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Costs-Outcome Description Arising From Side Effects due the Over-Prescription of Antibiotics in Oral Healthcare in Chile

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ABSTRACT

Objective: The aim of this study is to investigate the financial consequences of immediate side effects of antibiotic over-prescription in dentistry from a societal perspective; to improve resource allocation and antibiotic prescribing practices.

Methods: A cost-outcome description study was conducted, employing a decision tree model to estimate the costs arising from antibiotic over-prescription in oral healthcare. The model is based on a review of the relevant literature regarding current antibiotic prescribing practices in dentistry. It estimated the annual antibiotic prescription from 31 233 registered dentists in Chile (i.e., 1 624 428 prescriptions), with 55% of these considered unnecessary. Direct costs from a societal perspective were evaluated over a one-year time horizon, including medical services, lost income, and transportation costs. A sensitivity analysis was performed to assess the robustness of the findings.

Results: The total societal cost of antibiotic over-prescription in dentistry was estimated at CLP: 8545478768 (USD: 9519516), including CLP: 3275870238 (USD: 3649263) for unnecessary prescriptions, and CLP: 5269608530 (USD:5870253) for adverse reactions. The sensitivity analysis indicated that variations in the percentage of unnecessary prescriptions significantly influenced the overall costs, ranging from CLP: 6991755356 (USD: 7788695) to CLP: 10099202180 (USD: 11250337).

Conclusion: The study evaluated the economic burden of antibiotic over-prescription in oral healthcare, in terms of adverse reactions, highlighting the need for better prescribing practices. It suggested that significant cost-savings (USD: 9.5 million) could be achieved by reducing unnecessary antibiotic prescriptions. By addressing this challenge, we can not only alleviate the financial burden on society but also contribute to the global fight against antimicrobial resistance.

1 | Introduction

Antimicrobials are a standard and important therapy for the treatment of oral infections. When prescribed appropriately, there are benefits as well as risks for patients [1]. In addition to side effects and adverse reactions, increasing attention is being paid to the potential impacts of antimicrobial resistance. The dental profession highlights the importance of antimicrobial stewardship and promotes responsible prescribing [1]. Antimicrobials should only be prescribed when there is a clinical indication

Abbreviations: CHEERS, Consolidated Health Economic Reporting Standards; CLP, Chilean pesos; ICU, Intensive Care Unit; USD, USA dollars.

for this [2]. Oral infections (e.g., dental abscesses, pericoronitis) are a common occurrence within dental settings; they can lead to significant complications if not addressed promptly [3]. Moreover, it is estimated that dentists are responsible for 10% of all antibiotic prescriptions [4].

When antibiotics are needed, it is important to prescribe the right drug, at the right dose, and for the right duration, to minimize antimicrobial resistance risks [3]. On the other hand, overprescription of antibiotics in dentistry refers to the practice of prescribing antibiotics in dental treatment when they are unnecessary or the issue could be managed with alternative approaches [5]. Numerous studies of dental antibiotic prescribing show that overprescribing occurs worldwide, with dentists prescribing for unnecessary indications, often without concurrent dental treatment [6–9].

There are several factors that contribute to overprescription of antibiotics in dentistry [10]. One factor is the misconception that antibiotics are always necessary in treating dental infections [11, 12]. Dentists may also prescribe antibiotics as a precautionary measure or due to patient expectations, even in cases where infection could be managed effectively without them [9]. Lack of knowledge or of clear guidelines and the latest evidence-based guidelines about appropriate antibiotic use may also play a role in overprescribing [12, 13].

Addressing overprescription of antibiotics in dentistry requires a comprehensive approach. This includes educating dental practitioners on appropriate antibiotic use through continuing education programs and incorporating evidence-based guidelines into clinical practice [11]. Dentists should also engage in shared decision-making with patients, providing them with information about the risks and benefits of antibiotic treatment options [2].

To address the issue of overprescription, dental professionals should adhere to the most recent evidence-based guidelines and ensure appropriate diagnostic evaluation before prescribing antibiotics. Education, training, and awareness campaigns can help improve dentists' knowledge and promote responsible antibiotic use. Additionally, fostering effective patient communication and providing education on the appropriate use of antibiotics are essential in managing patient expectations [9].

Overprescription of antibiotics contributes to the growing problem of antibiotic resistance and has negative impacts on patient health and public health. Overprescribing can cause side effects, allergic reactions, and gastrointestinal issues, leading to costly healthcare burdens for individuals and society [14]. Quantifying healthcare expenses is crucial for decision-makers to take action against unnecessary spending, enabling resource reinvestment into new health services. Economic evaluations help manage resources effectively, identify inefficiencies, and optimize their use to maximize their impact on population health.

This study aims to investigate the immediate costs of side effects arising from antibiotics overprescription in dentistry and assess the potential financial consequences from a societal perspective in Chile. By analysing related costs and associated expenses, it seeks to provide insights for policymakers and dental professionals to enhance resource allocation and promote informed antibiotic prescribing practices. Understanding the societal impact of inappropriate antibiotic use will support the development of interventions aimed at improving prescribing practices and patient outcomes and optimizing healthcare resource allocation.

2 | Methods

2.1 | Study Design

A cost-outcome description study was conducted with the aim of calculating the costs arising from the over-prescription of antibiotics in oral healthcare and its consequences (i.e., adverse reactions to antibiotics) [15]. To this end, a decision tree was utilized; although in this case, only one branch representing the alternative of prescribing antibiotics was considered. From this branch, the probabilities of antibiotics being prescribed without appropriate indication—that is, being over-prescribed—were calculated. Additionally, the likelihood of patients with antibiotic over-prescription experiencing allergies and the various manifestations of these allergic reactions was evaluated.

2.2 | Population and Sample

The model was based on the number of dentists registered in the national registry in 2023; that is 31 233 dentists [16]. To estimate the number of patients receiving antibiotics, an approximation of the number of antibiotic prescriptions issued by dentists was calculated.

No data was found for how many antibiotics a dentist would prescribe in Chile; however, a review of the literature indicated a range of between 29 and 153 prescriptions a year [17–24]. Therefore, following Halling and collaborators [24], for this analysis an average of 52 antibiotics prescribed per year was assumed, equating to one prescription per week. Consequently, 31 233 dentists would prescribe an estimated 1 624 428 prescriptions in 1 year, regardless of whether the indication is appropriate or not. Of these prescriptions, it is estimated that 55% may not be required and are thus considered over prescribed [22].

2.3 | Perspective and Time Horizon

This study considered the phenomenon of antibiotic overprescription from a societal perspective. It examined the direct costs borne by payers, resulting from services utilized by patients. The services were used either due to the acquisition of over-prescribed antibiotics or care required due to adverse reactions. It also took into account costs incurred by patients, including lost income due to treatment or hospitalization, as well as transport costs to access medical care.

The time horizon considered was 1 year. All probabilities and costs were calculated for a year of dental care, both for antibiotic indications and for adverse reactions that may arise from their use. By limiting the time horizon to 1 year, the analysis allows for a focused examination of short-term outcomes, which is particularly relevant for this evaluation. Since the analysis is limited to 1 year, discount rates were not applied to either the outcomes or the costs.

2.4 | Health Outcomes

Four stages were defined in the potential outcomes stemming from antibiotic administration.

a. In the first stage, the probability that the antibiotic was unnecessary was assessed.
b. In the second stage, the likelihood of the patient experiencing an adverse reaction was considered.
c. In the third stage, the probabilities of the adverse reaction being mild—requiring only an antihistamine, and the patient recovering without further complications—were calculated.
d. Finally, in the fourth stage, the probabilities of the adverse reaction being moderate were considered, with four possible outcomes: subjective symptoms, skin reactions, angioedema, gastrointestinal issues attributable to the antibiotics, or anaphylactic reactions that may require the patient to spend 12 h in observation, in addition to receiving antihistamines [25].

   Within the group of patients experiencing anaphylactic reactions, a percentage may also present severe reactions necessitating hospitalization.

The probabilities for each of the outcomes utilized in the model were derived from the best available evidence in the literature (See Table 1).

According to the literature, approximately 10% of patients receiving antibiotics experience adverse reactions [26, 27]. Among those who have an allergic reaction, approximately 30%–35% will exhibit mild subjective symptoms and forgo care [26]. Conversely, 65%–70% will experience moderate symptoms requiring medical attention, although their symptoms typically resolve within 12 h [26]. Of those experiencing moderate symptoms, 56% will have a skin reaction and receive treatment [20, 28]; 9% will experience angioedema [28]; 24% will have subjective symptoms requiring care; 6% will experience gastrointestinal problems attributable to antibiotics [28]; and 5% will suffer from anaphylactic reactions [28].

Among patients experiencing anaphylaxis, around 90% resolve within 12 h [28]; while 10% will require hospitalization. These hospitalizations would require intensive care unit (ICU) care for an average of 4 days [26, 29–31]. In this analysis, two types of hospitalizations are considered [32]: the majority (98.5%) would need moderate care in the ICU. The remaining 1.5% would experience more severe, near-fatal reactions, such as hypoxia, hypotension, or shock [26, 32] and would require critical care at the ICU. Notably, the literature indicates that deaths due to adverse reactions to medications in dentistry are uncommon [20, 26, 33, 34]. Therefore, this model did not account for any deaths.

2.5 | Resources and Costs

To estimate costs, a table was created detailing the medical actions and medications required for each of the possible scenarios (See Supporting Information). This information was gathered based on relevant clinical guidelines [25, 33, 34] and validated with expert opinions in the area of emergency medicine. For medical procedures, the current National Health Fund's fee schedule for each procedure, based on the Ministry of Health's Institutional Care Modality, was employed [35]. Regarding medications, cost information available on the National Health Fund's website was used [36].

TABLE 1 | Conceptual outcome model outlining adverse reactions to antibiotics prescribed in dental settings.

Antibiotic needed [22]:

Yes: (45%) **Terminal node**

No: (55%):

Adverse reaction [26, 27]:

No (90%) **Terminal node**

Yes: (10%):

Mild (30%–35%. Patients with immediate reactions develop their symptoms with a time interval of minutes to 1 h after taking the drug [26]). **Terminal node**

Moderate (65%–70%. Hospital visit. 90% Improvement after 12 h [26]):
- Some subjective symptoms and receive diagnostic care (24%) [28].
- Skin reaction and receive treatment (56%) [20, 28].
- Angioedema (9%) [28].
- Gastrointestinal problems attributable to antibiotics (6%) [28].

Severe Anaphylaxis reaction (5%) [28]:
- No need for intensive care unit support. Resolve within 12 h (90%) [28].
- Require hospitalization for 4 days (10%) [26, 29–31].
  - No need for intensive care unit support (98.5%) [32].
  - Near-fatal reactions (1.5%): Hypotension or shock, life-threating [26, 32].

By adding the costs of medical actions and medications, the total cost for each possible scenario was derived. For more specific details on costing, Supporting Information provides additional information (See Supporting Information).

To calculate patients' resources used in adverse effect treatments (i.e., transport and productivity losses) work productivity losses were calculated by the minimum hourly salary in 2024 [37]. Transportation costs were calculated for one adult by multiplying the number of trips by the number of visits required using public transportation for moderate cases. For severe cases, it was assumed that an ambulance would be needed (See Supporting Information).

2.6 | Currency, Price Date, and Conversion

All cost analyses were conducted in Chilean pesos (USD1 = CLP 897.68) as of October 1, 2024 (https://www.xe.com/currencyconverter/convert/?Amount=1&From=USD&To=CLP).

2.7 | Analysis and Assumptions

A comprehensive analysis of the costs involved in the over-prescription of antibiotics in the context of oral healthcare was conducted. Costs were described separately for those arising from the use of over-prescribed antibiotics without adverse effects, and those patients who experienced adverse effects following the administration of inappropriately indicated antibiotics.

Among the most relevant assumptions considered in this analysis were:

a. That Amoxicillin would be the antibiotic prescribed in all cases. Amoxicillin is the most frequently prescribed antibiotic by dentists [20].

b. That the dose and regimen for amoxicillin would be 500 mg every 8 h or 1 g every 12 h for 7 days [10].

c. That each patient experiences only one adverse effect at a time.

d. That no fatal cases were associated with adverse reactions to antibiotics in dental settings [33, 34].

e. That patients were aware of their allergic conditions, asking for an alternative when necessary [28, 33].

f. Transportation costs: It was assumed that 80% of the patients were living in urban areas and 20% in rural areas [38]. Of the urban patients, 87.5% (70% of the total) used public transportation, and the rest used private transportation. Of the 20% of rural patients, 75% (15% of all patients) used public transportation; the rest used private transportation. The transportation cost in the model was a weighted average of the costs in the different circumstances and their estimated usage rates.

g. Loss of productivity: Adverse reactions can cause loss of workdays for patients, which translates into loss of income for individuals. It was also assumed that cases generally attend accompanied by another adult. It was assumed that 80% of mild cases attend accompanied and 100% of moderate to severe cases attend accompanied or receive company during treatment or observation time. The calculations of lost productivity were made based on the Chilean minimum wage [37].

h. For patients experiencing severe adverse reactions to antibiotics (i.e., life-threatening), the length of hospital stay was considered to be an average of 4 days [29].

i. That all patients will use the public health system to treat adverse reactions.

j. Long-term health consequences due to antibiotic misuse due to antibiotic resistance were not included in the current analysis.

2.8 | Sensitivity Analysis

A one-way sensitivity analysis was conducted to assess the robustness of the results with respect to varying estimated parameter values [39, 40]. The sensitivity analysis involved the following assumptions:

a. Number of prescribed antibiotics per year, varying by ±10% around the point estimate reported in the literature [24] (i.e., 46.8–57.2 prescriptions per year).

b. The impact of over-prescription on spending. A margin of ±10% from the average reported in the literature (i.e., 45% – 65%).

c. Proportion of patients experiencing allergic reactions to antibiotic administration, varying by ±1% (i.e., 9% – 10%).

d. Length of hospital stays of patients experiencing severe allergic reactions to antibiotic administration, varying by ±1 day (i.e., 3–5 days).

This report adheres to the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) [41]. Because this is a model-based analysis utilizing data from the literature, ethical approval is not required.

3 | Results

Based on an estimated 1 624 428 antibiotics prescribed in a year, and the evidence that approximately 55% of those prescriptions would be over-prescribed (i.e., 893 344), the model outlines that the costs associated with improperly prescribed antibiotics for patients who did not experience adverse effects amounted to CLP 3275870238 (USD 3649263).

According to the probabilities outlined in the model, 10% of patients receiving antibiotics may experience some form of adverse reaction. Considering the calculated costs for various levels of severity of these adverse reactions, which account for both the financial burden on the payer due to medical services rendered and the costs incurred by the patient, including lost productivity and transport expenses, it was found that the costs resulting from treatments related to adverse reactions to unnecessarily

prescribed antibiotics amounted to CLP 5269608530 (USD 5870253).

Calculating the expenditures arising from the over-prescription of antibiotics, the total monetary loss to society is CLP 8545478768 (USD 9519516). Table 2 presents details of the cumulative probabilities throughout the model and the costs associated with each service, along with their respective subtotals.

4 | Sensitivity Analysis

Overall, the sensitivity analysis indicated that the total financial losses incurred by society due to expenses associated with the over-prescription of antibiotics were influenced by assumptions related to various other costs. The different scenarios of the selected variables designed to characterize this uncertainty can be found in Table 3.

The variable that most influenced the model was the proportion of patients that received an unnecessary prescription of antibiotics (50% in base model; range: 45%–65%). Considering the lower and upper limit of consultations that may involve an unnecessary antibiotic prescription, keeping all other parameters unchanged, the society losses ranged between CLP 6991755356 (USD 7788695) to CLP 10099202180 (USD 11250337).

5 | Discussion

The findings of this study highlight the significant financial burden associated with the over-prescription of antibiotics within a mixed healthcare system, in the context of oral healthcare. Based on a population of 1 624 428 individuals who received antibiotics from approximately 31 239 dentists, our primary analysis suggests that over half of (55%) these prescriptions could be considered unnecessary, indicating a loss of over 8.5 billion

TABLE 2 | Antibiotic indication, allergic reaction, severity and probabilities, and respective costs related to patients experiencing adverse reactions.

Antibiotics indication	Allergic reaction	Severity allergic reaction	Type of allergic reaction	Probability (%)	Number of prescriptions	Costs of treatment (CLP)	Total costs (CLP)
No	No			0.4950000	804 091	4074	3 275 870 238
No	Yes	Mild		0.0178750	29 037	14 794	429 568 207
No	Yes	Moderate	Subjective Symptoms: patient receives attention	0.0089100	14 474	28 500	412 500 001
No	Yes	Moderate	Skin Reaction: patient receives treatment	0.0207900	33 772	95 295	3 218 285 126
No	Yes	Moderate	Angioedema	0.0033413	5428	91 575	497 033 649
No	Yes	Moderate	Gastrointestinal issues due to antibiotics	0.0022275	3618	83 270	301 304 843
No	Yes	Moderate	Anaphylactic reaction (improves in 12 h)	0.0016678	2709	113 084	306 377 833
No	Yes	Severe	Anaphylactic reaction (improves after four days of hospitalization with ICU moderate care)	0.0001856	302	330 594	99 685 511
No	Yes	Severe	Anaphylactic reaction (improves after four days of hospitalization with ICU critical care)	0.0000027	4.52	1 073 036	4 853 360
Yes				0.4500000	730 992	0	0
Total				1.0	1 624 428		8 545 478 768

Abbreviations: CLP: Chilean pesos; ICU: Intensive Care Unit.

TABLE 3 | Sensitivity analysis results.

	Quantity or probability	Expenditure on antibiotics*	Expenditure patients with adverse reactions*	Total expenditure*	Total expenditure US $**
Base model		3 275 870 238	5 269 608 530	8 545 478 768	9 519 516
Annual antibiotic prescriptions per dentist					
Lower limit	46.8	2 948 283 214	4 742 647 677	7 690 930 891	8 567 564
Upper limit	57.2	3 603 457 261	5 796 569 383	9 400 026 645	10 471 467
Patients who receive antibiotics when they are not medically necessary					
Lower limit	45%	2 680 257 467	4 311 497 888	6 991 755 356	7 788 695
Upper limit	65%	3 871 483 008	6 227 719 172	10 099 202 180	11 250 337
Expenditure related to patients' adverse reactions					
Lower limit	9%	3 312 268 796	4 742 647 677	8 054 916 473	8 973 038
Upper limit	11%	3 239 471 679	5 796 569 383	9 036 041 063	10 065 994

*CLP=Chilean Pesos.
**US$1 = CL$ 897.68 CLP.

Chilean pesos due to unnecessary expenditures on prescribed antibiotics, as well as additional expenses arising from adverse reactions experienced by patients. Adverse reactions, affecting 10% of patients, contribute significantly to the financial burden, which includes medical costs, lost productivity, transportation expenses, and the allocation of resources that could be utilized for other health conditions.

Moreover, findings indicate that even when the most positive assumptions in the primary analysis are used, the potential cost to society is significant. The sensitivity analysis showed that the percentage of dental visits involving antibiotic prescriptions was a key variable influencing the financial outcomes of the model. The primary analysis utilized an average of 55% of individuals, with a sensitivity range of 45%–65% (i.e., ranging from (6 991 755 356 (USD 7788695) to CLP 10099202180)). This emphasizes the need to accurately estimate this parameter. It also suggests that education and training of oral healthcare professionals aimed at reducing unnecessary prescriptions could lead to substantial cost savings to society.

To enhance antibiotic stewardship within dental settings, it is essential to implement strategies such as evidence-based interventions [42, 43], audits and feedback mechanisms, and increased awareness of established protocols for managing dental infections [1]. Collaboration among dental professionals and public health agencies is crucial in the development and enforcement of guidelines and policies that encourage responsible and appropriate antibiotic utilization in the field of dentistry [42, 44].

However, the financial burden to society presented in this analysis can be considered a conservative estimate for several reasons. This analysis only included the most immediate financial implications and outcomes. The over-reliance on antibiotics in dental practice not only affects individual patients but also has the potential to have an impact on community health at large. It is also critical to consider the broader longer-term outcomes (e.g., economic consequences and public health implications) of antibiotic over-prescription. For example, unnecessary use of antibiotics contributes to the global challenge of antimicrobial resistance, which poses a serious threat to healthcare systems worldwide. Antimicrobial resistance would lead to increased healthcare expenditure across the system, including the human costs due to premature death [45, 46]. Also, other non-health costs associated were not included in this analysis, such as the impact on work, family connections, living standards, social interactions, personal functioning, and quality of life for patients and their families. The human costs due to morbidity and mortality associated with antibiotic-resistant diseases and premature death should also be considered [45, 47]. Such costs add another layer of complexity to the issue and should be included in future research. In addition, the model assumed only one adverse reaction per patient. However, there is no guarantee that this would be the case. If these monetary and non-monetary consequences had been accounted for, the analysis of the overall impact of overprescribing would have been even more unfavorable.

Additionally, while the findings of this study provide valuable insights for healthcare policymakers and dental practitioners to prioritize strategies that promote correct antibiotic use, it is important to acknowledge its limitations. The model relied on several assumptions and estimates that may not fully encapsulate the complexities of real prescribing practices in dentistry. As such, this study represents merely the first step in understanding the immediate financial implications of antibiotic overprescribing in dental settings and its impact on the utilization of society's healthcare resources. Additionally, the model did not include dental consultations in general medical practice [48] and antibiotic prescribing associated with these consultations [6]. Importantly, as mentioned before, the model used did not include the impacts on society from antibiotic resistance.

The sensitivity analysis conducted in this study highlights the importance of understanding uncertainty within this model. The variation in outcomes, contingent upon the percentage of dental visits that involve antibiotics, underscores the necessity for further studies that can yield more precise estimates and consider various scenarios. Implementing public health policies based on robust and up-to-date data will be essential to addressing the antibiotic resistance crisis and enhancing dental care in Chile. Longitudinal studies examining prescribing trends, patient outcomes, and the effectiveness of intervention strategies would also be beneficial in informing future policies. Furthermore, while the model used and the findings are immediately valid for the local situation (i.e., Chile), they may not directly apply in other jurisdictions [49].

Despite these limitations, this research provides a framework for evaluating the costs associated with antibiotic over-prescription in dentistry, facilitating the identification of areas for improvement in clinical practice and contributing to the development of more effective health policies. However, further research is necessary to validate these findings and explore the underlying factors contributing to antibiotic over-prescription in dental care in Chile.

6 | Conclusion

The economic and public health ramifications of antibiotic over-prescription in oral healthcare are significant. With a budget of CLP 8.5 billion (USD 9.5 million) several dental public health initiatives could be implemented in the community, including extensive preventive care, restorative services, and educational programs. These findings highlight the urgent need for coordinated efforts to enhance prescribing practices, reduce unnecessary antibiotic use, and ultimately protect both individual and community health. Additionally, by addressing these challenges, we can not only alleviate the financial burden on society but also contribute to the global fight against antimicrobial resistance.

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Ethics Approval and Consent to Participate

Ethics approval and consent to participate are not applicable for this manuscript. The data utilized in this manuscript is publicly available.

Consent

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data used in this manuscript has been made available in the manuscript or as Supporting Information.

Peer Review

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1.** Supporting Information.