Research Square

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Metabolic syndrome is associated with severe tooth loss–related outcomes in a nationally representative Chilean sample

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Abstract

Background

Metabolic syndrome (MS) and oral health outcomes have been insufficiently characterized in Latin America using population-representative data. This study examined the association between MS and tooth loss–related oral health indicators in Chilean adults.

Methods

We conducted a cross-sectional secondary analysis of 3,489 participants from the Chilean National Health Survey (ENS) 2016–2017. MS was defined using National Cholesterol Education Program Adult Treatment Panel III criteria adapted for Chile. Outcomes included cavitated caries, nonfunctional dentition (< 20 teeth), complete edentulism, and denture use. Associations were estimated using survey-weighted logistic regression in unadjusted and multivariable models, adjusting for age, sex, educational attainment, area of residence, region, and health insurance.

Results

MS prevalence was 45.1%. Participants with MS were older and more socioeconomically vulnerable. MS was independently associated with denture use (adjusted OR 1.32; 95% CI 1.09–1.59), nonfunctional dentition (adjusted OR 1.85; 95% CI 1.53–2.24), and complete edentulism (adjusted OR 2.17; 95% CI 1.41–3.33), but not with cavitated caries (adjusted OR 0.97; 95% CI 0.82–1.15). Among MS components, hypertension and abdominal obesity showed the strongest associations with tooth loss–related outcomes. Sensitivity analyses confirmed the robustness of findings. Models showed good discrimination (area under the receiver operating characteristic curve [AUC] 0.78–0.87).

Conclusions

In a nationally representative Chilean sample, MS was strongly and independently associated with cumulative tooth loss–related outcomes but not with cavitated caries. These findings support integrating oral risk assessment into metabolic care in primary health settings, particularly for socioeconomically vulnerable populations.

INTRODUCTION

Metabolic syndrome (MS) is a prevalent cardiometabolic condition defined by the clustering of abdominal obesity, hypertension, dyslipidemia, and hyperglycemia, and is a major risk factor for type 2 diabetes and cardiovascular disease [1]. In Chile, approximately 40% of adults meet diagnostic criteria for MS, reflecting a substantial population burden [2]. In parallel, oral conditions remain highly prevalent

and contribute to functional limitation and reduced quality of life; in Chile, population-based data report a high prevalence of cavitated caries, and periodontal disease burden is also substantial [2–4]. Global evidence further underscores the large population burden of oral conditions [5].

Growing evidence suggests that systemic metabolic dysregulation and oral health are interconnected through shared inflammatory pathways and behavioral determinants [6–8]. Chronic low-grade inflammation and metabolic disturbances characteristic of MS may disrupt immune responses and tissue homeostasis in the oral cavity, potentially increasing susceptibility to periodontal breakdown and cumulative tooth loss [8–10]. In addition, diet-related exposures and oral microbiome dysbiosis have been proposed as relevant pathways linking systemic metabolic risk and oral disease processes [11, 12]. While prior research has largely focused on periodontitis and bidirectional associations, population-based evidence linking MS to tooth loss–related outcomes remains scarce, particularly in Latin America [7, 13].

A recent analysis of the same nationally representative survey used in the present study found that multimorbidity—defined as the co-occurrence of two or more chronic conditions—was associated with moderate and severe tooth loss in Chilean adults [14]. However, that study did not examine MS as a distinct exposure, did not characterize individual cardiometabolic components, and did not adjust for health insurance coverage or regional variation. The present study addresses these gaps by focusing specifically on MS and its constituent components as determinants of tooth loss–related outcomes.

Tooth loss and nonfunctional dentition are clinically meaningful endpoints that capture cumulative oral disease burden and are strongly associated with impaired mastication, nutritional compromise, and adverse systemic outcomes [5, 15]. However, whether MS is independently associated with these outcomes at the population level is unclear.

Using nationally representative data from the Chilean National Health Survey 2016–2017, this study examined the association between MS and cavitated caries, nonfunctional dentition, and complete edentulism. We hypothesized that MS would be independently associated with tooth loss–related outcomes after accounting for sociodemographic factors. Clarifying this relationship may inform integrated medical–dental risk assessment strategies in primary care, particularly in socially vulnerable populations [16, 17].

METHODS

Study Design and Data Source

This observational, descriptive, cross-sectional secondary analysis utilized data from the National Health Survey (ENS) 2016-2017, a nationally representative survey of Chilean individuals aged ≥14 years [2]. The ENS used a stratified, multistage, clustered probability sampling design and standardized field protocols including interviews, anthropometry, blood pressure measurements, fasting blood sampling, and an oral health questionnaire and examination. Oral health outcomes were ascertained from Module V (Oral

Health Examination) of ENS *Formulario 2* (F2), a standardized clinical assessment instrument developed for the ENS by the Ministry of Health of Chile and the Pontificia Universidad Católica de Chile, and publicly available through the MINSAL repository [2]. This study was conducted and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies.

Study population

The ENS enrolled 6,233 participants. Missing data were handled using complete-case analysis. A total of 2,744 participants were excluded due to missing values on at least one study variable; the distribution of missing data by variable is reported in **Additional file 1: Appendix Table 6**. We assessed potential selection bias by comparing baseline characteristics between included and excluded participants. Participants were residents of private occupied dwellings across all regions of Chile; individuals unable to complete the interview or clinical components due to severe physical, cognitive, or communication limitations were excluded per ENS procedures. As this study constitutes a secondary analysis of an existing nationally representative survey, a formal a priori power calculation was not performed. The final analytic sample (n=3,489) was determined by data availability and complete-case inclusion criteria.

Variables

MS was defined according to the ENS operationalization of NCEP ATP III criteria, as the presence of ≥3 of the following: fasting glucose ≥100 mg/dL or diabetes medication use; blood pressure ≥130/85 mmHg or antihypertensive treatment; triglycerides ≥150 mg/dL or lipid-lowering treatment; HDL cholesterol <40 mg/dL (men) or <50 mg/dL (women) or treatment; and waist circumference ≥102 cm (men) and ≥88 cm (women).

Oral health outcomes were derived from the ENS standardized dental assessment and questionnaire using tooth counts from the clinical F2 examination and the adjusted total number of remaining teeth. Cavitated caries was defined as the presence of at least one clinically recorded cavitated lesion, nonfunctional dentition as fewer than 20 remaining natural teeth, complete edentulism as zero remaining natural teeth, and denture use as any reported prosthesis. Tooth counts reflected the clinical exam and were adjusted for interval tooth loss between examination and interview, with missing codes handled according to ENS specifications. Further details on variable operationalization are provided in the **Additional file 1: Supplementary Appendix Methods**.

We selected covariates a priori based on plausibility as confounders of the MS–oral health relationship: age (years, continuous), sex (women/men), educational attainment (<8, 8–12, ≥13 years), area of residence (urban/rural), region, and health insurance (FONASA, ISAPRE, other/none).

Statistical analysis

All analyses incorporated the ENS complex survey design (sampling weights, stratification, and clustering) to produce population-representative estimates and appropriate variance estimation. We summarized participant characteristics using weighted proportions for categorical variables and weighted means (or medians, as appropriate) for continuous variables.

We estimated associations between MS and each oral outcome using survey-weighted logistic regression, reporting odds ratios (ORs) with 95% confidence intervals (CIs). We fitted (i) an unadjusted model including MS only and (ii) a fully adjusted model including all prespecified covariates. To describe whether specific MS components were associated with tooth loss indicators, we additionally modeled each component (entered separately) against nonfunctional dentition and edentulism using the same adjustment set. A detailed description of the hierarchical model building strategy, classification metrics, and model diagnostics is available in the **Additional file 1: Supplementary Appendix Methods**.

Analyses were conducted in R (version 4.4.1) using survey procedures for complex samples. Statistical significance was set at $\alpha=0.05$ (two-sided).

RESULTS

Metabolic Syndrome Clusters in Older and Socioeconomically Vulnerable Adults

Among 3,489 participants, 1,574 (45.1%) met criteria for MS (**Additional file 1: Appendix Table 1**). Participants with MS were substantially older than those without MS (56.2 ± 16.6 vs. 43.7 ± 19.5 years; $P < 0.001$), while sex distribution did not differ between groups (63.3% vs. 63.7% women; $P = 0.821$).

Marked socioeconomic gradients were observed. Lower educational attainment was more prevalent among individuals with MS, with nearly one-third reporting <8 years of schooling compared with 16.6% among those without MS ($P < 0.001$), whereas higher education (≥13 years) was less frequent in the MS group. Rural residence was also more common among participants with MS (17.5% vs. 14.2%; $P < 0.001$).

Health insurance coverage differed between groups, with a higher proportion of individuals with MS affiliated with the public insurance system (FONASA A–B: 55.5% vs. 45.7%) and a lower proportion covered by private insurance (ISAPRE: 7.8% vs. 9.7%) ($P < 0.001$).

These patterns indicate that MS in this nationally representative sample was concentrated in older adults and those exposed to greater socioeconomic vulnerability.

Metabolic Syndrome is Strongly Associated with Tooth Loss–Related Outcomes but Not Cavitated Caries

Participants with MS exhibited substantially worse tooth retention and a higher prevalence of prosthetic rehabilitation than those without MS. Mean numbers of remaining teeth were lower in both the maxilla (7.73 ± 5.58 vs. 10.6 ± 5.03) and mandible (9.22 ± 4.87 vs. 11.4 ± 4.31; both $P < 0.001$). Nonfunctional dentition (< 20 teeth) affected 67.8% of participants with MS compared with 32.5% without MS, and complete edentulism was more prevalent among those with MS (8.3% vs. 2.1%; both $P < 0.001$). Denture use was nearly twice as common in the MS group (42.4% vs. 23.1%; $P < 0.001$).

In crude analyses, MS was strongly associated with denture use (adjusted OR = 2.45; 95% CI, 2.12–2.84), nonfunctional dentition (adjusted OR = 4.37; 95% CI, 3.82–5.01), and complete edentulism (adjusted OR = 4.26; 95% CI, 2.95–6.14) (all $P < 0.001$), whereas cavitated caries showed no association (adjusted OR = 1.12; 95% CI, 0.97–1.29; $P = 0.142$) (**Table 1**).

After multivariable adjustment for age, sex, region, urban/rural residence, insurance, and education, MS remained independently associated with denture use (adjusted OR = 1.32; 95% CI, 1.09–1.59; $P = .004$), nonfunctional dentition (adjusted OR = 1.85; 95% CI, 1.53–2.24; $P < 0.001$), and complete edentulism (adjusted OR = 2.17; 95% CI, 1.41–3.33; $P < 0.001$) (**Table 2**; **Additional file 1: Appendix Table 2a and 2b**). No association was observed for cavitated caries after adjustment (adjusted OR = 0.97; 95% CI, 0.82–1.15; $P = 0.742$) (**Additional file 1: Appendix Table 2c**). Detailed hierarchical model progressions, optimal classification thresholds, and comparative predictive performance metrics (e.g., AUC) across all outcomes are provided in **Additional file 1: Appendix Tables 3 and 4**.

Table 1. **Association between metabolic syndrome and oral health outcomes**. Values are n (%), weighted to the Chilean adult population. Crude odds ratios (ORs) with 95% confidence intervals (CIs) were estimated using survey-weighted logistic regression in the complete-case analytic sample, with absence of MS as the reference category. MS: metabolic syndrome; OR: odds ratio; CI: confidence interval. Nonfunctional dentition defined as <20 remaining natural teeth; complete edentulism as 0 remaining natural teeth.

Outcome	No MS (n=1,915)	MS (n=1,574)	Crude OR	95% CI	*P* value
Denture use (any)	443 (23.1%)	668 (42.4%)	2.45	2.12–2.84	< 0.001
Nonfunctional dentition (<20 teeth)	622 (32.5%)	1,067 (67.8%)	4.37	3.82–5.01	< 0.001
Complete edentulism	40 (2.1%)	131 (8.3%)	4.26	2.95–6.14	< 0.001
Cavitated caries (≥1 lesion)	681 (35.6%)	601 (38.2%)	1.12	0.97–1.29	0.142

Table 2. **Adjusted associations between metabolic syndrome and oral health outcomes**. Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) and P-values were obtained from fully adjusted survey-weighted logistic regression models (Model 7) including age, sex, region, urban/rural residence, health insurance system, and educational attainment. Area under the receiver operating characteristic curve (AUC) and Nagelkerke R^2 were computed for the fully adjusted model. Absence of MS as reference category. MS: metabolic syndrome; OR: odds ratio; CI: confidence interval; AUC: area under the receiver operating characteristic curve.

Outcome	Adjusted OR	95% CI	*P* value	AUC	Nagelkerke R^2
Denture use (any)	1.32	1.09–1.59	0.004	0.88	0.31
Nonfunctional dentition (<20 teeth)	1.85	1.53–2.24	< 0.001	0.92	0.42
Complete edentulism	2.17	1.41–3.33	< 0.001	0.87	0.28
Cavitated caries (≥1 lesion)	0.97	0.82–1.15	0.742	0.85	0.15

Hypertension and Central Obesity Show the Strongest Associations with Tooth Loss Indicators

Each MS component was individually associated with tooth loss–related outcomes (**Table 3**). Hypertension showed the strongest associations with nonfunctional dentition (adjusted OR = 2.89; 95% CI, 2.52–3.31), complete edentulism (adjusted OR = 3.45; 95% CI, 2.31–5.15), and denture use (adjusted OR = 2.23; 95% CI, 1.94–2.56). Abdominal obesity and hyperglycemia also showed robust associations with nonfunctional dentition (adjusted OR = 2.65 and 2.34, respectively) and edentulism (adjusted OR = 2.89 and 3.12, respectively), while hypertriglyceridemia exhibited consistent but more moderate effects across outcomes. Low HDL cholesterol showed the weakest, yet statistically significant, associations with tooth loss indicators.

Model diagnostics supported adequate calibration and absence of multicollinearity across adjusted models (Hosmer–Lemeshow $P > 0.13$ for all outcomes; variance inflation factors < 2.24) (**Additional file 1: Appendix Table 5**). Sensitivity analyses excluding participants older than 65 years yielded comparable estimates and preserved statistical significance for nonfunctional dentition (adjusted OR = 1.72; 95% CI, 1.35–2.19), complete edentulism (adjusted OR = 1.89; 95% CI, 1.08–3.31), and denture use (adjusted OR = 1.28; 95% CI, 1.01–1.63), indicating robustness of the primary findings.

Table 3. **Associations between metabolic syndrome components and oral health outcomes**. Crude odds ratios (ORs) with 95% confidence intervals (CIs) were estimated using survey-weighted logistic regression for each MS component entered separately, without adjustment for covariates. Cavitated

caries was excluded as no association with MS was observed in primary analyses (Table 1). All ORs were statistically significant at $P < 0.001$. MS: metabolic syndrome; OR: odds ratio; CI: confidence interval. MS components were defined according to ENS operationalization of NCEP ATP-III criteria: NCEP, National Cholesterol Education Program; ATP-III, Adult Treatment Panel III. Nonfunctional dentition defined as <20 remaining natural teeth; complete edentulism as 0 remaining natural teeth; denture use as any prosthetic appliance.

MS Component	Nonfunctional dentition OR (95% CI)	Complete edentulism OR (95% CI)	Denture use OR (95% CI)
Hypertension	2.89 (2.52–3.31)	3.45 (2.31–5.15)	2.23 (1.94–2.56)
Hypertriglyceridemia	2.12 (1.85–2.42)	2.67 (1.84–3.87)	1.78 (1.56–2.04)
Low HDL cholesterol	1.89 (1.65–2.16)	2.31 (1.60–3.34)	1.65 (1.44–1.88)
Hyperglycemia	2.34 (2.04–2.69)	3.12 (2.15–4.53)	1.95 (1.70–2.24)
Abdominal obesity	2.65 (2.31–3.04)	2.89 (1.93–4.32)	2.08 (1.81–2.38)

DISCUSSION

This study provides the first population-representative evidence in Chile of an association between MS and tooth loss–related outcomes. MS was independently associated with nonfunctional dentition, complete edentulism, and denture use, but not with cavitated caries. These findings are consistent with international studies reporting links between MS and tooth loss or impaired functional dentition across diverse populations [13, 18–21] and extend prior Chilean evidence showing that multimorbidity broadly is associated with tooth loss using the same nationally representative data source [14]. While that study established a relationship between the overall burden of chronic disease and tooth loss, it did not examine MS as a specific entity, evaluate individual metabolic components, or adjust for health insurance coverage—gaps addressed in the present study.

The magnitude of tooth loss observed among participants with MS is clinically meaningful and aligns with the characterization of MS as a chronic low-grade inflammatory condition contributing to periodontal tissue breakdown and cumulative tooth loss [8–10]. Plausible mechanisms include systemic inflammation and metabolic dysregulation affecting periodontal homeostasis, with hyperglycemia impairing host immune responses and dyslipidemia contributing to oxidative stress and endothelial dysfunction [6, 9, 10]. In line with this framework, stronger crude associations were observed for hypertension and abdominal obesity, components that may reflect higher systemic inflammatory and cardiometabolic burden [18, 22].

In contrast, MS was not associated with cavitated caries. This may reflect both methodological and conceptual differences [12, 20]. The ENS oral assessment relies on visual clinical examination without radiographic methods, potentially underestimating early or interproximal lesions [23]. Moreover, tooth loss and edentulism capture cumulative, life-course consequences of oral disease and access-to-care patterns more directly than contemporaneous caries lesions [4, 15, 23].

Social determinants emerged as key correlates of both MS and severe oral outcomes. Lower educational attainment, rural residence, and reliance on the public health system (FONASA) were more prevalent among individuals with MS, consistent with evidence that socioeconomic disadvantage shapes both cardiometabolic and oral health inequities and limits access to preventive dental services [2, 4]. The rural–urban gradient aligns with national reports describing territorial disparities in oral health and access to dental care in Chile [4].

From a clinical and public health perspective, these findings support integrated medical–dental approaches within primary care. In Chile, CESFAMs provide a strategic platform for implementation through existing chronic disease programmes such as the PSCV. A feasible model would incorporate brief oral health screening into routine cardiometabolic visits, delivered by trained non-dental personnel and followed by risk-based referral and preventive counseling. For individuals with MS and periodontal involvement, structured maintenance programmes—delivered at regular intervals according to individual risk—may reduce local disease progression and systemic inflammatory burden [17, 24]. Importantly, given the observed socioeconomic gradients, such strategies should prioritize vulnerable populations to avoid reinforcing existing inequities [4].

This study has key strengths, including the use of nationally representative ENS data with standardized clinical and laboratory measurements and multivariable models adjusting for major sociodemographic confounders [2]. However, important limitations must be considered. The cross-sectional design precludes causal inference. In addition, a substantial proportion of participants (44%) was excluded due to missing data, primarily related to the fasting blood sample protocol requiring an additional visit and overnight fasting. Because complete-case analysis assumes data are missing completely at random, selection bias cannot be excluded. If excluded individuals had a higher burden of both metabolic risk and oral disease, the observed associations may underestimate the true effect; conversely, they may be overestimated if healthier individuals were disproportionately excluded. A detailed summary of missing data is provided in **Additional file 1: Appendix Table 6**. Furthermore, the absence of detailed periodontal measures and systemic inflammatory biomarkers limits mechanistic interpretation [6, 8, 10]. Finally, the results are generalizable to Chilean residents in private households and may not extend to institutionalized or geographically hard-to-reach populations [2]. Future analyses should consider multiple imputation strategies to assess the robustness of findings to missing data assumptions.

Future research should prioritize longitudinal designs to clarify temporal relationships between MS and tooth loss trajectories, incorporate periodontal and inflammatory biomarkers, and evaluate the effectiveness of integrated preventive strategies on both oral and cardiometabolic outcomes [16, 24].

CONCLUSIONS

In this nationally representative Chilean sample, MS was independently associated with nonfunctional dentition, complete edentulism, and denture use, but not with cavitated caries after adjustment for major sociodemographic confounders. These findings reinforce the role of oral health as part of the broader cardiometabolic risk profile and support the integration of oral health assessment into primary care. Implementing structured, risk-based medical–dental strategies within existing chronic disease programmes may improve both oral and systemic health outcomes, particularly in socioeconomically vulnerable populations. Longitudinal studies incorporating periodontal measures and inflammatory biomarkers are needed to clarify causal pathways and inform targeted interventions.

Abbreviations

MS Metabolic syndrome

ENS Encuesta Nacional de Salud (Chilean National Health Survey)

NCEP National Cholesterol Education Program

ATP III Adult Treatment Panel III

OR Odds ratio

CI Confidence interval

AUC Area under the receiver operating characteristic curve

STROBE Strengthening the Reporting of Observational Studies in Epidemiology

FONASA Fondo Nacional de Salud

ISAPRE Institución de Salud Previsional

HDL High-density lipoprotein

PPV Positive predictive value

NPV Negative predictive value

VIF Variance inflation factor

Declarations

Ethics Approval and Consent to Participate

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. ENS 2016–2017 participants provided written informed consent under the original ethical oversight of the survey. This secondary analysis was approved by the Ethics Committee of the Pontificia Universidad Católica de Chile (Protocol No. 241128011; approved December 4, 2024). All analyses were conducted using anonymized data accessed through a formal public transparency request (Ley de Transparencia No. 20.285), with restricted access limited to authorized investigators.

Consent for Publication

Not applicable

Data Availability Statement

The data that support the findings of this study are derived from the Chilean National Health Survey (ENS) 2016–2017, held by the Ministry of Health of Chile (Ministerio de Salud, MINSAL). These data are not publicly available due to institutional restrictions; however, they may be requested from MINSAL through a formal public transparency procedure (Ley de Transparencia No. 20.285; https://www.minsalresponde.cl). The analytical code used in this study is openly available in the Zenodo repository: https://doi.org/10.5281/zenodo.19225276 [25].

Competing Interests

FWD, JCL, AAJ, DDC, and MVM declare that they have no competing interests.

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Author Contributions

FWD contributed to the conception and design of the study, data acquisition and curation, data interpretation, and drafted and critically revised the manuscript. JCL contributed to study design and conceptualization, data interpretation, and critically revised the manuscript for important intellectual content. AAJ developed the statistical methodology and analysis plan, conducted formal statistical analyses, contributed to data interpretation, and drafted and critically revised the statistical sections. DDC contributed to the overall conception and supervision of the study, data interpretation, and drafted and critically revised the manuscript. MVM contributed to the overall conception and supervision of the

study, data interpretation, and drafted and critically revised the manuscript. All authors read and approved the final manuscript.

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