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Cost savings in the Swiss healthcare system resulting from professional periodontal care

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SUMMARY

More than 740 million people worldwide are affected by periodontal disease and are at higher risk of secondary damage such as cardiovascular disease and type 2 diabetes, which place a considerable financial burden on healthcare systems. The aim of this study was to use a computer simulation to estimate the direct and indirect costs of prevention and treatment of gingivitis, periodontitis and related secondary damage in the Swiss population, paid both out of pocket (OOP) and from social welfare (SW).

For three different scenarios, iterations with 200,000 simulated individuals over their assumed life span of 35 to 100 years corresponded to a period of four months, in which an individual could move from one periodontal condition to the next, each associated with presumed direct and indirect treatment costs.

Appropriate diagnosis and adherence to professional periodontal care had a strong benefit saving up to CHF 5.94 billion OOP and CHF 1.03 billion SW costs for the current Swiss population. Considering direct and indirect health care costs, the total expected costs for a 35-year-old individual until death were CHF 17,310 with minimal care and CHF 15,606 with optimal care, resulting in savings of CHF 1,704.

In conclusion, early detection and appropriate treatment of periodontitis can help to reduce both overall costs of treating periodontitis and associated secondary damage, especially in the second half of life. These cost savings may further pay off on an individual level through regular supportive periodontal care, both for treatments paid out of pocket and those covered by social welfare.

Introduction

Periodontitis is an inflammatory disease of the soft and hard tissues surrounding the teeth, leading to the formation of gingival pockets, progressive loss of periodontal attachment and increasing tooth mobility. If left untreated, periodontitis results in premature tooth loss and dysfunctions of the masticatory system, which inevitably causes a significant impairment of the individual's quality of life (Buset et al. 2016; Wong et al. 2021). In its milder form, periodontitis affects 45–50% of the global population, while its severe form affects 11% (Kassebaum et al. 2014; Sanz et al. 2020). Severe periodontitis is the sixth most common non-communicable disease (NCD) in the world, affecting around 743 million people globally (Kassebaum et al. 2014). Moreover, there is strong scientific evidence linking periodontitis to major NCDs such as cardiovascular disease (CVD), type 2 diabetes and respiratory disease, which can therefore be considered as secondary damages of periodontitis (Gomes-Filho et al. 2020; Sanz et al. 2018, 2020). With the epidemiological transition from highly infectious, communicable diseases with high mortality rates to chronic NCDs with low mortality but high morbidity, societies face an increasingly ageing population with rising prevalence and incidence rates of chronic NCDs, placing a major burden on healthcare systems worldwide (Omran 2005).

Since 1995, Swiss healthcare spending in Switzerland has increased by an average of 3.7% per year and most recently amounted to 82.5 billion Swiss francs (CHF) in 2017 (FSO 2022a). By 2040, health spending could rise from CHF 82 billion to 155 billion, an increase of about 90% (Dorninger et al. 2022). According to the Swiss Federal Statistical Office, the costs for dentistry amounted to CHF 4,236 million in 2020, which corresponds to 5.1% of the total health expenditure in Switzerland (FSO 2022a). In a recent study, the direct costs of prevention and treatment as well as the indirect costs of periodontitis due to root caries, edentulism, or loss of productivity were estimated at 158.64 billion Euros in Europe in 2018 (Botelho et al. 2022).

Despite its high epidemiological and economic burden, periodontitis is largely preventable. With early diagnosis and appropriate treatment, periodontitis can be managed in the long-term through individual supportive periodontal care, continued adequate oral hygiene, and reduction of risk factors. The comorbid relationship between periodontitis and NCDs such as CVD and type 2 diabetes provides a unique opportunity for policymakers and health organisations to re-evaluate their public health approach to the prevention, treatment and management of periodontitis in order to reduce complications and negative outcomes associated with NCDs, thereby reducing rising global healthcare costs (Sanz et al. 2018, 2020).

Currently, there are no nationwide data on the cost-effectiveness of gingivitis and periodontitis treatment and its impact on healthcare costs in Switzerland. The aim of this study was therefore to evaluate the direct and indirect costs of the treatment of gingivitis, periodontitis, and their secondary damage for the Swiss healthcare system across the population. A simulation model was used to investigate the question of whether or not the treatment of periodontal diseases by professional periodontal care reduces healthcare costs in the Swiss population. This simulation was based on an economic profitability model previously published by the European Federation of Periodontology (EFP) (Time to take gum disease seriously, The Economist Intelligence Unit Limited 2021), in which cost assessments were carried out to estimate the financial impact of treating (or not treating) gingivitis and periodontitis on dental treatment costs in six European countries (Chapple et al. 2021).

Materials and methods

This simulation was based on the economic return on investment model previously published by the European Federation of Periodontology (EFP) (Chapple et al. 2021). For the purpose of the present study, their model was adapted with some extensions and refinements. With reference to Chapple and co-workers, three types of periodontitis were used in the simulation: mild (type I), moderate (type II), and severe (type III) (Chapple et al. 2021). In essence, the present simulation estimated the lifetime healthcare costs of Swiss citizens until their death, cumulating the total costs of treating periodontal diseases and their secondary damage such as CVD and type 2 diabetes. In alignment with Chapple and co-workers, each iteration of the simulation corresponded to a 4-month period, in which an individual could move from one condition to another, each associated with assumed primary and secondary damage costs (Chapple et al. 2021). However, in contrast to Chapple and colleagues, in this simulation the transition probabilities from one condition to another were not estimated on the basis of expert knowledge but were derived from assumptions about general prevalences in the Swiss population (Chapple et al. 2021; Kassebaum et al. 2014; Schürch et al. 2015; Schürch & Lang 2004).

Demographic assumptions

The age of all simulated individuals ranged from 35 to 100 years. As in Chapple and co-workers, it was assumed that individuals under 35 years of age did not need treatment for periodontal diseases and did not have any secondary damage from NCDs such as CVD or type 2 diabetes (Chapple et al. 2021). The simulated individuals were categorised as either younger (35–64 years) or older (65–100 years). The only difference between the two groups was the prevalence of periodontal disease, which was assumed to be higher in the 65- to 100-year-old group than in the 35- to 64-year-old group. The probability of developing periodontitis was thus not modelled continuously across age but shifted to some extent when the simulated individuals reached the age of 65. The gender of the simulated individuals played a minor role, as it was assumed for simplicity that the proportion of men and women was the same in all age groups from 35 to 100 years and that gender, apart from a difference in life expectancy, had no influence on the simulation outcome of an individual.

The mortality probabilities for the age groups 35–100 for men and women were taken from the Federal Statistical Office (FSO) from 2019 (before the COVID-19 pandemic) (FSO 2021b). For simplicity, it was assumed that simulated individuals could not reach an age higher than 100, i.e., their death was automatically assumed when they reached the age of 101. For the calculation of the total costs in the Swiss population aged 35 to 100 years, the population distributions by age from the FSO (2019, pre-COVID) were again used (FSO 2021a).

Disease states and treatment steps

Most of the so-called disease states included in this simulation were adopted and expanded from Chapple and co-workers, including their special characteristics and costs (Chapple et al. 2021). Additionally, in alignment with Chapple and co-workers, a total of four treatment steps were adopted (Chapple et al. 2021). They included a) preparation for periodontal therapy with oral

hygiene instructions and risk factor control (step 1), b) initial periodontal therapy with professional debridement of biofilm and calculus (step 2), c) corrective periodontal surgery (step 3), and d) supportive periodontal care at personalised intervals (step 4) (Chapple et al. 2021).

The disease states and their respective treatment steps were assigned to two so-called cycles and one intermediate triage:

- The healthy-gingivitis cycle (HG-cycle) included the following disease states:
  - Healthy
  - Undiagnosed gingivitis
  - Managed gingivitis
  - Periodontitis: the individual progressed to the periodontitis triage in the simulation
- The periodontitis triage (P-triage) included the following disease states and respective treatment steps:
  - Periodontitis type I or III: the individual was excluded from the simulation
  - Periodontitis type II: the individual progressed in the simulation with one of the following new disease states from the periodontitis cycle:
    - Undiagnosed periodontitis
    - Managed periodontitis with:
      - Treatment step 1: preparation for periodontal therapy
    - Unmanaged periodontitis (irreversible disease state)
- The periodontitis cycle (P-cycle) included the following disease states and respective treatment steps:
  - Undiagnosed periodontitis
  - Managed periodontitis with:
    - Treatment step 1: preparation for periodontal therapy
    - Treatment step 2: initial periodontal therapy
    - Treatment step 3: corrective periodontal surgery
    - Treatment step 4: supportive periodontal care
  - Unmanaged periodontitis (irreversible disease state)

Typically, simulated individuals started in the HG-cycle where they were either healthy or had gingivitis (Fig. 1). In some cases, gingivitis progressed to periodontitis, which was considered irreversible. Once individuals reached this state, they could not return to the other states in the HG-cycle. When periodontitis was simulated in individuals, a triage was performed to determine if the individuals had type II periodontitis and continued in this simulation, or they were excluded with type I or III periodontitis (Fig. 2). If the individuals had type II periodontitis, they entered the P-cycle where they were either undiagnosed, treated or not treated (Fig. 3). Again, as in Chapple and co-workers, the untreated condition was assumed to be irreversible (Chapple et al. 2021).

Scenarios and prevalences

As presented in Table I, a total of three scenarios were simulated with the respective prevalences for the age groups 35–64 (younger) and 65–100 (older):

- **Scenario 1:** The present situation in Switzerland was assumed, with prevalences for gingivitis of 60%/40% (younger/older) and prevalences for periodontitis of 20%/40% (all types) and 10%/20% (type 2). Furthermore, it was presumed that a single individual in the HG-cycle spends CHF 150 per year for a dental hygiene (DH) appointment (= 1 appointment per year).
- **Scenario 2:** It was assumed that a single individual in the gingivitis state spends up to CHF 300 per year on DH appointments (= 2 appointments per year), and up to CHF 150 in the healthy state. This improvement reduces the prevalence rates for gingivitis and periodontitis (all types) drop to 50%/40% (younger/older) and 10%/20%, respectively.
- **Scenario 3:** It was assumed that a single individual spends up to CHF 300 per year on DH appointments (= 2 appointments per year) when in one of the gingivitis states and up to CHF 150 when in a healthy state. In addition, in this scenario,

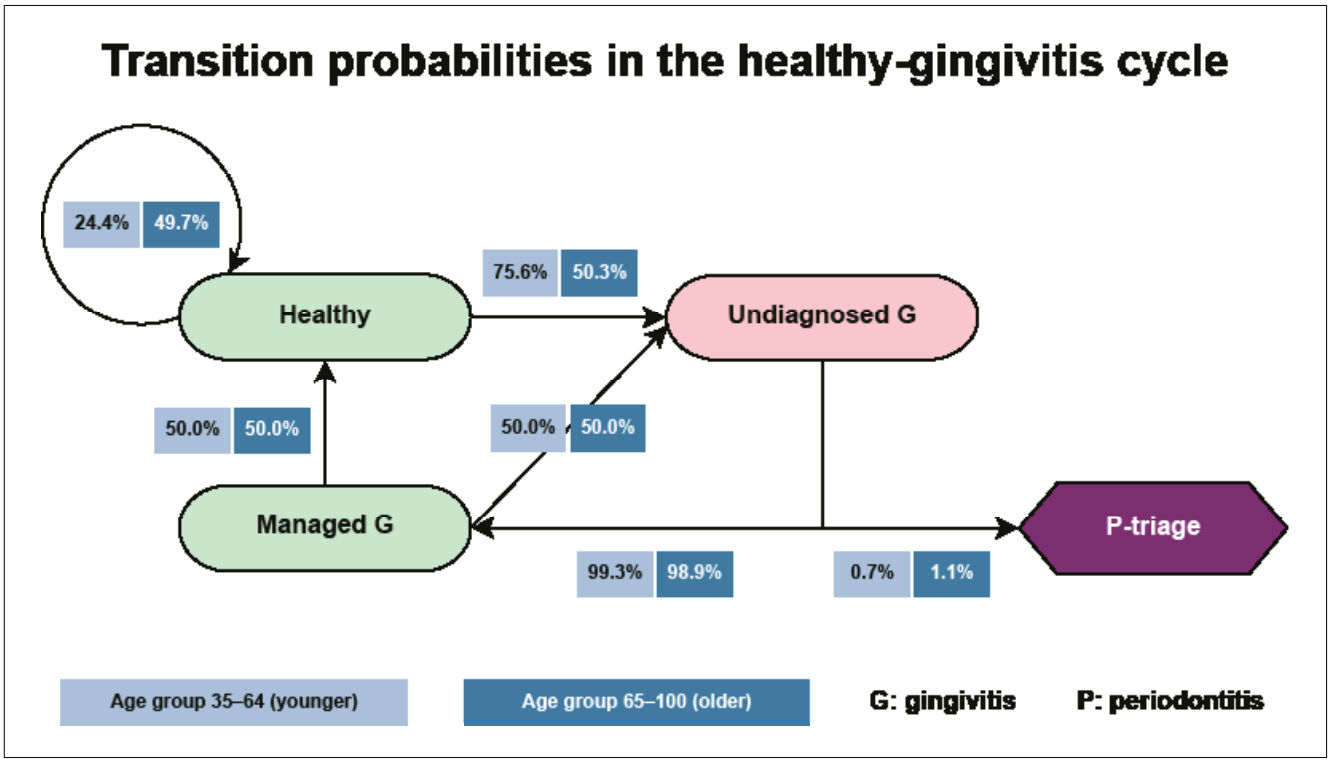

Fig. 1 Transition probabilities in the HG-cycle for both age groups 35–64 and 65–100 in scenario 1

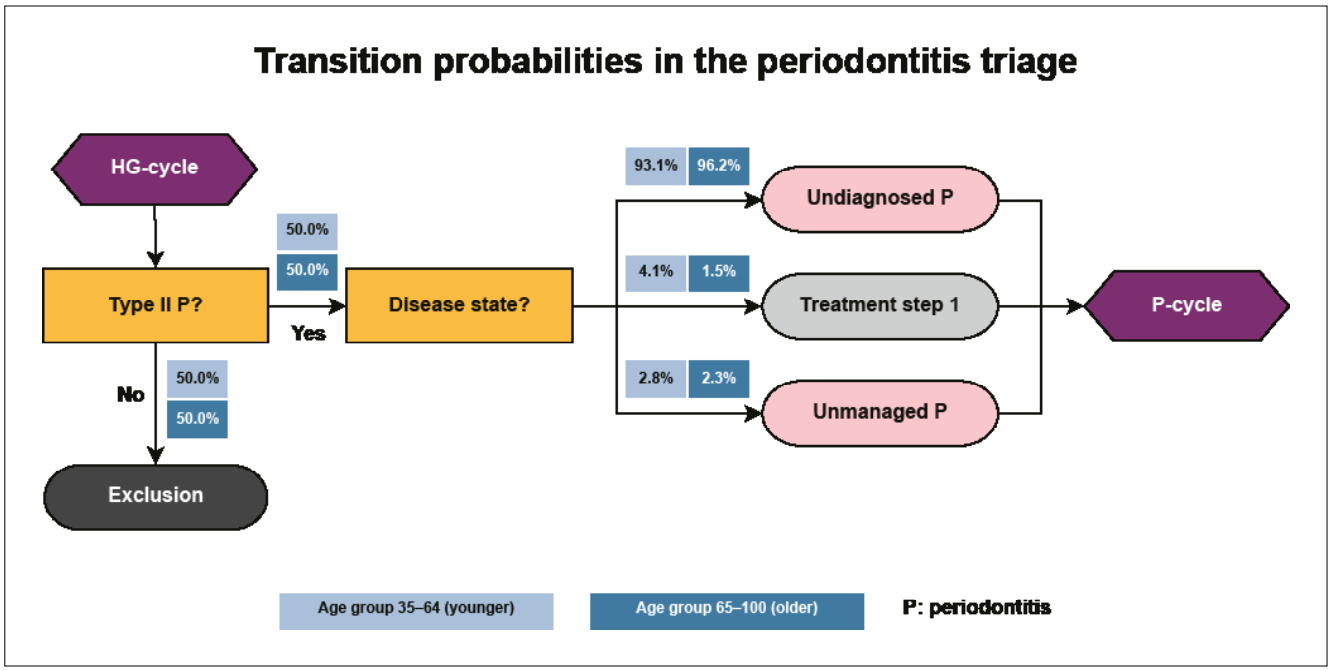

Fig. 2 Transition probabilities in the P-triage for both age groups 35–64 and 65–100 in scenario 1. HG: healthy-gingivitis

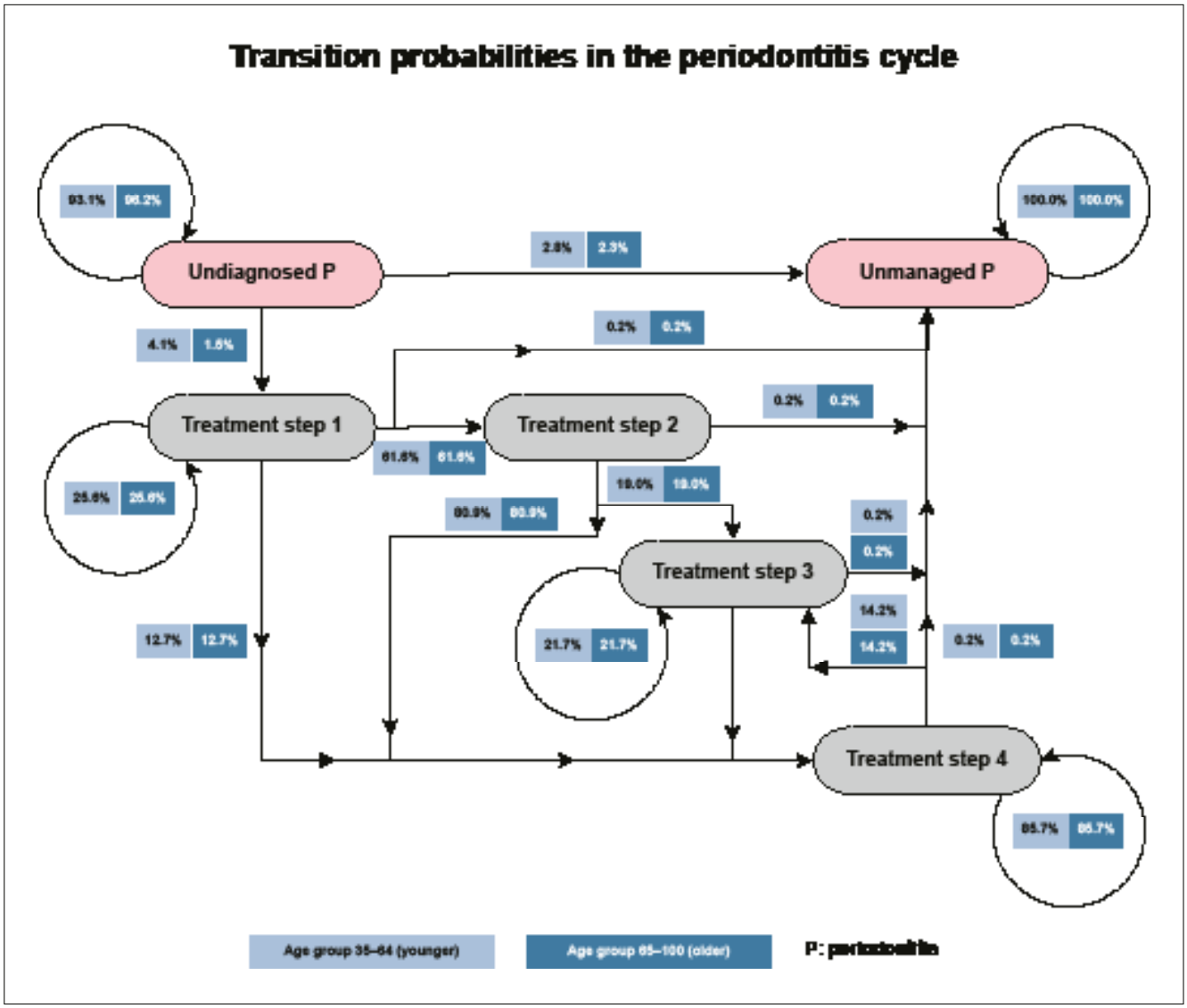

Fig. 3 Transition probabilities in the P-cycle for both age groups 35–64 and 65–100 in scenario 1

Tab. I Group and population prevalences assumed in the simulation for all scenarios

	Disease state	Group prevalence			Population prevalence			Calculations	
		Scenario 1 (%)	Scenario 2 (%)	Scenario 3 (%)	Scenario 1 (%)	Scenario 2 (%)	Scenario 3 (%)	Formula	Example
HG-cycle and P-triage									
Age 35–64 years	Periodontitis types I–III	20 (a_1)	10	10	20	10	10		
	thereof periodontitis type II	50 (a_2)	50	50	10 (a_3)	5	5	$a_1 * a_2 = a_3$	10% = 20% * 50%
	No periodontitis								
	Gingivitis	75 (b_1)	55.6	44.4	60 (b_2)	50	40	$b_1 * (100\% - a_1) = b_2$	75% * 80% = 60%
	Healthy	25 (c_1)	44.4	55.6	20 (c_2)	40	50	$c_1 * (100\% - a_1) = c_2$	25% * 80% = 20%
Age 65–100 years	Periodontitis types I–III	40 (d_1)	20	20	40	20	20		
	thereof periodontitis type II	50 (d_2)	50	50	20 (d_3)	10	10	$d_1 * d_2 = d_3$	40% * 50% = 20%
	No periodontitis								
	Gingivitis	66.7 (e_1)	50	37.5	40	40	30	$e_1 * (100\% - d_1) = e_2$	66.7% * 60% = 40%
	Healthy	33.3 (f_1)	50	62.5	20 (f_2)	40	50	$f_1 * (100\% - d_1) = f_2$	33.3% * 60% = 20%
P-cycle									
Age 35–64 years	Periodontitis type II								
	managed periodontitis	70 (g_1)	70	70	7 (g_2)	3.5	3.5	$a_3 * g_1 = g_2$	10% * 70% = 7%
	thereof undiagnosed periodontitis	20 (h_1)	20	20	1.4 (h_2)	0.7	0.7	$a_3 * g_1 * h_1 = h_2$	10% * 70% * 20% = 1.4%
	thereof treatment steps 1–3	13.3 (i_1)	13.3	13.3	0.9 (i_2)	0.45	0.45	$a_3 * g_1 * i_1 = i_2$	10% * 70% * 13.3% = 0.9%
	thereof treatment step 4	66.7 (j_1)	66.7	66.7	4.7 (j_2)	2.35	2.36	$a_3 * g_1 * j_1 = j_2$	10% * 70% * 66.7% = 4.7%
	unmanaged periodontitis	30 (k_1)	30	30	3 (k_2)	1.5	1.5	$a_3 * k_1 = k_2$	10% * 30% = 3%
Age 65–100 years	Periodontitis type II								
	managed periodontitis	70 (l_1)	70	70	14 (l_2)	7	7	$d_3 * l_1 = l_2$	20% * 70% = 14%
	thereof undiagnosed periodontitis	20 (m_1)	20	20	2.8 (m_2)	1.4	1.4	$d_3 * l_1 * h_1 = m_2$	20% * 70% * 20% = 2.8%
	thereof treatment steps 1–3	13.3 (n_1)	13.3	13.3	1.8 (n_2)	0.9	0.9	$d_3 * l_1 * i_1 = n_2$	20% * 70% * 13.3% = 1.8%
	thereof treatment step 4	66.7 (o_1)	66.7	66.7	9.4 (o_2)	4.7	4.7	$d_3 * l_1 * j_1 = o_2$	20% * 70% * 66.7% = 9.4%
	unmanaged periodontitis	30 (p_1)	30	30	6 (p_2)	3	3	$d_3 * p_1 = p_2$	20% * 30% = 6%

The letters in brackets in the columns of scenario 1 illustrate the use of the respective parameters in the calculation of the prevalences in the population.

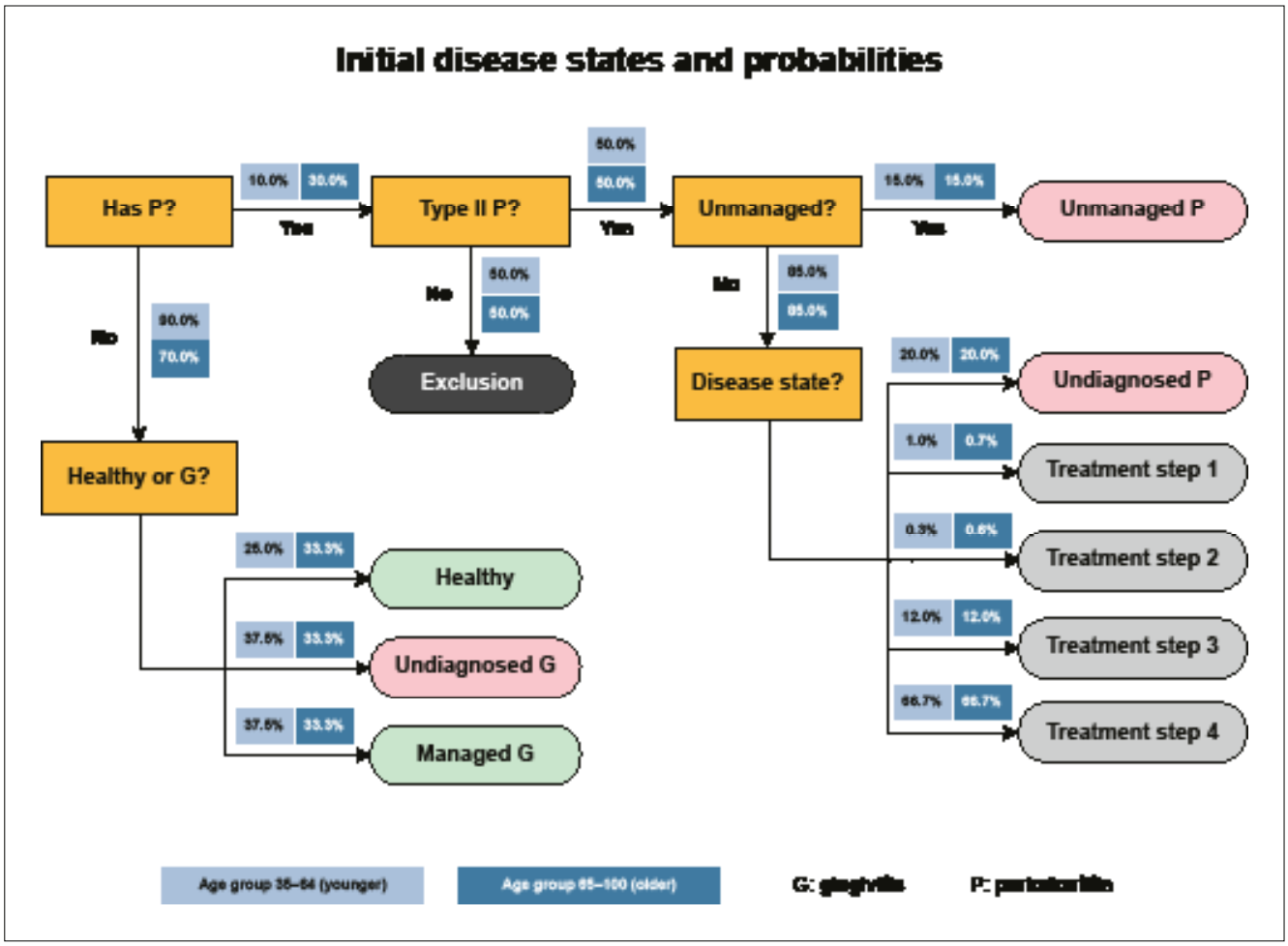

Fig. 4 Probabilities for starting in a particular disease state for both age groups 35–64 and 65–100 in scenario 1

individuals are better informed about the disease and its prevention. These improvements have again reduced the prevalence rates for gingivitis and periodontitis (all types) to 40%/30% (younger/older) and 10%/20%, respectively.

For all age groups in the P-cycle, the group prevalences were 70%/30% (younger/older) for treated and untreated periodontitis, respectively. Of those treated, 20% were undiagnosed, 13.4% were at treatment step 1 to 3 and 66.6% were at treatment step 4 (Tab. I). Note that the prevalences in this simulation were not considered as the "proportion of the population with the disease", but on an individual level as the "probability of getting the disease by the age of 65 or before death". Moreover, standard treatment was assumed in all scenarios, with all treatment steps, including possible periodontal surgery, performed when indicated.

Initial disease states

Initial states of periodontal disease were chosen according to the prevalences in each scenario. Figure 4 illustrates the initial states for scenario 1 for the age groups 35–64 and 65–100.

For the irreversible disease states "periodontitis", "periodontitis type I or III" and "untreated periodontitis", it was assumed for scenario 1 that the probabilities of onset of these states for the 35–64 age group were 10%, 5% and 15% and for the 65–100 age group 30%, 15% and 15%. The rational for this approach was that in this simulation, young individuals had a 5% chance of developing type II periodontitis and a further 5% chance of developing new periodontitis by the time they reached the age of 65. On the other hand, if the simulated individuals already had an increased age of onset of 68 years, they already had type II periodontitis with a 15% probability (10% by their 65th birthday plus 5% group onset probability) and if not, these individuals had another 5% to get the disease by the time they died. Thus, either individuals started with periodontal disease or became diseased during the simulation with a 5% probability in both age groups. For scenarios 2 and 3, the initial probabilities for these states were halved (Fig. 4). For simplicity, it was assumed that in this simulation, the initial disease states related to gingivitis always had the same probability.

Finally, initial values for the treatment steps 1 to 3 were chosen according to the transition probabilities described below so that they formed a stable state over time. Randomly selected individuals in the 35–64 age group presenting with type II periodontitis should remain stable at any point in the simulation until they were 65 years old. The same applied to randomly selected individuals aged 65–100 years until their death.

Transition probabilities

The transition probabilities for individual disease states in scenario 1 are shown in Figures 1 to 3. The transition probabilities were chosen so that for a randomly selected individual aged 35–64 years, the probability of being in a given state by the age of 64.99 years corresponded to the prevalences specified in the

Tab. II Direct and indirect secondary damage costs assumed in the simulation for all scenarios

	Disease state	Out-of-pocket costs (4 months)			Social welfare funded costs (4 months)		
		Scenario 1 (CHF)	Scenario 2 (CHF)	Scenario 3 (CHF)	Scenario 1 (CHF)	Scenario 2 (CHF)	Scenario 3 (CHF)
Direct costs							
	Healthy	50	50	50	40	40	40
	Gingivitis	50	100	100	40	80	80
	Periodontitis						
	Undiagnosed	0	0	0	0	0	0
	Treatment step 1	1,200	1,200	1,200	600	600	600
	Treatment step 2	2,500	2,500	2,500	800	800	800
	Treatment step 3	3,000	3,000	3,000	1,000	1,000	1,000
	Treatment step 4	150	150	150	120	120	120
	Unmanaged periodontitis	0	0	0	0	0	0
Indirect secondary damage costs							
	Healthy	0	0	0	0	0	0
	Gingivitis	20	20	20	15	15	15
	Periodontitis						
	Undiagnosed	150	150	150	120	120	120
	Treatment step 1	150	150	150	120	120	120
	Treatment step 2	150	150	150	120	120	120
	Treatment step 3	150	150	150	120	120	120
	Treatment step 4	150	150	150	120	120	120
	Unmanaged periodontitis	250	250	250	200	200	200

respective description of the scenarios above (in both the HG- and the P-cycle). The same applied to randomly selected individuals aged 65–100 until death.

The transition probabilities presented here thus imply a steady-state distribution in which the prevalences (on average) are fulfilled for an individual of each age group at each point in time of the simulation. The prevalences have therefore not changed during the entire life span of a simulated individual.

Note that for some disease states in the P-cycle it was impossible to move directly to another state, i.e., the transition probabilities were 0. These cases corresponded to those in Chapple and co-workers (Chapple et al. 2021).

Direct costs due to gingivitis and periodontitis

Table II presents the out-of-pocket and social welfare funded costs directly related to the treatment of periodontitis type II for each scenario. Out-of-pocket and social welfare funded costs were estimated assuming that Swiss citizens, even in good health, spend around CHF 150 per year (= 1 dental visit) today (scenario 1) and that they are willing to double their spending on gingivitis and periodontitis prevention to CHF 300 per year (= 2 dental visits) (scenarios 2 and 3). The costs for periodontitis treatment were estimated mean values for the treatments in the respective treatment steps (Tab. II).

Indirect costs due to secondary damage

All estimated indirect costs due to secondary damage from NCDs are presented in Table II. In this simulation, these additional costs were taken into account if the simulated individuals were in one of the P-cycle disease states or suffered from gingivitis. For individuals suffering from periodontitis, additional average costs of CHF 500 per year and individual were estimated, resulting in costs of between CHF 150 and CHF 250 per P-cycle disease state (out of pocket).

Simulation and statistical analysis

The simulation and its statistical analyses were performed with RStudio (version 1.4.1106, RStudio Team [2020], RStudio: Integrated Development Environment for R. RStudio, PBC, Boston, MA, URL www.rstudio.com). Means and percentages were calculated using descriptive statistics. For each age category (35–100), n = 200,000 samples were simulated to ensure that means and quantiles are accurately estimated.

Results

Total costs by scenario and source of funds

Figure 5 illustrates the expected mean total costs for the treatment of gingivitis, periodontitis, and associated secondary damage for each of the three scenarios, paid out of pocket and

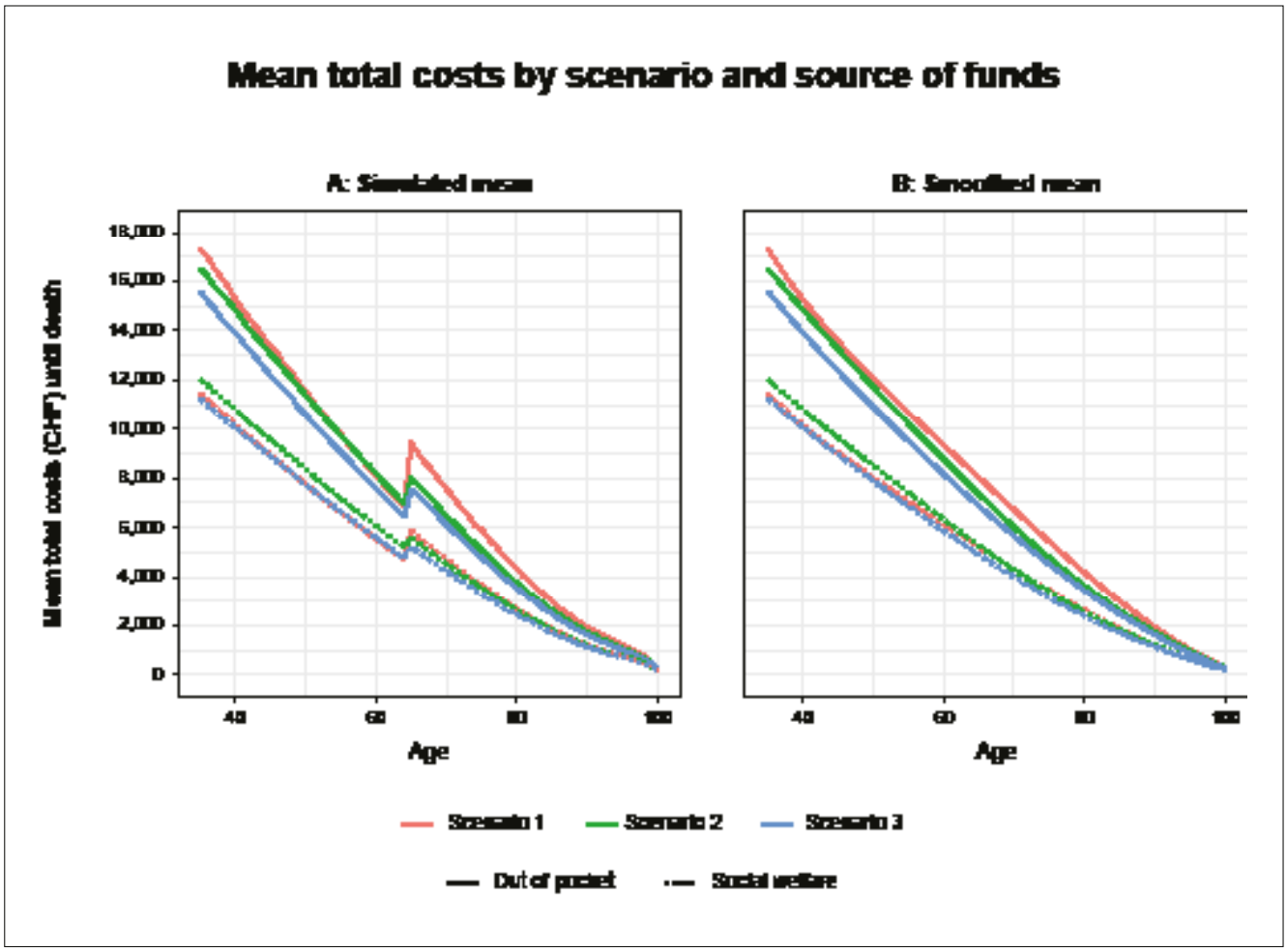

Fig. 5 Average expected total costs in CHF paid at a given age until death, by scenario and source of funds (out of pocket, social welfare). A: simulated curve, B: smoothed curve

from social welfare for a Swiss citizen aged 35 to 100 years. Figure 5-A reveals the mean costs with a leap at age 65, as in this simulation the prevalences change at that point. Figure 5-B shows a smoothed curve assuming that the simulated curve is correct below age 40 and above age 85.

The corresponding values from Figure 5 are presented in Table III (simulated values) and Table IV (smoothed values). For the out-of-pocket costs, it can be noted that the highest average amounts are obtained for scenario 1, followed by scenario 2 and scenario 3, which has the lowest expected total costs for

Tab. III Simulated expected average and annual per capita treatment costs at a given age until death, paid out of pocket and from social welfare for all scenarios and respective age group

Scenario	Type of disease	Age	Average OOP costs (simulated)	Annual OOP costs (simulated)	Average SW costs (simulated)	Annual SW costs (simulated)
1	Total	35	17,310	351	11,452	232
	Gingivitis		5,537	112	4,429	90
	Periodontitis		6,302	128	2,726	55
	Secondary damage		5,471	111	4,297	87
	Total	50	11,559	332	7,765	223
	Gingivitis		4,127	118	3,302	95
	Periodontitis		3,871	111	1,673	48
	Secondary damage		3,561	102	2,790	80

OOP: out-of-pocket, SW: social welfare

Tab. III Simulated expected average and annual per capita treatment costs at a given age until death, paid out of pocket and from social welfare for all scenarios and respective age group

continued

Scenario	Type of disease	Age	Average OOP costs (simulated)	Annual OOP costs (simulated)	Average SW costs (simulated)	Annual SW costs (simulated)
1	Total	65	9,456	442	5,891	276
	Gingivitis		2,076	97	1,661	78
	Periodontitis		4,487	210	1,944	91
	Secondary damage		2,893	135	2,286	107
	Total	80	4,348	445	2,717	278
	Gingivitis		1,059	108	847	87
	Periodontitis		2,036	208	881	90
	Secondary damage		1,252	128	988	101
2	Total	35	16,518	333	12,013	242
	Gingivitis		10,118	204	8,095	163
	Periodontitis		3,078	62	1,332	27
	Secondary damage		3,321	67	2,586	52
	Total	50	11,375	324	8,362	238
	Gingivitis		7,332	209	5,866	167
	Periodontitis		1,871	53	809	23
	Secondary damage		2,172	62	1,687	48
	Total	65	8,026	373	5,585	260
	Gingivitis		4,107	191	3,286	153
	Periodontitis		2,204	102	955	44
	Secondary damage		1,715	80	1,345	62
	Total	80	3,761	383	2,630	268
	Gingivitis		2,024	206	1,620	165
	Periodontitis		995	101	431	44
	Secondary damage		741	76	580	59
3	Total	35	15,606	315	11,250	227
	Gingivitis		9,283	187	7,427	150
	Periodontitis		3,214	65	1,391	28
	Secondary damage		3,109	63	2,433	49
	Total	50	10,574	301	7,729	220
	Gingivitis		6,724	192	5,379	153
	Periodontitis		1,882	54	814	23
	Secondary damage		1,968	56	1,535	44
	Total	65	7,570	352	5,217	243
	Gingivitis		3,751	174	3,001	140
	Periodontitis		2,231	104	966	45
	Secondary damage		1,588	74	1,250	58

OOP: out-of-pocket, SW: social welfare

Tab. III Simulated expected average and annual per capita treatment costs at a given age until death, paid out of pocket and from social welfare for all scenarios and respective age group

continued

Scenario	Type of disease	Age	Average OOP costs (simulated)	Annual OOP costs (simulated)	Average SW costs (simulated)	Annual SW costs (simulated)
3	Total	80	3,531	359	2,451	249
	Gingivitis		1,854	188	1,483	151
	Periodontitis		991	101	429	44
	Secondary damage		686	70	539	55

OOP: out-of-pocket, SW: social welfare

Tab. IV Smoothed expected average and annual per capita treatment costs at a given age until death, paid out of pocket and from social welfare for all scenarios and respective age group

Scenario	Type of disease	Age	Average OOP costs (smoothed)	Annual OOP costs (smoothed)	Average SW costs (smoothed)	Annual SW costs (smoothed)
1	Total	35	17,310	351	11,452	232
	Gingivitis		5,537	112	4,429	90
	Periodontitis		6,302	128	2,726	55
	Secondary damage		5,471	111	4,297	87
	Total	50	12,063	346	8,027	230
	Gingivitis		4,039	116	3,231	93
	Periodontitis		4,270	123	1,849	53
	Secondary damage		3,753	108	2,946	85
	Total	65	8,034	376	5,219	244
	Gingivitis		2,366	111	1,893	89
	Periodontitis		3,207	150	1,388	65
	Secondary damage		2,461	115	1,938	91
	Total	80	4,193	429	2,638	270
	Gingivitis		1,064	109	851	87
	Periodontitis		1,914	196	828	85
	Secondary damage		1,216	124	959	98
2	Total	35	16,518	333	12,013	242
	Gingivitis		10,118	204	8,095	163
	Periodontitis		3,078	62	1,332	27
	Secondary damage		3,321	67	2,586	52
	Total	50	11,717	333	8,526	243
	Gingivitis		7,236	206	5,789	165
	Periodontitis		2,168	62	936	27
	Secondary damage		2,313	66	1,801	51
	Total	65	7,362	342	5,291	246
	Gingivitis		4,343	202	3,474	161
	Periodontitis		1,552	72	672	31
	Secondary damage		1,467	68	1,145	53

OOP: out-of-pocket, SW: social welfare

Tab. IV Smoothed expected average and annual per capita treatment costs at a given age until death, paid out of pocket and from social welfare for all scenarios and respective age group

continued

Scenario	Type of disease	Age	Average OOP costs (smoothed)	Annual OOP costs (smoothed)	Average SW costs (smoothed)	Annual SW costs (smoothed)
	Total	80	3,653	372	2,572	262
	Gingivitis		2,008	205	1,606	164
	Periodontitis		924	94	402	41
	Secondary damage		722	74	564	57
3	Total	35	15,606	315	11,250	227
	Gingivitis		9,283	187	7,427	150
	Periodontitis		3,214	65	1,391	28
	Secondary damage		3,109	63	2,433	49
	Total	50	10,899	311	7,890	225
	Gingivitis		6,639	189	5,311	151
	Periodontitis		2,153	61	931	27
	Secondary damage		2,107	60	1,647	47
	Total	65	6,885	320	4,906	228
	Gingivitis		3,968	185	3,174	148
	Periodontitis		1,579	73	683	32
	Secondary damage		1,338	62	1,049	49
	Total	80	3,454	351	2,400	244
	Gingivitis		1,840	187	1,472	150
	Periodontitis		961	98	415	42
	Secondary damage		654	66	513	52

OOP: out-of-pocket, SW: social welfare

all age groups (smoothed curve). The expected total costs for a 35-year-old individual until death are thus CHF 17,310 for scenario 1, CHF 16,518 for scenario 2 and CHF 15,606 for scenario 3, respectively (Tab. III and IV). Since life expectancy at this age is 84.4 years, the average costs per year can be roughly estimated by dividing by 49.4 resulting in average costs of CHF 351, 333 and 315 per year for scenarios 1, 2 and 3 for a 35-year-old individual (Tab. III and IV). The expected total costs until death for a 65-year-old individual are CHF 8,034, 7,362 and 6,885 for scenarios 1 to 3 (smoothed curve). Since an individual of this age has on average about 21.4 years to live, the average annual costs for the three scenarios are CHF 376, 342 and 320, respectively (Tab. IV).

Looking at costs paid by social welfare, a slightly different picture emerges, as here the highest average amounts were generated for scenario 2, followed by scenario 1 up to the age of 69 (smoothed curve). Both curves cross from this age, so that the order then becomes the same as for out-of-pocket costs from the age of 70 (Fig. 5). The expected mean total costs are CHF 11,452 (232 per year), 12,013 (242 per year) and CHF 11,250 (227 per year) for a 35-year-old individual (smoothed curve) and CHF 5,219 (244 per year), 5,291 (246 per year) and 4,906 (228 per year) for a 65-year-old individual for the scenarios 1, 2 and 3, respectively (Tab. IV).

Total costs by type of treatment

Breaking the total costs down into the respective costs of treating gingivitis, periodontitis, and secondary damage, it can be noted that out-of-pocket costs and the costs paid by social welfare for the treatment of periodontitis and secondary damage account for more than 60% of all expected lifetime costs in scenario 1 (Fig. 6-A, 6-B). In scenarios 2 and 3, the costs of treating periodontitis and secondary damage are halved as the prevalence of periodontitis is approximately halved and thus the costs of gingivitis treatment increase significantly, accounting for up to 60% (out-of-pocket) and about 66% (social welfare) of all costs (Fig. 6-A, 6-B).

Return on investment

Since all information on the costs until the death of a single individual of a certain age was simulated for each of the three scenarios, it was possible to estimate the total costs in Switzerland, taking into account all 5.23 million Swiss citizens aged 35 to 100 (2019 data, pre-COVID). Assuming for simplicity that the population size and life expectancy remain stable over the next 65 years and that the costs would be paid entirely out of pocket or by social welfare, the totals of all scenarios will be comparable, so that a return on investment could be calculated.

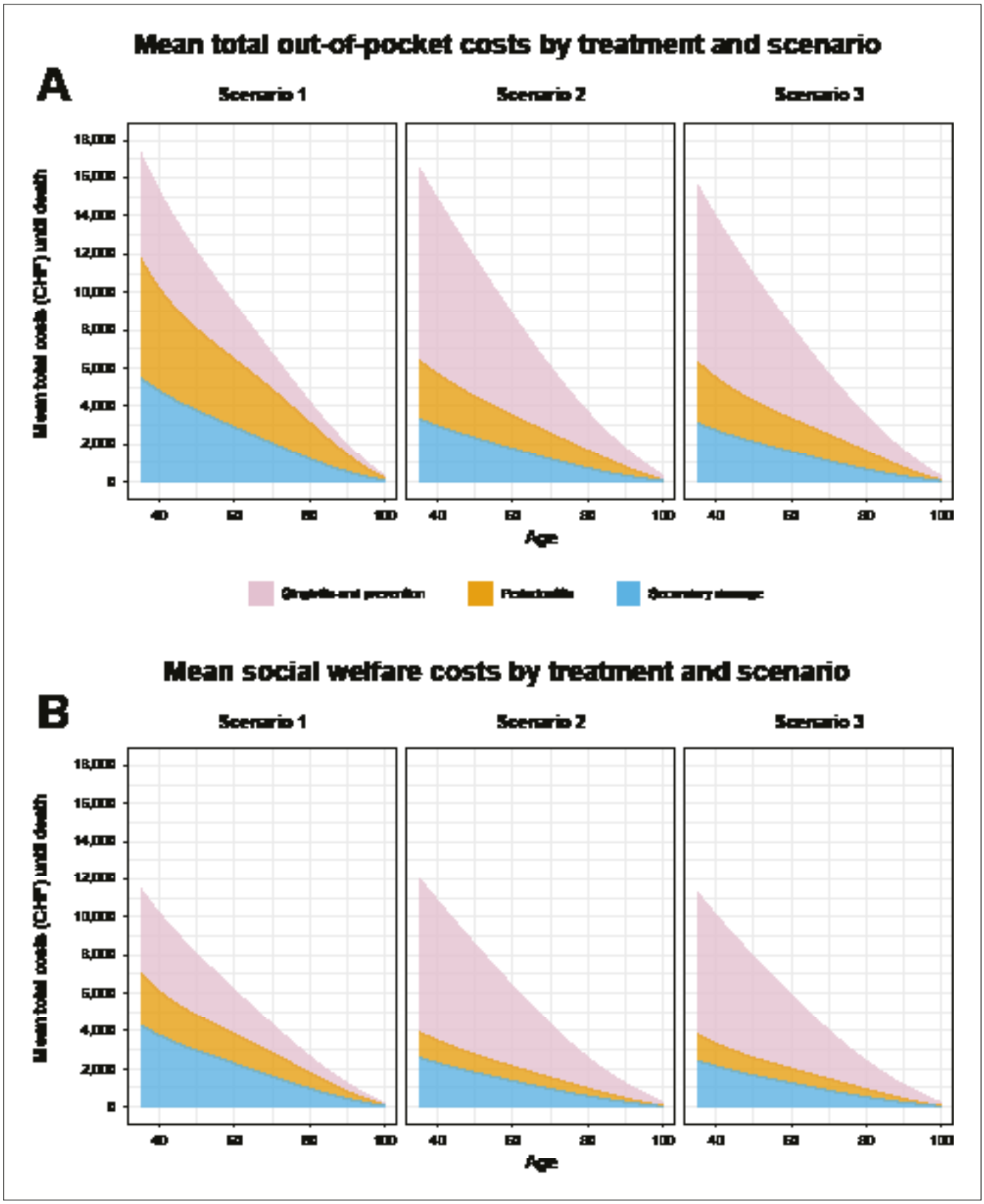

Fig. 6 Average expected total costs in CHF (smoothed curve) paid at a given age until death, by scenario and treatment measures for gingivitis and prevention, periodontitis and secondary damage. A: out-of-pocket costs, B: social welfare costs

Table V shows the expected mean out-of-pocket and out-of-social-welfare expenditure for the treatment of gingivitis, periodontitis and secondary damage for the current Swiss population aged 35 to 100 years and for each scenario. It can be noted that the total out-of-pocket costs (smoothed) for the 5.23 million Swiss citizens between 35 and 100 years of age are 53.89 billion, 51.28 billion and 47.95 billion for the scenarios 1 to 3, respectively. This corresponds to a ROI of 2.61 billion for scenario 2 and a ROI of 5.94 billion for scenario 3 (Tab. VI). Thus, individuals can save on average up to

Tab. V Expected mean costs (CHF) out of pocket and paid by social welfare for the current Swiss population (2019) from the age of 35 until death

Scenario	Type of disease	Costs OOP (simulated)	Costs OOP (smoothed)	Costs SW (simulated)	Costs SW (smoothed)
1	Total	52,761,527,508	53,892,044,970	34,955,800,973	35,526,674,176
	Gingivitis	17,426,351,604	17,193,382,906	13,941,080,818	13,754,717,067
	Periodontitis	16,256,368,121	16,685,139,209	12,760,730,353	13,108,488,190
	Secondary damage	19,078,800,611	20,013,486,432	8,253,984,852	8,663,455,450
2	Total	50,645,189,366	51,277,081,989	36,856,576,403	37,147,099,056
	Gingivitis	31,387,133,200	31,141,400,525	25,109,704,059	24,913,107,121
	Periodontitis	9,881,113,767	10,174,218,220	7,689,942,313	7,926,835,925
	Secondary damage	9,376,944,230	9,961,461,792	4,056,923,881	4,307,123,733
3	Total	47,335,353,347	47,954,424,450	34,212,905,307	34,497,051,749
	Gingivitis	28,794,917,329	28,555,998,706	23,035,932,958	22,844,807,727
	Periodontitis	9,039,920,584	9,316,621,725	7,067,192,872	7,290,851,874
	Secondary damage	9,500,512,497	10,081,789,251	4,109,776,035	4,361,401,758

OOP: out-of-pocket, SW: social welfare

Tab. VI Return on investment (CHF) comparing scenarios 2 and 3 with scenario 1

Scenario	Type of disease	ROI OOP (simulated)	ROI OOP (smoothed)	ROI SW (simulated)	ROI SW (smoothed)
2	Total	-2,116,338,142	-2,614,962,981	1,900,775,430	1,620,424,880
	Gingivitis	13,960,781,596	13,948,017,619	11,168,623,241	11,158,390,054
	Periodontitis	-6,375,254,354	-6,510,920,989	-5,070,788,040	-5,181,652,265
	Secondary damage	-9,701,856,381	-10,052,024,640	-4,197,060,971	-4,356,331,717
3	Total	-5,426,174,161	-5,937,620,520	-742,895,666	-1,029,622,427
	Gingivitis	11,368,565,725	11,362,615,800	9,094,852,140	9,090,090,660
	Periodontitis	-7,216,447,537	-7,368,517,484	-5,693,537,481	-5,817,636,316
	Secondary damage	-9,578,288,114	-9,931,697,181	-4,144,208,817	-4,302,053,692

OOP: out-of-pocket, SW: social welfare

CHF 500 (CHF 2.61 billion for 5.23 million citizens) in scenario 2 and more than 1,100 (CHF 5.94 billion over 5.23 million citizens) in scenario 3 over their lifetime. Regarding the total costs paid out of social welfare, the differences are smaller and scenario 2 even has a negative ROI: Table VI presents a ROI of -1.62 billion for scenario 2 and a ROI of 1.03 billion for scenario 3 (smoothed, total costs). Overall, this may not be surprising, as it can be noted that scenario 2 has higher expected costs up to the age of 70.

As previously mentioned, the expected total costs for a 35-year-old individual until death are CHF 17,310 for scenario 1 (Tab. IV). Appropriate diagnosis and adherence to professional periodontal care on an individual level, as assumed in scenario 3, can reduce the total costs by about CHF 1,700 to CHF 15,606 (Tab. IV). In this case, the total prevention costs for the individual increase by about CHF 3,750, but the total costs of treating periodontitis decrease by CHF 3,100 and those of treating secondary damage by CHF 2,350. Assuming that a Swiss citizen in scenario 3 attends supportive periodontal care visits 100 times on average, a total of CHF 17 in healthcare costs can be saved for each dental and dental hygiene visit.

Discussion

Reducing periodontitis prevalence by 50%, combined with improved oral healthcare to prevent further gingivitis, has a large benefit when considering the out-of-pocket costs of treating gingivitis, periodontitis, and associated secondary damage. Scenarios 2 and 3 in this simulation revealed a high ROI regarding expected mean out-of-pocket costs, saving up to CHF 5.94 billion (more than CHF 1,100 per individual per lifetime) for the current Swiss population aged 35–100 when scenario 3 is pursued.

If costs are paid by social welfare, the image varies. Scenario 2 has higher costs than the standard scenario 1 until a citizen has reached the age of 70 years. At this age, the proportion of individuals with periodontitis begins to predominate, driving up the costs of treatment not only for periodontitis but also for secondary damage. The overall ROI for this scenario in this simula-

tion is therefore negative. Moreover, scenario 3 shows a ROI for total costs of CHF 1.03 billion, revealing that further reduction of gingivitis by another 10 percentage points can already have a major impact leading to significant cost savings in the Swiss healthcare system.

Despite steady improvements in general and oral health, the global prevalence of periodontitis has changed little over the past 20 years (Kassebaum et al. 2014). As the present study demonstrates, untreated oral diseases such as periodontitis not only generate direct costs, but also indirect and thus intangible costs in the healthcare system (Peres et al. 2020). In 2010, direct treatment costs of oral diseases worldwide were estimated at US$ 298 billion (4.6% of global healthcare costs), and indirect costs at US$ 144 billion (Listl et al. 2015). In comparison to Switzerland, dental costs amounted to 5.1% of the total healthcare expenditure in the year 2020 (FSO 2022b).

The present simulation not only highlights the benefits of early disease detection and prevention of gingivitis (and therefore periodontitis) but also proposes an effective and feasible way to reduce direct and indirect costs of periodontitis. It demonstrates that decreasing the current prevalence of periodontitis to half its value, along with increased gingivitis management and home-led oral care performed by informed patients can reduce out-of-pocket costs by CHF 2.61 billion to 5.94 billion and save up to CHF 1.03 billion in social welfare expenditure in the Swiss population of CHF 5.2 million between the ages of 35–100 years. Moreover, the present simulation reveals that the earlier periodontal disease occurs in adults, the greater the secondary damage and the burden on the entire healthcare system.

To the best of our knowledge, this was the first study to conduct a simulation on this topic in the Swiss population. However, our outcomes are congruent with other studies that have explored the impact of periodontal therapy on NCD outcomes and healthcare costs (Blaschke et al. 2021; Chapple et al. 2021; Choi et al. 2020; Jeffcoat et al. 2014; Nasseh et al. 2017). For the purpose of this study, only publications on NCDs, such as CVD and type 2 diabetes, with the most consistent bidirectional associations with periodontitis were considered. With regard to the overestimation and underestimation of the CHF amounts assumed in the present simulation, it should be noted that the assumed costs associated with undiagnosed periodontitis were CHF 0. Furthermore, indirect costs for the management of secondary damage, including cardiac and diabetic care, were cautiously estimated in the lower ranges with a maximum of CHF 750 per year. Therefore, the actual cost savings could be even higher than estimated in this study, and future adjustments of the simulation with more up-to-date assumptions could provide even better estimates.

According to the European Federation of Periodontology (EFP) report *(Time to take gum disease seriously),* which simulated an economic return on investment model, the most beneficial scenarios in terms of healthy life years, cost-effectiveness and ROI are the elimination of gingivitis and a 90% increase in the diagnosis rate of periodontitis through early diagnosis, effective treatment and improved at-home oral care by a well-informed population. In fact, in all six European countries studied, there was a positive ROI in oral healthcare costs and an increase in health life years (Chapple et al. 2021). Another study by Jeffcoat and colleagues demonstrated the largest reduction in healthcare costs per individual per month (US$ 236.67) and lower hospitalisation rates in patients with CVD and type 2 diabetes following periodontal intervention (Jeffcoat et al. 2014). While Köster and colleagues estimated the average annual direct costs per diabetic patient at EUR 5,262, Nasseh and co-workers found a significant reduction in type 2 diabetes-related healthcare costs in patients who did not receive drug therapy but did receive periodontal treatment (Köster et al. 2006; Nasseh et al. 2017). Furthermore, a recent study from Germany demonstrated the positive impact of periodontal therapy in newly diagnosed diabetes patients by reducing healthcare costs by about 4%, lowering inpatient costs, diabetes-related drug costs, health complications and hospitalisations compared to the control group (Blaschke et al. 2021).

Moreover, Sung and co-workers used a mathematical model-based analysis to evaluate the cost-effectiveness of non-invasive periodontal treatment in patients with type 2 diabetes (Sung et al. 2020). The model produced a significant decline in tooth loss, type 2 diabetes-related complications and, to a lesser degree, CVD incidence, subsequently reducing healthcare expenditure relating to type 2 diabetes and CVD related complications (Choi et al. 2020). In line with this result has been a study by Smits and co-workers, in which a retrospective analysis of claims data from a Dutch health insurance company was used to determine whether periodontal treatment had an impact on diabetes-related healthcare costs (Smits et al. 2020). These authors reported cost-savings of around 12 Euros in quarterly diabetes-related healthcare cost pro capita, which can be related to our estimate of CHF 17 total healthcare costs savings for each supportive periodontal care visit.

Limitations of the study

Our study bears some limitations. Firstly, the present simulation was based on calculations and estimates in accordance with the current literature. As outlined above, however, certain assumptions were intentionally calculated at the lower end, which may lead to an underestimation of potential additional cost savings. Secondly, computer simulations may not be suitable for predictions from an individual perspective but are intended to show the impact of professional periodontal care on potential cost savings in the healthcare system. Moreover, the likelihood of developing periodontitis was not modelled continuously over age, but abruptly in a larger leap when those affected reached their 65th birthday. In addition, patients younger than 35 years were not included in the model and thus the age groups of 20 to 34 years are missing. However, according to the assumed prevalence and incidence, a significantly lower number is to be expected than in the included groups (Kassebaum et al. 2014). Nevertheless, this minority remains unconsidered. Finally, neither the new classification nor our model considered juvenile periodontitis, of which an estimated prevalence of 0.1% is assumed in the 16-year-old population in Switzerland (Kronauer et al. 1986; Papapanou et al. 2018). This specific prevalence does not seem to be a major public health issue. Nevertheless, the age restriction in the present simulation could be one of the main limitations of this study.

Impact on health policy in Switzerland

Both general practitioners and dentists have a duty not only to inform their patients about periodontitis and its relationship to type 2 diabetes and CVD, but also to make them aware of the benefits of regular dental check-ups and prophylaxis, for both medical and financial reasons. As strongly recommended by the EFP guidelines, a patient diagnosed with diabetes should be ad-

vised to have a routine check-up at the dentist to exclude or manage periodontitis and vice versa (Ramseier et al. 2020; Sanz et al. 2018). This highlights the need to integrate general and dental healthcare to adequately manage respective comorbidities.

With the findings from the present simulation, the legitimate question arises whether a sufficient number of oral health professionals such as dentists, dental hygienists and prophylaxis assistants are being trained in Switzerland to meet the needs and demands of an increasingly ageing population. The education of future dentists and dental hygienists must focus on the skills necessary to motivate patients so that they will be more adherent to healthy lifestyles and supportive periodontal care. In line with our findings, further efforts are needed to prioritise gingivitis prevention, promote early diagnosis of periodontitis and raise awareness of the detrimental effects of periodontitis on NCDs such as cardiovascular disease and type 2 diabetes, as well as the cumulative economic burden on the healthcare system in Switzerland.

Conclusion

Early detection and appropriate treatment of periodontitis can help reduce both the total costs of treating periodontitis and associated secondary damage, particularly in the second half of life. These cost savings may also pay off on an individual level through regular supportive periodontal care, both for treatments paid out of pocket and those covered by social welfare.

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Conflict of interest

The authors declare that there are no conflicts of interest in this study.

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Reproducibility and further improvements

All code used in this simulation is freely accessible from the journal's website and researchers are invited to reproduce, improve, and further discuss our simulation.

Zusammenfassung

Hintergrund und Ziel

Mehr als 740 Millionen Menschen weltweit sind von Parodontalerkrankungen betroffen und haben ein höheres Risiko für Folgeschäden wie Herz-Kreislauf-Erkrankungen und Typ-2-Diabetes, die eine finanzielle Belastung für die Gesundheitssysteme darstellen. Ziel dieser Studie war es, mithilfe einer Computersimulation die direkten und indirekten Kosten der Prävention und Behandlung von Gingivitis, Parodontitis und damit verbundenen Folgeschäden in der Schweizer Bevölkerung abzuschätzen, die sowohl aus eigener Tasche als auch von der Sozialhilfe bezahlt werden.

Material und Methoden

Bei drei verschiedenen Szenarien entsprachen die Iterationen mit 200 000 simulierten Personen über ihre angenommene Lebensspanne von 35 bis 100 Jahren einem Zeitraum von vier Monaten, in dem eine Person von einer Parodontalerkrankung zur nächsten wechseln könnte, die jeweils mit angenommenen direkten und indirekten Behandlungskosten verbunden sind.

Resultate

Eine korrekte Diagnose und die Einhaltung einer professionellen Parodontalbehandlung hätten einen grossen Nutzen, da sie für die derzeitige Schweizer Bevölkerung Kosten von bis zu 5,94 Mrd. CHF (bezahlt aus eigener Tasche) und 1,03 Mrd. CHF (von der Sozialhilfe bezahlt) einsparen würden. Unter Berücksichtigung der direkten und indirekten Gesundheitskosten betrugen die erwarteten Gesamtkosten für eine 35-jährige Person bis zum Tod 17 310 CHF bei minimaler Pflege und 15 606 CHF bei optimaler Pflege, was zu Einsparungen von 1704 CHF führte.

Schlussfolgerung

Zusammenfassend lässt sich sagen, dass eine frühzeitige Erkennung und angemessene Behandlung der Parodontitis dazu beitragen kann, sowohl die Gesamtkosten für die Behandlung der Parodontitis als auch die damit verbundenen Folgeschäden zu senken, insbesondere in der zweiten Lebenshälfte. Diese Kosteneinsparungen können sich auf individueller Ebene durch eine regelmässige unterstützende Parodontalpflege weiter auszahlen, sowohl für Behandlungen, die aus eigener Tasche bezahlt werden, als auch für solche, die von der Sozialhilfe übernommen werden.

Résumé

Contexte et objectif

Plus de 740 millions de personnes dans le monde sont touchées par des maladies parodontales et présentent un risque accru de dommages secondaires tels que les maladies cardiovasculaires et le diabète de type 2, ce qui représente une charge financière pour les systèmes de santé. L'objectif de cette étude était d'utiliser une simulation informatique pour estimer les coûts directs et indirects de la prévention et du traitement de la gingivite, de la parodontite et des dommages secondaires associés dans la population suisse, payés à la fois de sa poche et par l'aide sociale.

Matériel et méthodes

Pour trois scénarios différents, les itérations avec 200 000 individus simulés sur leur durée de vie supposée de 35 à 100 ans correspondaient à une période de quatre mois au cours de laquelle un individu pouvait passer d'une condition parodontale à une autre, chacune associée à des coûts de traitement directs et indirects présumés.

Résultats

Un diagnostic approprié et l'adhésion à des soins parodontaux professionnels ont permis d'économiser jusqu'à 5,94 milliards de francs suisses (coûts directs) et 1,03 milliard de francs suisses (aide sociale) pour la population suisse actuelle. En tenant compte des coûts directs et indirects des soins de santé, les coûts totaux attendus pour un individu de 35 ans jusqu'à son décès étaient de 17 310 CHF avec des soins minimaux et de 15 606 CHF avec des soins optimaux, soit une économie de 1704 CHF.

Conclusion

En conclusion, la détection précoce et le traitement approprié de la parodontite peuvent contribuer à réduire à la fois les coûts

globaux du traitement de la parodontite et les dommages secondaires associés, en particulier dans la seconde moitié de la vie. Ces économies peuvent également être rentabilisées au niveau individuel par des soins parodontaux réguliers, tant pour les traitements payés de sa poche que pour ceux couverts par l'aide sociale.

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