sweden´s position in first place has been stable over time since 2005.[5] Generally, the DHI´s development is more significant.

Table 3 DHI comparisons 2013/14 and around 2019[16]

Country	DHI 2013/14	Rank	DHI 2019	Rank
SE	3.2	1	2.6	1
DK	4.4	2	4.4	8
DE	4.5	3	4.8	9
CA	4.6	4	4.2	6
UK	4.7	5	3.9	4
US	4.7	5	3.8	3
JP	4.7	5	4.2	6
AU	5.2	6	4.1	5
CH	5.2	6	4.3	7
KR	-	-	3.5	2

Worthy of note are the improvements in the DHI of Sweden, the USA, Japan, Australia and Switzerland. The DHI´s deterioration in Germany is due to a lower value with respect to caries freedom in 5/6-year olds. Korea, a country which ranked first in a similar study on Asian countries from 2016,[17] performed better than all of the European countries investigated, except Sweden. That shows the effectiveness of the Korean dental care system.

A look at the single indicators of all countries demonstrates that most of them achieved a very high level of dental health in 12-year olds. Further improvements can only be expected for Korean and American youngsters. In the middle-age-group many countries need to make considerable progress to approach the low values experienced by Korea and Sweden. Thanks to the very good dental health exhibited by the young generation that goal is likely to be achieved. Regarding the M-T indicator for seniors, Germany has the greatest backlog. Owing to the late start of wide scale group prophylaxis for children and adolescents in the late 1980´s, it will take until 2030, for seniors to achieve missing teeth figures of 5.6, levels that Sweden, Korea, Canada and others already exhibit today.[50] The situation is similar for edentulism in seniors (65-74), where 4.2% are predicted for 2030.[51] Japan and Sweden currently achieve that level or even lower. These two facts illustrate the huge reserves in effectiveness that exist in Germany. Even more urgent is a reduction in edentulism among seniors in Canada, the USA and the United Kingdom. In summary, most of the investigated countries have considerable scope for improvements. However, because Sweden has already achieved an unrivalled high level of oral health in its population, Norderyd[24] predicts a waning rate of improvement for the future.

When comparing the level of the population´s oral health status with the macroeconomic resource consumption (DCCI), Germany is taken as the index baseline (DE=100; Table 4). As it turns out, Germany still has the most cost-intensive dental care system (0.77%). However, the trend since 1980 (1.15%), 1990 (0.83%), 2000 (0.89%)[5] and 2019 (0.77%) is a downward one. Canada (0.71%) and the USA (0.67%) are also rather cost-intensive. The majority of countries need 0.48% to 0.60% of GDP to finance their dental care sector. By far the lowest percentage is spent in the United Kingdom (0.30%).

When we consider the costs of the dental system alone, it is evident that all of the other countries require far less resources than Germany. Sweden, whose citizens have a much higher level of dental health, spends a fifth less on oral health care than Germany. What is striking is the extremely low consumption of resources by the British system (almost two-thirds less than Germany). Projections up to 2040 predict that Germany, the USA and Canada will continue to be the countries with the highest expenditure rates. Low expenditure rates per capita are predicted for Korea, Australia and the United Kingdom.[52]

To make sure the cost shares of 2019 are not an outlier, Table 5 shows how the shares developed between 2015 and 2019.

Table 4 Efficiency Index of the dental care systems 2019 (DE= 100)[53]

Country	Dental Health Index (DHI)		Dental Care Cost Index (DCCI)		Efficiency Index[1] (3)	Rank
	Value	Index (1)	Total dental care costs in % of GDP	Index (2)		
DK	4.4	92	0.52	68	160	7
DE	4.8	100	0.77	100	200	10
SE	2.6	54	0.6	78	132	2
UK	3.9	81	0.3	39	120	1
CH	4.3	90	0.45	58	144	4
US	3.8	79	0.67	87	166	8
CA	4.2	88	0.71	92	180	9
JP	4.2	88	0.52	68	156	6
KR	3.5	73	0.49	64	137	3
AU	4.1	85	0.48	62	147	5

1. EI: (3) = (1) + (2)

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Table 5 Development of dental care costs in % of GDP between 2015 and 2019[53]

Country	2015	2019	Difference (abs.)
DK	0.56	0.52	- 0.04
DE	0.81	0.77	- 0.04
SE	0.61	0.60	- 0.01
UK	0.27	0.30	+ 0.03
CH	0.43	0.45	+ 0.02
US	0.66	0.67	+ 0.01
CA	0.70	0.71	+ 0.01
JP	0.52	0.52	0
KR	0.38	0.49	+ 0.11
AU	0.58	0.48	- 0.10

In summary, the figures show little variability. Only Korea and Australia have greater fluctuations of +0.11% and -0.10% respectively. In Korea, the rise is probably a consequence of the expanded dental healthcare coverage that took place between 2009 and 2017 and in Australia cost-effectiveness may have improved in this period.

When looking at both the benefits and costs (Table 4), which is seldom done in international comparisons, the United Kingdom (EI: 120) and Sweden (EI: 132), two national health systems, perform best. Korea and Switzerland follow, demonstrating that their dental care systems are also highly efficient. Slightly less efficient are Australia, Japan and Denmark. Low-efficiency systems are the private insurance models of the USA and Canada and, especially, Germany´s social security model (EI: 200). Germany ranks last in oral health status (DHI) and in cost-effectiveness (DCCI), resulting in the least efficient dental care system of the compared countries. These findings are similar to study results from 2005 where Germany was second to last in terms of efficiency, just before Canada.[5] Since the total cost expended on dental care systems remained rather stable compared with 2015 (Table 5), the observed improvements in system efficiency are mainly caused by improved dental health status. Positively expressed, major progress in populations´ dental health has been achieved by nearly the same percentages of macroeconomic resources, irrespective of the type of health system, and even though the dental workforce increased in many countries, except Sweden, Denmark and Switzerland.[8]

The connections between the DHI and the macroeconomic costs are presented in Figure 1. If we look at the efficiency matrix, what catches the eye are Sweden´s outstanding oral health status and the United Kingdom´s excellent cost-effectiveness, whereas Germany stands out for its extreme resource-intensity. Many of the countries, comprising all system-types, spend around 0.5% to 0.6% of GDP on their dental care systems. Somewhat more cost-intensive are the private insurance models of the USA and Canada, with a cost-share of around 0.7%. It is quite possible that the vastness of these two countries makes it more expensive to maintain efficient oral care structures and the higher dental disease burden of the indigenous populations (US: 2.9%; CA: 4.0%),[47,49] living in remote areas, might increase provision costs. On the other hand, Australia, the population of which also includes 3.2% of indigenous people[48], manages its care system at the same cost level as Japan, Switzerland, Denmark and Korea, countries with much more favourable infrastructural conditions. The matrix also shows that quite different oral health levels can be financed with 0.5% of GDP. For instance, using nearly the same amount of resources, the Korean population enjoys an oral health status that is 20% better than that of Australia.

So far, we have used only objective data for measuring dental status and costs. We will add one subjective indicator to complement our system-evaluation approach. In all advanced dental care systems, quality oral treatment should generally be provided irrespective of socioeconomic circumstances. To what degree this assumption is fulfilled is measured by the indicator *unmet needs for dental care due to costs*. The reality at present is shown in Figure 2.

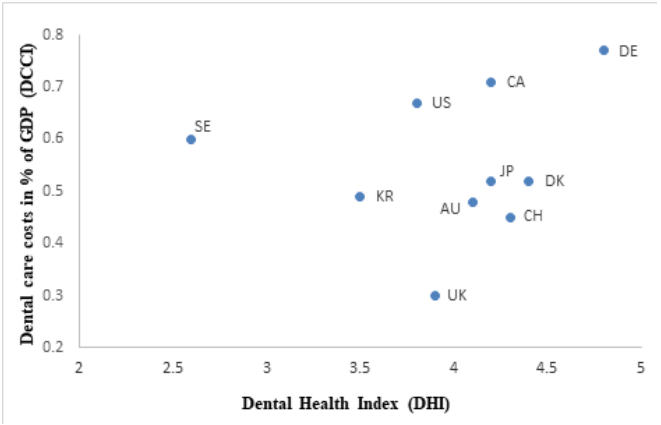

Figure 1 Efficiency matrix of the dental sector in selected highly developed countries 2019.

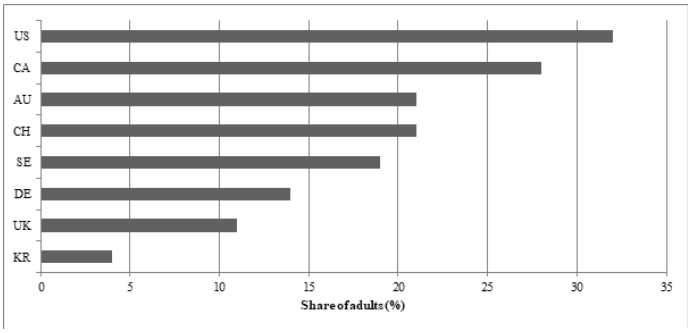

Figure 2 Share of adults (%) with unmet dental care needs due to costs in the past year, 2016.[1,2]

1. Japan is not included as needy households are provided free of costs; 2.Value for Korea refers to 2019.[54,55]

Unmet needs are culminating in the private insurance systems of the USA and Canada and are lowest in the Korean social security, the United Kingdom´s national health and Germany´s social security system. Sweden, Switzerland and Australia have moderate levels of between 19% and 21%. A consideration of the individual type of care system does not lead to any clear conclusion. On the one hand the USA and Canada, two private insurance models, reveal the highest percentages of *unmet need*. On the other hand, Switzerland and Australia prove that systems that are predominantly privately financed are also capable of adequately providing for those in need. In Switzerland, this is emphasised by the fact that the progress in the dental health of the Swiss population, achieved in the last two decades, has been greatest in the lowest socioeconomic group.[12] The systems of Korea, the United Kingdom and Germany perform best in serving their vulnerable groups. In Germany´s case, this might partially explain the permanently high total cost of dental care. By contrast, the Korean and British systems show that the above-mentioned goal (oral care irrespective of socioeconomic factors) can be achieved while expending significantly less economic resources.

Further insight into connections affecting costs might be found by comparing two indicators *amount of out-of-pocket payments* and *total dental care costs in relation to GDP* (Figure 3).

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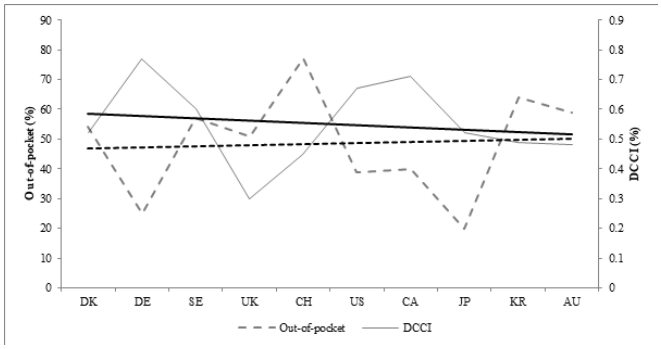

Figure 3 Comparison of out-of-pocket payments in dental care[1] and total dental care costs in % of GDP 2019.

1.Value refers to 2020[53,56]

Both trend curves show a weak association between the two value rows, which is in line with health-related economic knowledge, whereby a certain amount of out-of-pocket payment keeps system-costs down and fosters price consciousness. The two indicators, *unmet need* and *out-of pocket share,* are in conflict to some degree. However, it is not scientifically possible to make both indicators match each other. It is a question of priorities which are to be set by health policy decision-makers.

Discussion

As the main dental diseases, caries and periodontitis, are preventable in principle, the population´s oral health depends on

a) broad prophylactic programmes for toddlers, children, adolescents up to the age of 18,

b) appropriate individual oral health behaviour and awareness,

c) regular dental check-up habits,

d) the treatment philosophy of the dentist and

e) a suitable health policy framework.

An overview of the state of actual oral care habits is given in Table 6. The index for severe periodontal disease in seniors (PPD ≥6) is included as an additional indirect measure indicating the quality of individual´s oral hygiene. As only combined figures for moderate and severe periodontal probing depths exist for some countries, these values are also shown for the purpose of comparisons. So as to facilitate the comparison of DHI and dental behaviours, countries are ranked according to their DHI value.

Table 6 Oral care habits of adults 35 -74 in the observed countries (approx. 2015 -2020)

DHI	Dentist/dental hygienist attendance rates/year		Tooth brushing ≥ 2x/day (In %)	Dental floss/ toothpick (In %)	PPD[1] in 65-74 year olds (In %)	
	Visits (In %)	Of which: Check-ups (%)			≥ 4 + ≥ 6	≥ 6
SE: 2.6	93	95	85	40	-	11
KR: 3.5	-	28	92	7.2	41.9	-
US: 3.8	-	64	69	41	-	12.8
UK: 3.9	71	61	75	-	60	-
AU: 4.1	-	52	96[2]	56	51.1	-
JP: 4.2	50	19	77	-	-	15
CA: 4.2	-	65	73	28	-	4
CH: 4.3	75	58	78	50.4	-	3.7
DK: 4.4	-	79	68	28	-	20
DE: 4.8	86	81	92.5	35.7	75.4	24.6

1. Periodontal probing depth; 2. ≥1x/day. [1, 11, 33, 57– 69]

On comparing the population´s oral health status, we discover that the Swedish national health system performs best compared with all other countries studied. This finding is in line with another study which showed that the type of dental care system accounts for 8.1% of the difference in oral health status and the Scandinavian regime of Sweden performed better in population dental status than other European welfare systems.[70] That result corresponds to the high level of oral health behaviour demonstrated by Swedish adults (Table 6). In Sweden, there have been continuous improvements in dental health and oral care habits enabling major reductions in the need for dental treatment.[22,60] This is consistent with earlier studies[5,16,17] and with the fact, that most of the oral health goals for children, adolescents, middle-aged and seniors have been achieved there. In the future, only small advancements can be expected because *very low* and *low levels* of caries burden in WHO reference age-brackets have already been achieved. The 2014 nationwide data furnished by the newly founded Dental Health Register proves the representativeness of the Jönköping study (2013), as the key indicators for adults, *remaining teeth* at senior age and the share of *edentulism in seniors*, are almost identical.[25] The Swedish Quality Registry for Caries and Periodontal Diseases (SKaPa) set up in 2008 and providing nationwide data for quality development in dental care, also supports the findings of the Jönköping study in its first report covering the years 2010 to 2016. It concludes that a decrease in the prevalence of caries and fillings in individuals aged 35 to 65 is evident[71] and that the levels of DMF-surfaces are very similar to those of the last Jönköping study (2013). It also confirms improvement in the quality of periodontal diagnosis and treatment of periodontal pocket depths. Sweden could, therefore, serve as benchmark for other countries in the area of population´s oral health status. The reasons for the impressive dental health improvements can be summarized as follows:

a) Implementation of stringently designed oral health policies by the county governments and yearly monitoring of developments beginning in the early 1970´s,

b) 5-year educational training programme for public dental service as well as for private dental practices,

c) Integrated preventive dental care for children and adolescents,

d) Fissure sealing programmes for all permanent molars after eruption and

e) High risk-oriented regular dental care attendance rates (95% for 50-80 year olds).[72]

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Thus, most citizens up to age 60 were exposed to preventive dental programmes and oral hygiene training in their first twenty years of life.[72] These habits were largely maintained into early senior age, resulting in greatly reduced numbers of crowned teeth and endodontically treated teeth in 50-year olds as well as improved periodontal health in the population over the age of 40 with diminishing prevalence of severe periodontitis.[22,72] All in all, a preventive and tooth-retaining approach is widely practiced in the Swedish dental care system and the population supports that approach with appropriate oral self-care.

When it comes to the costs of the Swedish system there are several advantages that other countries do not possess: a relatively large public sector with salaried personnel and a dental workforce that boasts a dentist/dental hygienist/dental technician ratio of 1:0.45:0.2, which is suitable for fostering prevention-oriented and cost-saving treatment concepts.[73] Furthermore, the dentist per inhabitants´ ratio is sufficiently high and stable since 2008,[8] meaning that no cost-pressure is exerted by enlarged numbers of dentists.

A closer look at the densely populated Korea with its young but fast aging society, which ranks second in population´s dental status, reveals an astonishing insight. As recently as 1997, Korea operated a social security system with a National Health Insurance (NHI), which provides coverage for 96% of the population. Initially, NHI covered only a minimum of dental services. In 2009 a reform process began that lasted until 2017, focusing on the younger generation (sealants for <18-year olds), the middle-aged (scaling for ≥20-year olds) and primarily on the elderly (prostheses for ≥65-year olds including implants). Soon implants became the most preferred prosthodontic treatment[74] making Korea the world leader in dental implants per 10,000 people.[75] That is why, over 70% of Korean dental practitioners offer their patients implant surgery.[76] With a share of 12.2% of dental implant wearers (2013),[77] the rate in Korea is almost twice as high as in Sweden (6.6%), the second country where dental implants for over 65-year olds are being subsidised.[22]

Apart from Korea and Sweden, dental implants are intended as elective treatments and are not included in social health insurance catalogues and public health programmes across the world.[77] Whether the inclusion of dental implants in Korea is beneficial for patients and the dental system remains open. Until now, the level of missing teeth´ for Korean seniors (5.6) is as low as in Sweden (5.5) and Canada (5.6). This could change rapidly as marketing strategies and economic incentives cause increasing pressure on clinical practice in the field of dental implants. Many teeth are extracted in favour of implants, because extraction is perceived as easier and more lucrative than saving a natural tooth.[78] But such treatment is neither simple nor ethical and is frequently conducted without addressing the risks of this most invasive treatment (failures, longevity, and, most important, biological and technical complications).[78] Reports on implant complications reveal high ratios of difficulties with cleaning and peri-implantitis.[79] According to Seo et al. it would be advisable to avoid highly invasive interventions in older patients due to frequent risks of systemic diseases, and therefore social insurance coverage of dentures might be more appropriate than the coverage of dental implants.[80] If the trend of forced demand for implant procedures persists, there is a danger of the Korean dental system repeating the error committed by the German system in the 1970´s and 1980´s, when invasive prosthetic procedures dominated adult dental care provision. That approach had a major negative impact in terms of dental health status and resulted in excessive levels of expenditure for the sickness funds. Recent findings seem to confirm this danger as some authors affirm, that the inclusion of implants led to decreasing numbers of existing teeth and to increasing numbers of extracted teeth.[77]

The current good level of dental health among the Korean population is noteworthy, because it was achieved in a period where 84% of dental expenditure had to be spent out-of-pocket[74] and the dental care system was just in its infancy. Furthermore, the regular rate of visits to dentists or dental hygienists is only 28% (Table 6). Now, what might be the reasons for Korea´s good performance? First of all, Koreans are generally health-conscious[86] and especially tooth-conscious because a culture prevails in which Koreans ´feel ashamed to live with missing teeth´.[76] To lose a tooth is seen as 'symbol of social incompetence´.[76] Second, systematic tooth brushing is considered as key method to prevent oral diseases. Korea consequently emphasizes regular tooth brushing from elementary school age. Elementary school teachers are appropriately trained to teach correct tooth brushing to their pupils.[76] Third, the sugar consumption per capita/year (2021: 30.4 kg), although increasing since 2012, is still lower than in most of the other countries studied, except Japan (2021: 15.6 kg).[23] Fourth, diet matters in preventing dental diseases[81] and Korean food is generally tooth friendly (almost no sugar, little processed grains, low in fat, lots of vegetables, fruits and healthy spices) and the quality of the diet is associated with the number of teeth retained by the Korean population.[82] The mean intake of vegetables (354g/day) surmounts the WHO-recommended quantity of ≥240g/day, a figure achieved by only a few countries in the world.[83] Moreover, Koreans consume 96.3g/day of kimchi, a traditional food with probiotic properties that contains high levels of vitamins, minerals, and dietary fibres. This high intake of kimchi seems to be associated with a lower prevalence of periodontitis[84]. Fifth, 92% of Koreans brush their teeth on average 2.7 times a day,[57,85] and over 90% use fluoridated toothpaste[87]. The level of access to fluoridated drinking water (6%, Table 1) is relatively low. As full-time employees brush their teeth above average (2.9 times/day),[85] many of them obviously practise tooth brushing at work. Moreover, brushing one´s teeth after meals is a frequent habit as authentic Korean cuisine uses garlic, ginger and chili and this requires tooth brushing as a basic etiquette. Therefore, it is common for Koreans to carry portable toothbrush kits with them as they go about their daily activities. Sixth, as other Asian countries or regions, such as Singapore, Hongkong and Taiwan also have similarly low DMFT values (7.4, 6.9, 7.3 respectively)[17] as middle-aged Koreans (5.5), when compared with the other countries studied, it cannot be excluded, that genetic factors also play a role in explaining the low values for 35-44 year old Koreans. At any rate, it is proven that genetics have an important effect on the aetiology of dental caries and are one of the decisive factors causing inter-individual variations in caries susceptibility.[88]

Considering the high dental health status and the large share of implant treatments (the most expensive procedures in dentistry), the rate of total expenditure needed (0.49%) can be considered quite moderate leading the country to rank third in the area of system efficiency. Thus, this young social security system performs substantially better than many of the well-established dental care systems. Nevertheless, it should be mentioned that the expenditure rate in recent years increased from 0.38% (2015) to 0.49% of GDP (2019), owing to the expanded benefit catalogue and a constantly growing number of dentists from 40.232 (2013) to 57.949 (2019). However, the favourable dental workforce situation, a dentist to dental hygienist ratio of 1 to 1.5 (2019)[89] has probably helped to keep costs down. Compared with a country with a similar population density, Japan, with its dentist ratio of 0.83 per 1000 inhabitants, Korea still has potential for increasing its dentist numbers. In 2019 the dentist ratio per 1000 inhabitants was 0.52%.[89] Nevertheless, Jevdjevic et al. predict a below average per capita growth in oral health spending for Korea compared to other industrialised countries until 2040.[52]

The good oral health status of Japanese citizens corresponds to improvements in periodontal status, brought about by enhanced oral hygiene levels and dental health behaviour.[90] The marked improvements over several decades were achieved by a consistent oral health policy that sets goals and intervenes when necessary. The country offers sophisticated public dental health services, provided by private dental practitioners under contract with local governments. The health insurance system provides easy access to dental care, at relatively low costs, with a standardised fee schedule for the entire country.[46] As in Korea, associations between diet and health benefits[91] also exist in Japan. The healthy traditional Japanese diet is largely fresh, minimally processed, has only a few refined ingredients, uses lots of fish and vegetables and seaweed and is low in fat and added sugars.[92] Too, Japanese individuals have a high intake of unsweetened green tea with its antioxidant ingredients (catechins).[6] These factors and a traditionally extreme low sugar consumption of 15.6 kg/capita (2021), by far the lowest value compared to industrialised countries,[23] have presumably helped to lessen the prevalence and severity of dental diseases. Surprisingly, the improvements in dental status have been achieved, although the proportion of Japanese adults who regularly utilise preventive care visits (19%) is very small and misses the aspired goal of *Healthy Japan 21* of 65% regular dental check-ups in 2022.[46] Ishimaru et al., therefore, advocate for health policy activities.[63]

A recent study compared the efficiency of the Japanese and German dental systems, both of which are social security models, and its results were similar to our findings. The study concluded that Japan used the resources expended on dental care more efficiently than Germany.[93] The causes, which the authors suggested might partly explain the country differential in dental health, included a lower level of risk in the Japanese population (higher proportion of tertiary education, and lower smoking rate). To what degree Japan´s larger dental workforce (103 dentists per 100,000 compared with 85 per 100,000 in Germany) has a role to play remained open. Be that as it may, it is probable that the high ratio (1 to 1.2) of dental hygienists to dentists in Japan[93] does have a relevant impact on oral health and prevention, whereas, in Germany, the ratio of dental technicians to dentists is nearly 1 to 1, a relic of the prosthetic approach that dominated the 1970´s and 1980´s.[94] Dental hygienists in Germany are few and far between. This fact might explain the backlog in oral health and simultaneously the extreme cost-intensity that characterises German dental provision. Furthermore, the Japanese system offers more incentives for retaining teeth by paying a high fee for *supportive periodontal therapy*, which is often performed by dental hygienists.[93] In 1989 the *8020 Campaign* was launched based on a joint decision by health policy-makers and the Japan Dental Association, with the aim of maintaining ≥20 or more teeth up to the age of ≥80 years. This collaboration demonstrated, that health policy-makers and the association of dentists share the common goal of promoting oral health and both play an active part in reaching this goal. Finally, regarding the cost side of dental care, the German population paid around 54% more than the Japanese (measured in costs per capita/year).[93]

The study findings for the three large-scale countries with challenging living conditions (US, CA and AU) and similar dental care systems (private insurance and mixed private/public) will be analysed together. These countries´ oral health levels are alike in the young, middle-aged and senior generations. Forecasts on edentulism in American seniors predict values of around 5% by 2050,[95] figures that have already been achieved by some of the countries under observation (SE, DK, CH, JP; Table 2). All three countries show good oral hygiene results (Table 6) and enjoy the advantage of having a high level of fluoridated drinking water, which has a strong positive effect on dental health and is extremely effective because it is free of charge and easily accessible for everyone.

However, the cost-effectiveness of these similarly designed systems differs substantially: the two private insurance systems, Canada and the USA, are relatively cost-intensive expending 0.71% and 0.67% of GDP respectively. Canada´s higher cost ratio could be a consequence of increased efforts to improve the poor oral health of the indigenous populations, which started in 2004.[96] Forecasts for per capita expenditure on dental care by 2040 predict further above-average expenditure rates for the USA and Canada.[52] By contrast, Australia manages its private/public system rather cost-effectively. That is remarkable because with a dentist/dental hygienist ratio of 1 to 1.2 and 1 to 0.5 respectively in Canada and the USA the dental workforce situation is more favourable than in Australia (1 to 0.3).The reason might be a greater influence of active oral health policy[97] and the fact that the public service in Australia from time to time publishes recommendations for implementing preventive strategies among the Australian population,[98] strategies that in many cases also have cost-reducing effects.

The populations of Denmark and Switzerland, served by a national health and a private insurance system respectively, enjoy very similar dental health levels in all age groups. Both countries, together with Sweden, have been forerunners for systematic preventive dental strategies in early childhood and adolescence (up to 18 years) and have accordingly achieved excellent oral health among the young generation. The adult age-brackets benefitted from this preventive, tooth-retaining environment and the oral care habits learned in their youth. Both countries started their activities in the 1960´s (Switzerland) and at the beginning of the 1970´s (Denmark).[99,100] The preventive approach in Denmark was introduced in 1972 whereby prevention in dental care became a legal obligation very early on[100]. Since 1989 this programme covers all 3- to 18-year olds and is often carried out in schools. Every municipality has a register of resident children for checking regular appointments. A Child Dental Health Service is responsible for making contacts with the parents of the newly-borns to arrange a visit when the child is one year old. Parents who do not keep the appointment are reported to the social services. Thus, almost 100% of children are enrolled in the service.[100] As access to prevention for minors has been free of charge since the 1980´s the DMF-T values have dropped abruptly in 12- and 15-year olds.[100] In short, introducing prevention and free access to care as well as a favourable dentist/dental hygienist ratio of 1 to 0.36 were the key to achieving good oral health in the young. In the adult age classes the good results are probably due to the high attendance rates at annual preventive dental visits (79 % in 45-99 year olds).[11] Surveys on adults´ oral health from different countries show, that regular dental check-ups help to preserve natural teeth.[10,22,33,68] In light of this relationship the Danish Health Authorities updated their guidelines for individual dental check-ups in 2016 and made individual risk-assessments obligatory for dental check-ups. It recommended that the shortest interval should be twelve months, and the longest 24 months.[11] Risk-oriented approaches in preventive systems are meant to be cost saving. In summary, the Danish dental system performs well in terms of benefits and costs.

The Swiss population (15-74 year olds) has a similar rate of attendance (75% annual visits to a dentist or dental hygienist). 58% of such visits are initiated by voluntary check-ups or recall-ups. It is remarkable that between 1992 and 2012 the check-up visits to a dentist decreased from 70% (1992) to 62.5% (2012) whereas visits to a dental hygienist increased respectively. 78.3% brushed their teeth ≥2 times a day and 54.4% used dental floss or a toothpick (Table 6).

Apart from the canton of Basel, where drinking water is fluoridated at 1 ppm (mg/l) all other cantons rely on fluoridated salt at 250 ppm F as the main source of fluoride exposure. The market share of fluoridated table salt is over 84%.[101] On the whole, the Swiss population practises sound oral care habits and shows good preventive oral health awareness.[102] These findings explain why periodontal complaints were not mentioned as a reason for annual dental visits and severe periodontitis (PPD ≥6 mm) was low (3.7%, Table 6) among Swiss seniors.[103] The knowledge, that in the event of dental disease, one would have to pay 80% out-of-pocket, seems to be a strong incentive for such behaviour.

The Swiss cost ratio for dental care in relation to GDP is moderate (0.45%), particularly, when considering that Switzerland has by far the highest GDP per capita (Table 1). As the bulk of total dental costs is caused by the number of dentists and the structure of the dental workforce, it is striking that Switzerland is one of the few countries in Europe where the number of dentists per 100.000 inhabitants shrunk between 2008 and 2019.[8] This fact and a good dentist/dental hygienist ratio (1 to 0.6)[8] certainly contributes to the Swiss system´s moderate rate of expenditure.

The population of the United Kingdom has also made great progress in almost all indicators of oral health over the last two decades, particularly in the key indicators for adults *missing teeth* and *edentulism in seniors.*[104] Improvements in oral health began twenty years ago in the younger generation and are now evident all the way up to age 45.[68] Larger portions of the adult population than ever before practise good oral health: three quarters of the adult population clean their teeth at least twice a day with fluoridated toothpaste. The annual attendance rate is 71% and the main reason for visits is a regular check-up (61%). Nearly 80% make their recall with the same dentist which shows that dentist-patient communication is working well.[68]

What is most striking in the national health system of the United Kingdom is the very low percentage of resources needed to finance British dental care provision. One explanation could be the relatively low ratio of dentists per 100.000 inhabitants, which is the second lowest among the high-income countries of Europe. Only Switzerland has an even lower ratio.[8] The existence of dental hygienists/dental therapists might also play a role in holding costs down although with a dentist/dental hygienist or -therapist ratio of 1 to 0.26,[105] their share is not particularly high. Probably more important is the existence of a Review Body on Doctors´ and Dentists´ Remuneration (DDRB) that advises the Government on rates of pay for doctors and dentists working for the National Health Service (NHS).

Every year this body analyses the NHS´ entire economic situation, including areas such as:

a) recruiting, retaining and motivating dentists,

b) the funds available to health departments, as set out in the Government´s departmental expenditure limits and

c) ensuring that overall strategy meets patient needs.[106]

For instance, on the advice of this body the Government provided an additional sum of over 1.7 billion pounds in income protection for the period 2020-2022 to ensure that NHS dentists' capacity was retained. And, owing to underfunding, the NHS received an additional 50 million pounds for primary care dentistry.[107] The existence of this economic body probably explains best why the British dental system is so cost-conscious and cost-effective and needs so few economic resources to provide good dental care. Consequently, system efficiency in Great Britain is superior to that of all the countries studied. This holds true, even when considering complaints regarding structural underfunding of the NHS,[108] because our analysis includes all costs accrued by the dental system, so that changes in dental service providers are irrelevant from a total cost perspective. This is the only method by which meaningful comparisons on the cost side of different dental care systems can be made.

On the other hand, the on-going complaints of dentists and patients about the NHS, which most of the citizens rely on, of underfunding and too long waiting lists for dental appointments respectively lacking dental services in more isolated regions recently were addressed by a UK government reform package on dental care. This Dental plan until the 2030´s intends to reform the NHS in England. The concept comprises a better remuneration for NHS dentists, financial incentives for practice foundations in underserved areas, new skill mix guidance, dental mobile facilities, better preventive programmes for toddlers, increasing dental workforce capacities and enhanced access to fluoridated water.[109] Nevertheless, the forecast for the future dental care spending up to 2040 is still a very moderate increase in the United Kingdom compared with most other high-income countries.[52]

As economic interventions cannot be expected to reduce the cost-intensity of the most expensive dental care system, that of Germany, the key for improving system efficiency lies on the outcome side. Here, dental decay, tooth loss and edentulism have been decreasing at a remarkable pace for the last two decades. This leads to substantially fewer restorations in younger adults.[33] As more teeth are retained and the German population rapidly ages, periodontal diseases will drastically increase, especially in adults >51 years by 2030.[110] These trends need to be addressed from the dental workforce side (increase in the number of dental hygienists) and from the statutory insurance side, where *supportive periodontal therapy* is currently not covered.[110] This is probably the main reason why the periodontal status of German´s elderly is less satisfactory, when compared with all of the other countries observed (Table 6). While, in the past, some countries have made systematic progress in adult periodontal status (SE, CH, JP, KR) this is only true for Germany´s younger adults.[110] The way forward could be to combine the current incentive for adults to visit the dentist regularly once a year (in form of a bonus in case of necessary prosthetic procedures), with an obligatory patient risk-assessment (as in Denmark). In addition, *supportive periodontal therapy* should be introduced into the health insurance benefit catalogue. This could serve to improve the periodontal status of older adults (>50 years) which is necessary, because in the second half of life more teeth are lost through periodontitis than through dental decay.[111]

Our findings rely solely on objectively measured indicators on both the benefit and the cost side. The one subjectively measured indicator *unmet need due to costs* was additionally included to measure the degree to which the vulnerable sections of the population are protected in the different systems. The main results of the study are in short:

i. In principle, good oral health has been achieved in each of the different dental care systems studied. However, with some advance, the national health system of Sweden and the social security system of Korea performed better than all other systems.

ii. All system-types have functioning regulations for protecting vulnerable groups. But here, too, a social security (KR) and a national health system (UK) perform best, although the Swiss and Australian systems show that mostly privately-financed systems can also effectively protect the needy. The reality in the private systems of the USA and Canada, however, does not meet this standard.

iii. With respect to necessary expenditure on dental care, the best results were achieved by a national health system (UK) and a privately-financed system (CH). The most cost-intensive system is Germany´s social security system.

iv. The highest system efficiency was observed in two national health systems (UK, SE) and in one social security system (KR). One privately-financed and one mixed private/public model (CH, AU) follow in fourth and fifth place. The least efficient dental care systems are Germany (social security model) and the private insurance systems of Canada and the USA.

v. Countries that regularly monitor the performance of dental provision, where systematic research on treatment quality and on evidence-based dental activities accompany the development of dental provision and where, if necessary, there is intervention in the form of legislation or guidelines, achieve better oral health outcomes and are more cost-effective (UK, SE, DK, JP, KR). This confirms the hypothesis formulated at the beginning of this paper.

This study has some limitations. Although, the newest available data were used, the DMFT value for Swiss middle-aged adults is from 1999. But this does not mean the value is wrong. At that time the value was already low and, therefore, does not distort the composite DHI for Switzerland. Also, in some countries no representative country-wide figures existed for caries-free 5/6-year old children, that´s why in these cases greater regional studies had to be used. The most relevant figures for our comparison, adolescents at age 12 and the elderly, are widely up-to-date, so that the comparison should mirror the current conditions.

Conclusion

In summary, it can be asserted that the oral health of the whole population of all of the advanced high-income dental systems studied, has improved considerably over the last decades. However, countries operating a national health model (SE) or a social security model (KR) performed best. With respect to system efficiency two national health systems (UK, SE) and one social security model (KR) achieved the best results. Across the variety of systems, models fostering preventive and tooth-retaining approaches for the entire population make faster progress in oral health status and are more cost-effective and system-efficient. A range between 5% and 6% of GDP turns out to be a good benchmark for cost-efficacy in advanced dental care models in high-income countries. Using this standard, Germany in particular, still possesses substantial economic reserves that could be exploited, although a slight improvement in cost-effectiveness has been observed over the last two decades.

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Conflicts of interest

The author declares that there is no conflict of interest.

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