Global Economic Impact of Dental Diseases

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Abstract
Reporting the economic burden of oral diseases is important to evaluate the societal relevance of preventing and addressing oral diseases. In addition to treatment costs, there are indirect costs to consider, mainly in terms of productivity losses due to absenteeism from work. The purpose of the present study was to estimate the direct and indirect costs of dental diseases worldwide to approximate the global economic impact. Estimation of direct treatment costs was based on a systematic approach. For estimation of indirect costs, an approach suggested by the World Health Organization’s Commission on Macroeconomics and Health was employed, which factored in 2010 values of gross domestic product per capita as provided by the International Monetary Fund and oral burden of disease estimates from the 2010 Global Burden of Disease Study. Direct treatment costs due to dental diseases worldwide were estimated at US$298 billion yearly, corresponding to an average of 4.6% of global health expenditure. Indirect costs due to dental diseases worldwide amounted to US$144 billion yearly, corresponding to economic losses within the range of the 10 most frequent global causes of death. Within the limitations of currently available data sources and methodologies, these findings suggest that the global economic impact of dental diseases amounted to US$442 billion in 2010. Improvements in population oral health may imply substantial economic benefits not only in terms of reduced treatment costs but also because of fewer productivity losses in the labor market.

Keywords: treatment costs, indirect expenditures, health expenditures, costs and cost analysis, oral health, teeth

Introduction
Identifying the economic burden of a disease is useful to understand the maximum amount of resources that could be saved or gained if that disease were to be partially or fully eradicated (Rice 1967). Describing and highlighting the magnitude of the economic impact of dental diseases on society or on different population groups would provide relevant information for decision makers in public health policy to evaluate the importance of addressing oral diseases. In the context of oral health and care, however, information about the economic impacts of disease has been very limited so far. To our knowledge, there is not a comprehensive worldwide estimation of the economic burden of oral diseases, including direct and indirect cost, to the extent that this is possible today given the currently available primary data recently reported.

Although the World Health Organization (WHO) estimates that oral diseases are the fourth-most expensive diseases to treat in most industrialized countries (Petersen 2003), its analysis was done only for direct cost and included only a subset of countries. Few sound studies reported estimates for individual countries (Beaglehole et al. 2009; Patel 2012; Wall et al. 2014). Across Organisation for Economic Co-operation and Development (OECD; 2013) countries, on average 5% of total health expenditures have been reported to originate from treatment of oral diseases. While treatment is a costly consequence of oral diseases, reductions in morbidity may also imply other economic benefits. Importantly, there are indirect costs to consider in terms of productivity losses due to absenteeism from school and work, yet relatively little evidence exists in this regard. Recent findings from Canada suggest that oral diseases accounted for productivity losses >$1 billion yearly for Canada alone (Hayes et al. 2013). A recent US study estimated the labor market value of the marginal tooth to be nearly $720 per year for an urban-residing woman earning $11/h and working full time (Glied and Neidell 2010).

Different economic approaches exist to estimate the economic burden of a disease. The cost-of-illness approach views the cost of disease as the sum of several categories of direct (treatment) costs and indirect costs (Byford et al. 2000). This typically includes personal medical care costs (diagnosis, treatment, drugs), nonmedical costs for travel associated with economic benefits.

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health care, and nonpersonal costs (e.g., costs for research, income losses, and sometimes pain and suffering). Another approach relates to measuring the value of lost output (i.e., the economic growth approach), which estimates the expected impact of disease on aggregate economic output (gross domestic product [GDP]) due to depletion in labor, capital, and other production factors (Bloom et al. 2012). The value-of-statistical-life approach seeks to identify a population’s willingness to pay to reduce the risk of disability or death due to disease, hence factoring in other factors than GDP alone (Bloom et al. 2012). While such methods to estimate the economic impact of diseases are, in principle, well founded, limited availability of comprehensive data sources and nonharmonized international reporting standards make estimating the full economic impact of oral diseases difficult.

New data from the Global Burden of Disease Study 2010 (GBD 2010) provided comparable worldwide information on disability-adjusted life years (DALYs) by country. The data also showed that oral conditions remained highly prevalent in 2010 and collectively affected 3.9 billion people in the globe. Untreated caries in permanent teeth was the most prevalent condition evaluated for all of the GBD 2010 (global prevalence of 35% for all ages combined; Kassebaum et al. 2015), 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. On the contrary, the prevalence and burden measured by DALYs associated with tooth loss have decreased in the past 20 y; specifically, tooth loss was the 36th-most prevalent condition, with a global estimate of 2.3% in 2010 (Marcenes et al. 2013; Kassebaum et al. 2014).

Following publication of the Budapest Declaration under the auspices of the Global Oral Health Inequalities Research Agenda of the International Association for Dental Research (IADR-GOHIRA®), 1 objective for future research was to estimate the global costs (direct and indirect) of oral disease (Mossey and Petersen 2014). The purpose of the present study was to systematically produce comparable estimates of the economic burden of the 3 most prevalent oral conditions as specified above in 2010. We aimed to consolidate all economic data about the direct and indirect costs of these conditions and, subsequently, to generate internally consistent estimates for all countries where data are available and to provide estimates for all 21 world regions.

Methods

A systematic approach was used to generate information to estimate the current direct and indirect costs of dental diseases worldwide. Direct costs were defined as overall expenditures for dental health care (including public and private expenditures). Indirect costs were intended to capture productivity losses due to the 3 most common oral conditions—namely, untreated caries in permanent and deciduous teeth, severe periodontitis, and severe tooth loss. Identification of appropriate methods was informed by current best practice in evidence synthesis and heuristic piloting to test the feasibility of various approaches. The most suitable approach to estimate worldwide direct and indirect costs of oral diseases was determined by consensus among all authors. To facilitate alignment with the GBD 2010, the year 2010 was defined as the primary target period for estimation of global economic impacts of dental diseases.

Estimation of Direct Costs:

Dental Health Care Costs

Selection of studies. Our search strategy was oriented to identify country-specific yearly national expenditure for outpatient dental care in 2010 or nearest year available. An electronic search was performed focusing on the following online resources:

- WHO Global Health Expenditure Database: http://www.who.int/health-account/ghed/en/
- OECD Data: https://data.oecd.org/
- Platform for Better Oral Health in Europe: http://www.oralhealthplatform.eu
- Council of European Chief Dental Officers: http://www.cecco.org/
- Intergovernmental Organization Search: http://www.uia.org/igo-search
- Google (noncustomized search): http://www.google.com

Search words for dental expenditure included “expenditure,” “expenditures,” “cost,” “costs,” or “treatment costs” combined with “dentist,” “dental,” “dentistry,” “oral health,” “oral health care,” “oral health services,” or “dental care.” The search was focused on 187 countries as defined in Murray et al. (2012). For each country, individual searches were carried out with the respective “[country name]” as an additional search term. We also searched MEDLINE via PubMed (keyword- and MeSH-based searches), EMBASE via OVID, LILACS via BIREME, the Cochrane Database of Systematic Reviews, the Database of Abstracts of Reviews of Effects, the Health Technology Assessment Database, and the NHS Economic Evaluation Database for relevant information on dental expenditure (see Appendix for details). Additional hand searches focused on relevant publications.

Information sources were included if they fulfilled the following criteria: country-specific representative reporting; overall expenditures for dental services reported, including public and private source of funds, as specified in the International Classification of Health Accounts (categories: HC.1.3.2, “outpatient dental care”; HP.3.2, “offices of dentists”; OECD 2000); annual expenditures reported for at least 1 y between 2000 and 2014; and expenditures reported either as absolute monetary values or as a percentage of GDP. An information source was excluded if it was nonrepresentative of a country’s entire population (selective sample; e.g., only representative for a local patient group with specific morbidity), or it reported only...
limited parts of overall dental expenditures (e.g., only private out-of-pocket or only government expenditures).

Two authors (S.L., J.G.) performed all searches and selected information fulfilling the inclusion criteria independently and in duplicate. Those information sources found to be relevant after initial screening were kept in the database. It was distinguished between countries for which there was “relevant information identifiable” versus countries for which there was “no relevant information identifiable.” Remaining uncertainties were resolved by consensus among all authors. Duplication between results was removed. All information sources meeting the criteria for inclusion in this review were used in the estimation of the direct costs of oral diseases.

**Data extraction and imputation.** For countries for which relevant information was identifiable, yearly dental expenditure values were extracted in terms of absolute values and as proportion of GDP. Annual expenditure values were reported in or converted to US dollars (midyear conversion rates for the reporting year [http://www.xe.com]; purchasing power adjustment based on inflation rates relative to 2010 US dollars [http://www.usinflationcalculator.com]). If expenditure information was originally reported as proportion of GDP, it was translated to absolute US dollar values by using the relevant country’s GDP in US dollars in the reporting year and applying inflation rates relative to 2010 US dollars. Estimates of GDP per capita and population size were extracted from the World Economic Outlook Database (International Monetary Fund 2011). In case of missing information, supplementary values were extracted from UN data (United Nations 2015). As a robustness check, worldwide dental expenditures were also computed by using solely GDP information from UN data (United Nations 2015).

Estimation of worldwide dental expenditures involved imputation of missing expenditure values, which leaned on expenditure information from the nearest geographic unit for which expenditure information was identifiable. To this end, countries were grouped into 21 regions and 7 super-regions, following the classification of the GBD 2010 (Fig.). When expenditure information was not available for a particular country, its 2010 expenditure was approximated by multiplying the average expenditure (in proportion of GDP) of the nearest geographic unit (region, super-region, world), which included primary expenditure information with the GDP value of the country without primary data. As an additional robustness test, worldwide dental expenditures were estimated by using the mean (95% confidence interval) expenditure level of all GBD 2010 regions containing primary expenditure information to impute missing expenditure values.

**Estimation of Indirect Costs**

Indirect costs were estimated according to an approach suggested by the WHO’s Commission on Macroeconomics and Health (WHO 2001), which was recently used to estimate global economic costs of cancer (Cancer Society 2010). This approach is based on valuing 1 DALY at 1 y of per capita GDP to approximate productivity losses. Following this approach, we factored in 2010 values of GDP per capita (International Monetary Fund 2011) and extracted DALY estimates for untreated caries, severe periodontitis, and severe tooth loss (<9 remaining permanent teeth) in 187 countries from a recent study (Marcenes et al. 2013). Note that untreated caries included deciduous teeth, whereby respective productivity losses include parents taking time off to look after their children. Country-specific GDP values were aggregated on the level of the 21 GBD 2010 regions and weighted according to country-specific population sizes (International Monetary Fund 2011). In case of missing information, supplementary values were extracted from UN data (United Nations 2015). Relevant data for estimation of indirect costs (i.e., GDP per capita in US dollars and DALYs in thousands [2010 values]) are summarized in Table 1. All analyses were carried out with Microsoft Excel (v. 14.0.7015.1000).

**Results**

**Direct Costs: Treatment Costs**

The systematic information search started with identification of countries relevant to estimate global expenditures. Accordingly, 187 country-specific electronic searches were carried out and submitted to initial screening. At this stage, 107 countries were excluded because no relevant information could be identified. Of the remaining 80 countries, 14 more countries were excluded because the respective information did not meet the inclusion/exclusion criteria. For the remaining 66 countries, relevant information was found to be identifiable. Full lists of included and excluded information sources (with reasons for exclusion) are presented in Appendix Tables 1 and 2.

Worldwide expenditure estimations are presented in Table 2. Aggregate direct treatment costs due to dental diseases worldwide were estimated at $297.67B; 82% of the estimated expenditures ($244.40B) occurred in high-income countries (North America: $120.08B; Western Europe: $91.05B; High-Income Asian Pacific: $23.30B; Australia: $7.03B; Southern Latin America: $2.93B). Latin America and the Caribbean accounted for $14.06B (Tropical Latin America: $6.92B; Central Latin America: $5.79B; Andean Latin America: $0.76B; Caribbean: $0.59B). South Asia contributed $12.84B. Eastern Europe ($6.12B), Central Europe ($2.75B), and Central Asia ($0.45B) together contributed $9.32B. North Africa and the Middle East contributed $8.33B. The region comprising East Asia ($5.02B), Southeast Asia ($0.75B), and Oceania ($0.02B) accounted for $5.79B; $2.96B was attributed to Sub-Saharan Africa (Southern: $2.70B; East: $0.20B; West: $0.04B; Central: $0.01B).

The results from robustness checks are shown in Appendix Tables 3 and 4. Findings in Appendix Table 3 show somewhat higher worldwide expenditures of $299.61B if GDP values from UN data are compared with $297.67B when based on GDP values from the World Economic Outlook Database. Appendix Table 4 highlights the extent of uncertainty in the estimation of...
worldwide dental expenditures. Using the mean expenditure level (95% confidence interval) of all GBD 2010 regions with primary expenditure information to impute missing expenditure values, worldwide expenditures were estimated at $311.14B (lower bound: $281.43B; upper bound: $340.85B). Uncertainty stems mostly from areas with sparse primary information on expenditure.

**Indirect Costs**

The estimates of worldwide productivity losses are set out in Table 3. Indirect costs due to major dental diseases amounted to $144.25B. Thereof, $63.03B (44%) was attributable to severe tooth loss, $53.99B (37%) to severe periodontitis, $25.14B (17%) to untreated caries in permanent teeth, and $2.09B (1%) to untreated caries in deciduous teeth. The highest productivity losses are found for Western Europe ($40.98B), High-Income North America ($30.19B), East Asia ($15.70B), High-Income Asia Pacific ($13.82B), and Eastern Europe ($6.17B); the lowest productivity losses are found for Oceania ($21.46 million), Sub-Saharan Southern Africa, Sub-Saharan Central Africa, and Sub-Saharan West Africa.

**Discussion**

The findings of the present study suggest that direct treatment costs due to dental diseases worldwide were $298B in the year 2010, corresponding to 4.6% of global health expenditure.
In addition, the annual indirect costs due to dental diseases (i.e., productivity losses) were estimated at $144B. Direct and indirect costs together amounted to an annual economic impact of $442B for 2010 alone; 83% of direct treatment costs were attributable to high-income countries. The global region with the next-largest amount of dental expenditures was Latin America and the Caribbean (5%), followed by South Asia (4%), Central/Eastern Europe and Central Asia (3%), North Africa and the Middle East (2%), Southeast Asia, East Asia and Oceania (2% of global expenditures), and Sub-Saharan Africa (1%). Forty-four percent of productivity losses were attributable to severe tooth loss, 38% to severe periodontitis, and 17% to untreated caries in permanent teeth. Economic losses of the top 10 global causes of death were recently estimated through a similar approach as the present study, to range between $895B (cancer) and $126B (lower respiratory infections; Cancer Society 2010). Therefore, the present study’s estimate for productivity loss due to dental diseases ($144B) may be interpreted in the sense that indirect costs due to dental diseases worldwide correspond to economic losses within the range of the 10 most frequent global causes of death.

Due to limitations in the underlying data sources, the findings of the present study should be interpreted with caution. For estimation of direct costs, relevant information was identifiable for only 66 of 187 countries (35%). Expectedly, our results emphasize considerable uncertainty in estimating global costs of dental diseases. Routine health expenditure information was found to be primarily published by departments of health or international organizations. Although information availability tended to be better for high-income countries, there is ample room for improvement in the quality,
standardization, and reporting of dental expenditures. In the absence of more comprehensive information, estimates of global expenditure are at risk of substantial upward or downward bias. Moreover, it is important to appreciate that without appropriate detail on coding the direct costs, figures cannot distinguish between the percentage of the economic burden aimed toward different treatment categories (e.g., disease avoidance [checkup, diagnosis, prevention]) and interventive treatment of dental disease (restorative, periodontal, and optional cosmetic care [tooth whitening]). For estimation of indirect costs, it was assumed that each DALY can be valued at 1 y of per capita GDP. In addition to limitations implied by the concept of DALYs themselves (Anand and Hanson 1997), the economic value of DALYs is affected by the size of per capita GDP of the various regions examined. Prioritization of health policies to improve oral health according to regions with high estimated economic impacts may impose risks of neglecting regions and countries with comparably small GDPs. Nevertheless, the results of the present study may serve as informative approximation of global economic impacts of oral diseases.

The present study emphasizes the urgent need to increase the availability of internationally comparable data on dental treatment costs, disease-specific absenteeism from work and school, as well as intangible costs of oral diseases in terms of quality of life. While in principle there are a number of suitable approaches available to estimate the economic burden of a specific disease, these have been rarely applied (Cancer Society 2010). In this regard, oral health is no exception. Data relevant to comprehensively assess the full magnitude of direct and indirect costs of dental and oral diseases still seem very sparse.

### Conclusion

Within the limitations of currently available data sources and thus still restricted methodologies to estimate the full costs of oral diseases, the findings of the present study suggest that the global economic burden of dental diseases amounted to $442B in 2010, of which $298B was attributable to direct treatment costs and $144B to indirect costs in terms of productivity losses due to caries, periodontitis, and tooth loss. The actual burden and cost of oral conditions are likely to be much higher as dental conditions such as oral cancer dysplasias of the oral mucosa, oral infections, oral developmental disorders (e.g., clefts of the lip and palate) and noma could not pertinently be included in this study. Further research on the cost of oral conditions should include all oral conditions, rather than be restricted to the most common dental conditions. Improvements in population oral health may imply substantial economic benefits not only in terms of reduced treatment costs but also because of fewer productivity losses in the labor market.
Author Contributions

S. Listl, W. Marcenes, contributed to conception, design, data acquisition, analysis, and interpretation, drafted the manuscript; J. Galloway, contributed to conception, design, data acquisition, analysis, and interpretation, critically revised the manuscript; P.A. Mossey, contributed to conception, design, data acquisition, analysis, and interpretation, critically revised the manuscript. All authors gave final approval and agree to be accountable for all aspects of the work.

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