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W. Marcenes[1]*, N.J. Kassebaum[2], E. Bernabé[3], A. Flaxman[2], M. Naghavi[2], A. Lopez[2,4], and C.J.L. Murray[2]

[1]Institute of Dentistry, Barts and The London School of Medicine and Dentistry, Queen Mary University of London, London, UK; [2]Institute for Health Metrics and Evaluation, University of Washington, Seattle, USA; [3]King's College London Dental Institute, Unit of Dental Public Health, London, UK; and [4]School of Population Health, University of Queensland, Brisbane, Australia; *corresponding author, w.marcenes@qmul.ac.uk

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Global Burden of Oral Conditions in 1990-2010: A Systematic Analysis

ABSTRACT

The Global Burden of Disease (GBD) 2010 Study produced comparable estimates of the burden of 291 diseases and injuries in 1990, 2005, and 2010. This article reports on the global burden of untreated caries, severe periodontitis, and severe tooth loss in 2010 and compares those figures with new estimates for 1990. We used disability-adjusted life-years (DALYs) and years lived with disability (YLDs) metrics to quantify burden. Oral conditions affected 3.9 billion people, and untreated caries in permanent teeth was the most prevalent condition evaluated for the entire GBD 2010 Study (global prevalence of 35% for all ages combined). Oral conditions combined accounted for 15 million DALYs globally (1.9% of all YLDs; 0.6% of all DALYs), implying an average health loss of 224 years *per* 100,000 population. DALYs due to oral conditions increased 20.8% between 1990 and 2010, mainly due to population growth and aging. While DALYs due to severe periodontitis and untreated caries increased, those due to severe tooth loss decreased. DALYs differed by age groups and regions, but not by genders. The findings highlight the challenge in responding to the diversity of urgent oral health needs worldwide, particularly in developing communities.

KEY WORDS: dental caries, periodontal diseases, mouth, edentulous, world health, disability evaluation, trends.

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INTRODUCTION

Summary measures of population health provide a unique perspective in the shaping of public health policy. They provide governments and national and international non-governmental agencies with the evidence-based data from which to determine priorities for research, development, policies, and funding (Murray and Lopez, 1996a; Murray *et al*., 2012a). The disability-adjusted life-years (DALYs) metric, which is the sum of years of life lost due to premature mortality (YLLs) and years lived with disability (YLDs) (Murray *et al*., 2002), provides a single standardized measure by which to compare the effects of all fatal and non-fatal diseases, injuries, and risk factors on population health. Disability refers to any short- or long-term health loss other than death (Murray and Lopez, 1997; Vos *et al*., 2012). The relevance of DALYs to estimate the health loss associated with morbidity and mortality has been demonstrated by extensive references in global health debates and decision-making (Murray *et al.*, 2012b).

To date, the only comprehensive effort to estimate summary measures of population health for the world by cause is the Global Burden of Diseases, Injuries, and Risk Factors (GBD) Study. The GBD 1990 Study assessed the burden of oral diseases in 8 major world regions (World Bank, 1993; Murray and Lopez, 1996b, 1997). Although the World Health Organization (WHO) updated DALYs for 1999 to 2004, this was done for only a subset of disease sequelae, which excluded oral conditions. Few narrative attempts to report the global burden of oral diseases have been published subsequently (Petersen *et al.*, 2005; Petersen and Ogawa, 2012). These studies differ from the GBD Study because they did not systematically search the literature, assess the quality of publications, or produce comprehensive and comparable global estimates of the burden of oral diseases. The burden of oral diseases as estimated by the GBD 1990 Study was moderate (Murray and Lopez, 1996b).

The goal of GBD 2010 Study has been the systematic production of comparable estimates of the burden of 291 diseases and injuries and their associated 1,160 sequelae in 1990, 2005, and 2010. Estimates for 1990 and 2005 were recalculated following the GBD 2010 Study protocol. This article reports on the global burden of untreated caries, severe periodontitis, and severe tooth loss in 2010 and compares those figures with the new estimates for 1990.

METHODS

Data to inform models came from 3 independent systematic reviews of observational studies conducted at the Department of Clinical and Diagnostic

Oral Science, Queen Mary University of London, between 2007 and 2011 (Marcenes *et al*., 2013, in preparation). Detailed methods for each component of the GBD 2010 Study have been described elsewhere (Murray *et al*., 2012a). We provide only a brief description here, with emphasis on oral conditions.

The GBD study cause list included untreated caries, severe periodontitis, and severe tooth loss. The case definition of untreated caries for literature review was "teeth with unmistakable coronal cavity at dentin level, root cavity in cementum that feels soft or leathery to probing, temporary or permanent restorations with a caries lesion." The GBD study definition of disability associated with untreated caries was "a toothache, which causes some difficulty eating". In order of preference, we used 3 case definitions of severe periodontitis: "a Community Periodontal Index score of 4, a clinical attachment loss more than 6 mm or a gingival pocket depth more than 5 mm", depending on which was used in the publication. Disability was defined as "bad breath, a bad taste in the mouth, and gums that bleed a little from time to time, but this does not interfere with daily activities." Severe tooth loss was defined as "having fewer than 9 remaining permanent teeth", while the definition of disability was "great difficulty in eating meat, fruits, and vegetables".

Two trained reviewers working independently and in duplicate searched the literature following the Cochrane Handbook (Higgins and Green, 2011), extracted the data, and assessed the validity of publications retrieved. The systematic searches sought to identify all published (MEDLINE *via* PubMed, EMBASE *via* OVID, and LILACS *via* BIREME without language restrictions) and unpublished observational population-based studies presenting information on the prevalence, incidence, case fatality, and cause-specific mortality related to untreated caries, severe periodontitis, and severe tooth loss between January 1980 and December 2010. The quality of all publications was assessed based on the STROBE checklist (Vandenbroucke *et al.*, 2007).

Prevalence estimates were calculated on the database for all age-gender-country-year groups, by means of DisMod-MR, a Bayesian meta-regression tool developed for the GBD 2010 Study (Flaxman *et al*., 2012). The generalized negative binomial model includes: covariates that predict variations in true rates; covariates that predict variations across studies due to measurement bias; super-region, region, and country random intercepts; and age-specific fixed effects. Where appropriate, it can be assumed that the rates have been constant over time, which allows data on incidence, prevalence, excess mortality, and cause-specific mortality to inform prevalence estimates. Untreated caries of deciduous and permanent teeth was estimated first in separate models, and then combined when DALYs were calculated.

Since death as a direct result of oral diseases is rare, DALYs estimates were based on YLDs only. They were calculated as the product of prevalence (frequency) times the disability weight of the associated sequelae (severity) times the duration of symptoms. Metrics were not age-weighted or discounted (Murray *et al*., 2012b). We report DALYs (in thousands), which represent the total number of cause-specific DALYs for the entire world or region population, and DALYs *per capita* (*per* 100,000), which account for changes into growth in total population and age-and-gender distribution.

Disability weights were calculated based on population-based surveys in 5 countries (USA, Peru, Tanzania, Bangladesh, and Indonesia) and an open Internet survey of more than 31,000 respondents, as described elsewhere (Salomon *et al*., 2012). Their empirical basis was thus derived from judgments of the general public about health severity rather than from researchers themselves or from individual health conditions reported by health-care professionals.

Untreated caries can be asymptomatic, mild, or severe. We approximated individuals with mild disability as having periodic pain lasting 1 hr *per* day. Those with severe symptoms were modeled as having 2 phases: an "initial" phase with periodic pain and a "terminal" phase with constant pain, the length of which was determined by log-normal distribution of symptom duration from casualty ward studies.

Uncertainty from all inputs into the calculations of DALYs was propagated by Monte Carlo simulation techniques, with 1,000 draws taken for each age, gender, country, year, and cause. Aggregations were made at the level of the 1,000 draws for all estimates. The uncertainty interval (UI) around each quantity of interest is presented as the 2.5th and 97.5th centiles, which can be interpreted as a 95% UI.

In analyses by region, the 21 GBD regions were categorized by the mean age of death, which reflects both population age-structure and age-specific death rates and is a simple summary measure of the demographic and epidemiological transition (Murray *et al*., 2012b; Wang *et al.*, 2012).

RESULTS

Oral conditions remained highly prevalent in 2010, collectively affecting 3.9 billion people. Untreated caries in permanent teeth was the most prevalent condition evaluated for the entire GBD 2010 Study (global prevalence of 35% for all ages combined), whereas severe periodontitis and untreated caries in deciduous teeth were the 6th and 10th most prevalent conditions, affecting, respectively, 11% and 9% of the global population. Severe tooth loss was the 36th most prevalent condition, with a global estimate of 2% (Table 1). Disability weights were 0.0079, 0.012, and 0.073 for severe periodontitis, untreated caries, and severe tooth loss, respectively.

Oral conditions all ranked among the top 100 detailed causes of DALYs (Table 2). Severe periodontitis ranked 77th (95%UI, 50-116), untreated caries ranked 80th (95%UI, 56-115), and severe tooth loss ranked 81st (95%UI, 61-103). In 2010, oral conditions combined accounted for 15 million DALYs globally (1.9% of all YLDs and 0.6% of all DALYs), implying an average health loss of 224 years *per* 100,000 people (Table 3). Each of the oral conditions had a comparable estimate of DALYs (in thousands), including untreated caries (4,988; 95%UI, 2,066-9,686), severe periodontitis (5,413; 95%UI, 2,036-11,258), and severe tooth loss (4,668; 95%UI, 2,675-7,359). The distribution of DALYs (in thousands) due to oral conditions by gender and age-group is shown in Appendix Table 1. The burden of oral

Table 1. Global Prevalence of Oral Conditions in 2010, by Gender

		Overall		Men		Women	
Rank	Condition Name	n[a]	%	n[a]	%	n[a]	%
1	Untreated caries of permanent teeth	2,431,636	35.29	1,194,051	34.37	1,237,585	36.23
2	Tension-type headache	1,431,067	20.77	655,937	18.88	775,131	22.69
3	Migraine	1,012,944	14.70	371,072	10.68	641,873	18.79
4	Fungal skin diseases	985,457	14.30	516,167	14.86	469,291	13.74
5	Other skin and subcutaneous diseases	803,597	11.66	417,129	12.01	386,468	11.32
6	Severe periodontitis	743,187	10.79	378,407	10.89	364,780	10.68
7	Mild hearing loss	724,689	10.52	386,147	11.11	338,543	9.91
8	Acne vulgaris	646,488	9.38	311,349	8.96	335,140	9.81
9	Low back pain	632,045	9.17	334,793	9.64	297,252	8.7
10	Untreated caries of deciduous teeth	621,507	9.02	352,085	10.13	269,421	7.89
36	Severe tooth loss	158,284	2.3	67,264	1.94	91,020	2.66

[a]Numbers of cases reported in thousands.

Table 2. Disability-adjusted Life-years Ranks for Oral Conditions in 1990 and 2010

1990 Mean Rank (95% UI)			2010 Mean Rank (95% UI)		
1.0	(1-2)	01 Lower respiratory infections	1.0	(1-2)	01 Ischemic heart disease
2.0	(1-2)	02 Diarrheal diseases	2.0	(1-3)	02 Lower respiratory infections
3.4	(3-5)	03 Preterm birth complications	3.2	(2-5)	03 Cerebrovascular disease
3.8	(3-5)	04 Ischemic heart disease	4.8	(4-8)	04 Diarrheal diseases
5.2	(4-6)	05 Cerebrovascular disease	6.5	(4-9)	05 HIV/ AIDS
6.3	(5-8)	06 COPD	6.7	(3-11)	06 Malaria
8.0	(6-13)	07 Malaria	7.2	(3-11)	07 Low back pain
9.9	(7-13)	08 Tuberculosis	7.9	(5-11)	08 Preterm birth complications
10.1	(7-14)	09 Protein-energy malnutrition	8.1	(5-11)	09 COPD
10.2	(7-15)	10 Neonatal encephalopathy	8.4	(4-11)	10 Road injuries
68.8	(58-87)	69 Severe tooth loss	76.9	(50-116)	77 Severe periodontitis
85.3	(61-121)	86 Untreated caries[a]	79.3	(56-115)	80 Untreated caries[a]
90.0	(61-125)	90 Severe periodontitis	80.0	(61-103)	81 Severe tooth loss

COPD, Chronic Obstructive Pulmonary Disease; HIV/AIDS, Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome.
[a]Untreated caries included caries in both deciduous and permanent teeth.

conditions was similar among women and men (7,805 *vs.* 7,265 DALYs globally) and increased with aging. The burden of untreated caries predominated below age 35 yrs and decreased with increasing age, though it remained non-trivial in the oldest age groups. Conversely, the burden of severe periodontitis increased with age to become the most predominant cause of DALYs in individuals from 35 to 59 yrs of age before decreasing slightly in the oldest age groups. Severe tooth loss was the main cause of DALYs in individuals over age 60 yrs.

DALYs due to oral conditions increased by 20.8% in 2010 compared with 1990 (Table 3). The percentage changes in DALYs associated with population growth, population aging, and change in age- and gender-specific disease rates were 44.9%, 11.8%, and -35.8%, respectively (Table 3). The largest increases in DALYs were observed in Eastern (51.7%) and Central Sub-Saharan Africa (50.5%) and Oceania (47.4%). DALYs *per capita* increased only in 2 regions, East and South Asia, over the 20-year period (Table 4).

DALYs due to severe periodontitis and untreated caries in deciduous and permanent teeth increased by 57.3%, 5.3%, and 38.1% respectively, while those due to severe tooth loss decreased by 12.3% (Table 3). Severe periodontitis was the leading cause of DALYs in 9 regions (Australasia, Sub-Saharan Africa East, Central, East, and Southeast Asia, and Southern, Central, Tropical, and Andean Latin America), followed by untreated caries (Oceania, South Asia, North Africa/Middle East and West, Central and Southern Sub-Saharan Africa) and severe tooth loss (High-income North America, Western Europe, High-income Asia-Pacific, Eastern and Central Europe, and the Caribbean), each leading in 6 regions. Detailed information on DALYs due to each oral condition by region is presented in Appendix Tables 2-5.

Table 3. Changes in Global Disability-adjusted Life-years (DALYs, in thousands) and DALYs *per capita* (*per* 100,000 population) between 1990 and 2010, Shown as Changes (Δ) due to Population Growth, Aging, and Changes in Gender- and Age-specific Disease Rates

Cause	1990 DALYs[a]	Isolated Pop. Growth[b]	Isolated Pop. Aging[c]	2010 DALYs	% Δ Due to Pop. Growth	% Δ Due to Pop. Aging	% Δ Due to Δ Rates	% Δ 1990-2010
DALYs (in thousands)								
All GBD causes	2,502,601	3,444,678	3,386,762	2,490,385	37.6	-2.3	-35.8	-0.5
All GBD causes (YLDs only)	578,068	751,962	815,116	769,275	30.1	10.9	-7.9	33.1
All oral conditions	12,473	18,067	19,534	15,070	44.9	11.8	-35.8	20.8
Untreated caries in deciduous teeth	405	434	429	426	7.2	-1.1	-0.8	5.3
Untreated caries in permanent teeth	3,304	4,422	4,441	4,562	33.9	0.6	3.7	38.1
Severe periodontitis	3,441	4,862	5,372	5,413	41.3	14.8	1.2	57.3
Severe tooth loss	5,324	7,749	8,508	4,668	45.5	14.3	-72.1	-12.3
DALYs *per capita* (*per* 100,000 population)								
All oral conditions	242	242	290	224	0.1	19.7	-27.4	-7.6
Untreated caries in deciduous teeth	25	25	25	25	0.0	-1.0	-0.7	-1.7
Untreated caries in permanent teeth	71	71	71	73	0.0	0.4	2.7	3.2
Severe periodontitis	97	97	107	108	0.0	10.5	0.8	11.3
Severe tooth loss	175	175	192	106	0.0	9.8	-49.5	-39.8

[a]Estimates for 1990 were recalculated following the GBD 2010 Study protocol.
[b]DALYs expected with 2010, 1990 population age structure, and 1990 DALY rates (in thousands).
[c]DALYs expected with 2010, 2010 population age structure, and 2010 DALY rates (in thousands).

DISCUSSION

The global burden of oral conditions increased from 1990 to 2010, while a reduction was observed for all conditions. The observed 20.8% increase in the global burden of oral conditions was mainly due to population growth and aging, since DALYs *per capita* due to oral conditions decreased 8%. These findings are in contrast to 0.5% and 23% decreases in DALYs and DALYs *per capita* due to all conditions, respectively, in the same period.

Untreated caries was the most prevalent of all 291 conditions. Oral conditions caused some disability and, coupled with their high prevalence, accounted for a substantial number of DALYs. The disability weight associated with severe tooth loss (0.073) was between those reported for moderate heart failure (0.068) and moderate consequences of stroke (0.074). Among non-fatal outcomes, oral conditions were ranked 31st, 34th, and 35th of health outcomes causing YLDs and were comparable with many non-communicable diseases, including maternal conditions, hypertensive heart disease, schizophrenia, and the totality of hemoglobinopathies and hemolytic anemias. Oral conditions accounted for more YLDs than 25 of 28 categories of cancer, and only stomach, liver and trachea, and bronchus and lung cancers ranked higher than oral conditions (Vos *et al.*, 2012).

The global burden of oral conditions is shifting from severe tooth loss toward severe periodontitis and untreated caries. Tooth loss is a final common pathway when preventive or conservative treatments to alleviate pain fail or are unavailable. Thus, a dramatic reduction in the prevalence of caries and periodontitis in regions with advanced demographic and epidemiologic transition may underlie some of the reduced prevalence of severe tooth loss. Conversely, it is quite conceivable that the increases observed in untreated caries and severe periodontitis in the younger age groups in regions less advanced in the demographic and epidemiologic transition may lead to high levels of tooth loss in these areas in the future.

Challenges in this analysis were inherent in either the measuring or reporting of oral diseases and highlighted areas with incomplete data. The relationship between untreated caries (DT > 0) and lifetime prevalence (DMFT > 0) is not constant and has not been quantified, and, unfortunately, studies that included only DMFT > 0 data had to be excluded because DisMod-MR relies on fixed effects being relatively constant with respect to time and age. Periodontal diseases are not uniformly defined or recorded, and prevalence studies preferentially omitted young and old age groups. Severe tooth loss literature generally included only the proportion of edentate people, and only 3 valid studies reported the number of teeth present. Therefore, DALYs calculation was based on the prevalence of total tooth loss. Furthermore, oral health of populations varies more than for many other conditions. Uncertainty of models was relatively high, especially where input data were scarce or results were examined globally (Murray *et al*., 2012b).

It is possible that the GBD approach has underestimated the burden of oral conditions. The GBD case definitions included only the most severe forms of the 3 most common oral conditions. Mouth cancer, noma (*Cancrum oris*), and maxillofacial injuries were not computed. Mild to moderate tooth loss and periodontitis may also cause some disability, and symptomatic filled teeth are common. Also, oral conditions may lead to several disabilities (Slade *et al*., 2005; Sanders *et al.*, 2009; Locker and Quinonez, 2011). A more thorough appraisal of symptoms related to oral conditions (proportion, duration, frequency, and nature), ability to eat, and socio-psychological impact would be ideal to help inform quantification of the burden of these health states in the future.

Table 4. Changes in Disability-adjusted Life-years (DALYs, in thousands) and DALYs *per capita* (*per* 100,000 population) between 1990 and 2010 by GBD Regions*, Shown as Changes (Δ) due to Population Growth, Aging, and Changes in Gender- and Age-specific Disease Rates (all oral conditions combined)

Region	1990 DALYs[a]	Isolated Pop. Growth[b]	Isolated Pop. Aging[c]	2010 DALYs	% Δ Due to Pop. Growth	% Δ Due to Pop. Aging	% Δ Due to Δ Rates	% Δ 1990-2010
DALYs (in thousands)								
Asia-Pacific, High income	375	433	585	375	15.3	40.6	-56.0	-0.1
Europe, Western	1,156	1,320	1,504	1,057	14.2	15.9	-38.7	-8.6
Australasia	64	86	100	73	33.3	22.4	-42.2	13.6
North America, High income	644	822	916	644	27.7	14.6	-42.2	0.1
Europe, Central	486	529	587	393	8.7	12.0	-39.9	-19.2
Latin America, Southern	149	202	219	176	35.4	11.4	-28.9	18.0
Europe, Eastern	883	911	970	731	3.2	6.7	-27.1	-17.2
Asia, East	2,390	3,217	3,698	3,048	34.6	20.1	-27.2	27.5
Latin America, Tropical	459	698	836	572	52.1	29.8	-57.5	24.4
Latin America, Central	411	665	770	525	61.8	25.6	-59.7	27.8
Asia, Southeast	968	1,490	1,673	1,310	53.9	18.9	-37.5	35.3
Asia, Central	178	237	243	189	33.1	3.7	-30.7	6.1
Latin America, Andean	95	152	171	129	59.3	20.4	-44.5	35.2
North Africa/Middle East	670	1,196	1,284	875	78.6	13.1	-61.0	30.7
Caribbean	93	129	145	98	38.3	18.0	-51.4	4.9
Asia, South	2,490	4,085	4,308	3,500	64.0	8.9	-32.4	40.5
Oceania	8	15	15	12	74.3	7.8	-34.8	47.4
Sub-Saharan Africa, Southern	108	169	183	128	56.0	13.0	-50.8	18.2
Sub-Saharan Africa, East	434	821	820	659	89.1	-0.3	-37.1	51.7
Sub-Saharan Africa, Central	99	193	187	149	95.2	-6.4	-38.3	50.5
Sub-Saharan Africa, West	310	569	562	428	83.6	-2.4	-43.1	38.1
DALYs *per capita* (*per* 100,000 population)								
Asia-Pacific, High income	225	213	332	212	-5.0	52.5	-53.0	-5.5
Europe, Western	307	283	366	257	-7.8	26.9	-35.4	-16.3
Australasia	320	299	392	286	-6.6	29.2	-33.2	-10.6
North America, High income	236	220	273	192	-6.8	22.7	-34.4	-18.4
Europe, Central	404	395	499	334	-2.3	25.8	-40.8	-17.3
Latin America, Southern	311	307	370	297	-1.5	20.2	-23.3	-4.6
Europe, Eastern	404	393	474	357	-2.8	19.9	-28.9	-11.7
Asia, East	207	207	269	222	0.4	30.1	-22.9	7.5
Latin America, Tropical	305	315	421	288	3.0	34.7	-43.5	-5.8
Latin America, Central	254	265	340	232	4.2	29.6	-42.6	-8.8
Asia, Southeast	216	224	280	219	3.5	25.9	-28.0	1.3
Asia, Central	267	274	310	241	2.9	13.4	-26.1	-9.8
Latin America, Andean	253	262	326	246	3.4	25.4	-31.9	-3.1
North Africa/Middle East	229	248	295	201	8.2	20.5	-41.0	-12.3
Caribbean	310	310	389	261	0.3	25.4	-41.3	-15.6
Asia, South	229	236	274	222	3.1	16.5	-22.4	-2.8
Oceania	149	153	174	141	2.2	14.4	-22.3	-5.7
Sub-Saharan Africa, Southern	212	222	265	186	4.8	20.3	-37.6	-12.5
Sub-Saharan Africa, East	217	222	239	192	2.3	7.7	-21.6	-11.6
Sub-Saharan Africa, Central	193	195	202	161	0.7	3.5	-21.1	-16.9
Sub-Saharan Africa, West	161	164	174	132	1.7	6.2	-25.7	-17.7

*Regions are ordered by mean age of death.
[a]Estimates for 1990 were recalculated following the GBD 2010 Study protocol.
[b]DALYs expected with 2010, 1990 population age structure, and 1990 DALY rates (in thousands).
[c]DALYs expected with 2010, 2010 population age structure, and 2010 DALY rates (in thousands).

The implications of this study for oral health care investment are useful in the planning of workforce needs and the content of dental education. One of the fundamental challenges is responding to the diversity of urgent oral health needs for communities. The DALYs and DALYs *per capita* metrics should inform priorities. They can help identify those populations with both the highest concentration as well as the greatest overall need. East, South, and Southeast Asia and Western Europe had the highest

estimates of total population disease burden, with East and South Asia having the least favorable changes in *per capita* oral health needs. This diversity reminds us that the organized social response to health problems must deal with a wide array of health care and public health priorities for action.

To conclude, the burden of oral conditions seems to have increased in the past 20 years, but not evenly. While the DALYs (in thousands) due to untreated caries and severe periodontitis increased since 1990, those due to severe tooth loss decreased. Oral conditions combined accounted for 15 million DALYs globally, implying an average health loss of 224 yrs *per* 100,000 persons. Oral conditions all ranked among the top 100 detailed causes of DALYs.

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