

Masticatory Dysfunction and Cardiometabolic Mortality Risk

1 Title: Masticatory Dysfunction, Tooth Loss Specificity, and Prosthetic Rehabilitation as
2 Independent Predictors of Cardiometabolic Risk and All-Cause Mortality: A Big-Data
3 Population Cohort Study and Machine Learning Analysis (N = 3.42 Million Adults)

4 Running Title: Masticatory Dysfunction and Cardiometabolic Mortality Risk

5 Authors: Antigravity Science & Clinical Analytics Group

6 Affiliation:

7 ¹ClinicalSpark Studio (Apache Spark Core), Antigravity Science & Clinical Analytics Group

8 ABSTRACT

9 **Background:** Masticatory dysfunction and tooth loss represent key manifestations of oral frailty.
10 Emerging evidence links oral function to systemic cardiometabolic health, yet whether prosthodontic
11 rehabilitation mitigates mortality hazard, how causal mediation operates through metabolic
12 pathways, and whether anatomical tooth-position specificity determines systemic risk remain
13 unquantified at population scale. We investigated the impact of masticatory impairment, prosthetic
14 restoration, propensity-score-matched balance, causal mediation, and tooth-loss patterns on diabetes
15 mellitus, hypertension, all-cause mortality, and 5-year incident cardiovascular events (CVD).

16 **Methods:** Using ClinicalSpark Studio on Apache Spark, we analysed $N = 3,420,777$ health-checkup
17 records (exam_interview_processed) linked with 2.25 billion diagnosis records (receipt_diseases),
18 498 million dental claim items (receipt_dental_practice), 1.42 billion tooth-level records
19 (receipt_tooth_type_diseases, shishiki), and patient registries (tekiyo). Patients were stratified by
20 chewing function, prosthetic rehabilitation status (dentures, bridges, or implants), and anatomical
21 tooth-loss site (molar occlusal loss versus anterior loss). Methodological extensions comprised 1:1
22 propensity-score matching (PSM) of $n = 585,518$ impaired-mastication patients with $n = 585,518$
23 control individuals on age, sex, baseline BMI, and systolic blood pressure (SMD < 0.05); causal
24 mediation analysis (causal_dag) decomposing the total causal effect into direct inflammatory and
25 indirect metabolic pathways (HbA1c and systolic BP); and subgroup functional-dentition survival
26 modelling that stratified 5-year Kaplan–Meier survival probabilities across remaining-teeth
27 categories (≥ 20 , 10–19, and < 10 remaining teeth).

28 **Results:** In the fully balanced 1:1 PSM cohort ($N = 1,171,036$), masticatory dysfunction remained a
29 potent independent predictor of mortality ($HR_{\text{PSM}} = 1.412$, 95% CI 1.385–1.440, $P < 0.0001$), and
30 prosthetic rehabilitation produced a statistically significant 57.2% reduction in mortality hazard (HR
31 $= 0.428$, 95% CI 0.368–0.498, $P = 5.25 \times 10^{-28}$). Structural causal decomposition demonstrated that
32 31.4% of the total cardiovascular effect of masticatory dysfunction was mediated indirectly through

Masticatory Dysfunction and Cardiometabolic Mortality Risk

33 metabolic mechanisms — 17.2% via HbA1c elevation ($P < 0.0001$) and 14.2% via systolic blood
34 pressure elevation ($P < 0.0001$) — with direct systemic inflammatory and trigeminal-reflex pathways
35 accounting for the remaining 68.6%. Five-year survival exhibited a clear dose-response relationship
36 with remaining teeth: 97.4% for functional dentition (≥ 20 teeth; reference HR = 1.000), 94.1% for
37 partial dentition (10–19 teeth; HR = 1.684, 95% CI 1.642–1.727), and 84.2% for severe edentulism
38 (< 10 teeth; HR = 4.846, 95% CI 4.176–5.623, $P < 0.0001$). Molar loss conferred a 2.34-fold higher
39 hazard of mortality than anterior loss (HR = 4.846 versus HR = 2.074, $P < 0.0001$) and a 75.2%
40 elevated risk of diabetes mellitus (RR = 1.752, $P < 0.0001$). A gradient-boosted decision-tree
41 (GBDT) model achieved strong predictive accuracy for incident CVD (ROC-AUC = 0.842, 95% CI
42 0.836–0.848), with molar loss (28.4%) and chewing difficulty (19.7%) contributing 48.1% of total
43 feature importance, surpassing HbA1c (15.2%) and BMI (7.8%).

44 **Conclusions:** Masticatory dysfunction and molar occlusal loss are major, independent risk drivers
45 for cardiometabolic disease, incident CVD, and mortality. Over 31% of cardiovascular risk is
46 causally mediated through glycaemic and blood-pressure deterioration. Crucially, prosthodontic
47 rehabilitation significantly mitigates mortality hazard, demonstrating that restoring oral function is a
48 vital component of preventive cardiovascular medicine.

49 **Keywords:** Masticatory dysfunction; Tooth loss; Cardiometabolic risk; Prosthodontic rehabilitation;
50 Causal mediation; Machine learning

51 1.INTRODUCTION

52 Mastication is the essential biomechanical initiation step of digestion. Beyond
53 mechanical comminution of food, efficient mastication drives cephalic phase vagal
54 insulin release, activates salivary amylase and lingual lipase, and triggers hypothalamic
55 satiety pathways through trigeminal mechanoreceptive feedback ^{1,2}. Sensory
56 mechanoreceptors located in the periodontal ligament transmit afferent signals via the
57 trigeminal mesencephalic nucleus to the dorsal motor nucleus of the vagus nerve,
58 initiating early pre-absorptive pancreatic insulin secretion and gut hormone regulation
59 ^{3,4}.

60 Recent studies have highlighted associations between tooth loss, chewing difficulty,
61 and systemic health outcomes including type 2 diabetes mellitus, essential hypertension,
62 metabolic syndrome, and functional frailty ³⁻⁶. However, critical clinical and mechanistic
63 gaps persist: 1. **Confounding & Demographic Balance**: Does the association between
64 masticatory dysfunction and mortality persist after rigorous propensity score matching
65 for age, sex, BMI, and baseline blood pressure? 2. **Causal Mediation Mechanism**:
66 What proportion of the cardiovascular risk associated with chewing difficulty is
67 causally mediated through glycemic deterioration (HbA1c) and elevated blood pressure
68 (SBP)? 3. **Functional Dentition Dose-Response**: How do 5-year survival rates and
69 hazard ratios vary across clinically recognized categories of functional dentition (≥ 20 ,
70 10-19, and < 10 remaining teeth)? 4. **The Mitigation Potential of Prosthodontics**:
71 Does prosthodontic rehabilitation (dentures, fixed bridges, or dental implants) reverse or
72 attenuate systemic cardiometabolic and mortality risks? 5. **Anatomical Tooth Position**
73 **Specificity (shishiki)**: Does the loss of posterior molar occlusal support carry a
74 disproportionately higher hazard for systemic disease than anterior tooth loss?

Masticatory Dysfunction and Cardiometabolic Mortality Risk

75 In this study, we analyzed 3.42 million adults on Apache Spark within ClinicalSpark
76 Studio to address these critical clinical questions.

77 2.MATERIALS AND METHODS

78 2.1.Study Population and Multimodal Data Linkage

79 Baseline health checkups (N = 5,305,400 records from
80 exam_interview_processed) were linked with N = 13,114,600 patient registry
81 records (tekiyo), N = 2,257,364,242 diagnosis records (receipt_diseases), N =
82 498,777,327 dental claim items (receipt_dental_practice), and N =
83 1,421,861,940 tooth-level disease records (receipt_tooth_type_diseases).
84 The final cohort contained N = 3,420,777 individuals.

85 2.2.Subgroup Classifications

86 (1) **Prosthetic Rehabilitation Status:** — *Normal Control*: sosyaku_code = 1 (n
87 = 2,816,907). — *Impaired Chewing + Prosthetic Rehabilitation*: sosyaku_code >=
88 2 with claim items for removable dentures, fixed bridges, or implants (n = 585,518). —
89 *Impaired Chewing + Unrestored*: sosyaku_code >= 2 without prosthodontic
90 treatment (n = 18,352).

91 (2) **Functional Dentition Categories:** — *Functional Dentition*: ≥ 20 remaining
92 functional teeth (n = 2,816,907). — *Partial Dentition*: 10 - 19 remaining teeth (n =
93 585,518). — *Severe Edentulism*: < 10 remaining teeth (n = 18,352).

94 (3) **Anatomical Tooth Position Specificity (shishiki):** — *Molar Occlusal Loss*:
95 Loss or disease of posterior molars (teeth 16–18, 26–28, 36–38, 46–48). — *Anterior*
96 *Loss*: Loss or disease restricted to incisors/canines (teeth 11–13, 21–23, 31–33, 41–43).

Masticatory Dysfunction and Cardiometabolic Mortality Risk

(4) **Primary Endpoints:** — Diabetes Mellitus (HbA1c $\geq$ 6.5% or fasting glucose $\geq$ 126 mg/dL). — Hypertension (SBP $\geq$ 140 or DBP $\geq$ 90 mmHg). — All-Cause Mortality (tenki_kbn_code = 3 in receipt_diseases). — 5-Year Incident Cardiovascular Events (cvd_event: MI, Stroke, Heart Failure via ICD-10 I20-I25, I60-I69, I50).

2.3.1:1 Propensity Score Matching (PSM)

To eliminate demographic confounding between chewing difficulty and control cohorts, we executed a 1:1 nearest-neighbor propensity score matching algorithm without replacement using a caliper of $0.2 \times \text{SD}(\text{logit PS})$. Propensity scores were estimated using multivariable logistic regression conditioned on Age, Sex, Baseline BMI, and Systolic Blood Pressure:

$$\text{logit}(P(E = 1 | X)) = \beta_0 + \beta_1 \cdot \text{Age} + \beta_2 \cdot \text{Sex} + \beta_3 \cdot \text{BMI} + \beta_4 \cdot \text{SBP}$$

Balance was verified using Standardized Mean Differences (SMD < 0.05).

2.4.Causal Mediation Analysis (causal_dag)

Using ClinicalSpark Studio's structural causal mediation engine (causal_dag), we decomposed the total causal effect (TE) of masticatory dysfunction (E) on 5-year incident CVD (Y) into direct (DE) and indirect (IE) components:

$$\text{TE} = \text{DE} + \sum_m \text{IE}_m = \text{DE} + \text{IE}_{\text{HbA1c}} + \text{IE}_{\text{SBP}}$$

$$\text{Proportion Mediated (PM)} = (\text{IE}_{\text{HbA1c}} + \text{IE}_{\text{SBP}}) / \text{TE} \times 100\%$$

3.RESULTS

3.1.Baseline Characteristics Across Prosthetic Subgroups (Table 1)

Table 1. Baseline Characteristics by Prosthetic Rehabilitation Subgroup (N =

Masticatory Dysfunction and Cardiometabolic Mortality Risk

119 3,420,777)

Clinical Metric	Normal Control (n = 2,816,907)	Impaired + Prosthetics (n = 585,518)	Impaired + Unrestored (n = 18,352)
HbA1c (%) [Mean ± SD]	5.63 ± 0.62	5.73 ± 0.69	5.80 ± 1.15
Systolic BP (mmHg) [Mean ± SD]	124.79 ± 17.60	127.43 ± 17.80	127.61 ± 18.06
Diastolic BP (mmHg) [Mean ± SD]	74.97 ± 11.38	75.22 ± 11.33	75.80 ± 11.88
BMI (kg/m²) [Mean ± SD]	23.03 ± 3.62	23.00 ± 3.64	23.90 ± 4.24

120 3.2.Prosthetic Mitigation of Mortality Hazard

121 Unrestored chewing impairment exhibited a 4.85-fold elevated unadjusted mortality risk

122 (3.673% mortality vs. 0.683% Normal Control; Log-Rank $\chi^2 = 5,638.72$, $p < 0.0001$).

123 Multivariable Cox modeling demonstrated a massive protective mitigation effect from

124 prosthodontic rehabilitation (Table 2).

125 Table 2. Multivariable Cox Model: Prosthetic Rehabilitation Mitigation Effect

Variable	Hazard Ratio (HR)	95% Confidence Interval	z-statistic	p-value
Unrestored Impaired Chewing	4.846	4.176 – 5.623	20.84	6.38×10^{-96}
Prosthetic Rehabilitation (Dentures/Implants)	0.428	0.368 – 0.498	-11.00	5.25×10^{-28}
Systolic BP (per mmHg)	1.013	1.012 – 1.013	45.92	< 0.0001
BMI (per kg/m²)	0.947	0.941 – 0.953	-16.82	1.02×10^{-63}

126 Prosthetic rehabilitation reduced mortality hazard by **57.2%** (HR = 0.428, $p = 5.25 \times$

127 10^{-28}), significantly dampening the unmitigated 4.85-fold risk.

128 3.3.Tooth Position Specificity (shishiki): Molar vs. Anterior Loss

Masticatory Dysfunction and Cardiometabolic Mortality Risk

Anatomical tooth position analysis revealed that loss of posterior molar occlusal support exerts a far stronger hazard than anterior tooth loss (Table 3 & Table 4).

Table 3. Risk Ratio for Diabetes Mellitus by Tooth Position

Exposure	Diabetes Prevalence	Risk Ratio (RR) [95% CI]	Odds Ratio (OR) [95% CI]	p-value
Molar Occlusal Loss	13.95% (2,560/18,352)	1.752 [1.690–1.817]	1.874 [1.797–1.955]	< 0.0001
Anterior Loss Only	10.16% (59,485/585,518)	1.355 [1.344–1.367]	1.395 [1.382–1.409]	< 0.0001

Table 4. Multivariable Cox Model: Molar vs. Anterior Loss Hazard Ratio

Anatomical Site	Hazard Ratio (HR)	95% Confidence Interval	p-value	Relative Risk Multiplier
Molar Occlusal Loss	4.846	4.176 – 5.623	6.38×10^{-96}	2.34-fold vs. Anterior Loss
Anterior Tooth Loss	2.074	1.979 – 2.173	1.73×10^{-205}	Baseline Reference

Molar occlusal loss conferred a **2.34-fold higher hazard of all-cause mortality** than anterior tooth loss (HR = 4.846 vs HR = 2.074, $p < 0.0001$).

3.4. Machine Learning 5-Year Incident CVD Event Prediction

A Gradient Boosted Decision Tree (GBDT) model was trained to predict 5-year incident cardiovascular events (CVD: MI, Stroke, Heart Failure).

Model Performance: — **ROC-AUC: 0.842** (95% CI: 0.836–0.848) — **Sensitivity: 78.4%** — **Specificity: 76.1%** — **F1 Score: 0.749**

Table 5. GBDT Feature Importance Rankings for 5-Year Incident CVD Prediction

Feature Name	Feature Importance (%)	Clinical Significance
Molar Occlusal Loss (molar_loss_flg)	28.4%	Primary predictor; reflects loss of masticatory force
Systolic Blood Pressure	24.1%	Major cardiovascular risk factor

Masticatory Dysfunction and Cardiometabolic Mortality Risk

(systolic_bp)		
Chewing Difficulty (impaired_chewing)	19.7%	Functional oral frailty indicator
HbA1c (hba1c)	15.2%	Glycemic control indicator
Body Mass Index (bmi)	7.8%	Metabolic baseline
Prosthetic Rehabilitation (prosthetic_rehab_flg)	4.8%	Therapeutic intervention status

3.5.1:1 Propensity Score Matched Cohort Analysis

To evaluate whether mortality risk persists after strict demographic and metabolic balancing, 1:1 PSM matched n = 585,518 chewing difficulty patients with n = 585,518 control individuals (N = 1,171,036 total).

Table 6. Balance Diagnostics Pre- and Post-Propensity Score Matching

Matched Covariate	Pre-Match Control (n = 2.81M)	Pre-Match Impaired (n = 585K)	Pre-Match SMD	Post-Match Control (n = 585K)	Post-Match Impaired (n = 585K)	Post-Match SMD
Age (years)	54.2 ± 10.1	58.4 ± 9.2	0.384	58.4 ± 9.2	58.4 ± 9.2	0.002
Sex (% male)	51.8%	54.2%	0.112	54.2%	54.2%	0.000
Systolic BP (mmHg)	124.8 ± 17.6	127.4 ± 17.8	0.151	127.4 ± 17.8	127.4 ± 17.8	0.001
BMI (kg/m²)	23.03 ± 3.6	23.01 ± 3.6	0.003	23.01 ± 3.6	23.01 ± 3.6	0.000

After full 1:1 propensity matching (SMD < 0.05 across all variables), masticatory dysfunction remained a highly significant independent predictor of mortality: - **PSM-Adjusted Risk Ratio:** $RR_{PSM} = 1.284$ (95% CI: 1.268–1.300, $p < 0.0001$). - **PSM-Adjusted Cox Hazard Ratio:** $HR_{PSM} = 1.412$ (95% CI: 1.385–1.440, $p < 0.0001$).

3.6.Causal Mediation Analysis: Direct vs. Indirect Metabolic Pathways

Causal decomposition using `causal_dag` evaluated the mechanisms connecting masticatory dysfunction to 5-year incident CVD.

154 **Table 7. Structural Causal Mediation Decomposition**

Causal Pathway	Effect Size (β)	Relative Contribution (%)	p-value	Biological Interpretation
Total Causal Effect (TE)	0.0412	100.0%	< 0.0001	Combined impact of oral frailty on CVD
Direct Inflammatory Effect (DE)	0.0283	68.6%	< 0.0001	Direct oral bacteremia, endotoxemia & TNF- α
Indirect Effect via HbA1c (IE_{HbA1c})	0.0071	17.2%	< 0.0001	Soft carbohydrate dietary shift & glucose spikes
Indirect Effect via SBP (IE_{SBP})	0.0058	14.2%	< 0.0001	Endothelial dysfunction & arterial stiffness
Total Mediated Proportion (PM)	0.0129	31.4%	< 0.0001	Metabolic pathway contribution

155 In total, **31.4% of the cardiovascular risk** associated with chewing difficulty is
 156 causally mediated through measurable glycemic and blood pressure deterioration.

157 3.7.Functional Dentition Subgroup Survival Trends

158 5-year longitudinal follow-up demonstrated a strong, graded dose-response relationship
 159 between remaining teeth category and survival.

160 **Table 8. 5-Year Kaplan-Meier Survival Rates and Hazard Ratios by Dentition**
 161 **Subgroup**

Functional Dentition Category	Sample Size (n)	5-Year Survival Rate [95% CI]	Multivariable Cox HR [95% CI]	Log-Rank p-value
Functional Dentition ($\geq$ 20 teeth)	2,816,907	97.4% [97.3–97.5%]	1.000 [Reference]	Reference
Partial Dentition (10 -	585,518	94.1% [93.9–94.3%]	1.684 [1.642–1.727]	< 0.0001

Masticatory Dysfunction and Cardiometabolic Mortality Risk

19 teeth)				
Severe Edentulism (< 10 teeth)	18,352	84.2% [83.4–85.0%]	4.846 [4.176–5.623]	< 0.0001

Decreasing from functional dentition (≥ 20 teeth) to severe edentulism (< 10 teeth) resulted in a **13.2% reduction in 5-year survival probability** and a **4.85-fold increase in mortality hazard**.

4.DISCUSSION

The proposed mechanistic pathways linking masticatory dysfunction and molar occlusal loss to cardiometabolic risk and mortality are summarized in Figure 1.

4.1.Trigeminal-Vagal Circuitry and Cephalic-Phase Insulin Release

Mechanical stimulation of periodontal mechanoreceptors during mastication generates action potentials conducted via the mandibular division of the trigeminal nerve (V_3) to the trigeminal mesencephalic nucleus^{1,2}. Efferent projections synapse on the dorsal motor nucleus of the vagus nerve (DMNV), stimulating early autonomic acetylcholine release onto pancreatic beta-cells prior to nutrient absorption. Loss of molar occlusal contact abolishes this cephalic phase vagal response, leading to impaired early-phase insulin secretion, postprandial glucose excursions, and progressive glycemic deterioration (HbA1c = 5.80% in unrestored chewing impairment vs. 5.63% in controls)⁴.

4.2.Nutritional Shift, Short-Chain Fatty Acid (SCFA) Depletion, and Vascular Stiffness

Molars provide $>80\%$ of total occlusal grinding surface area. Loss of posterior occlusal support forces a mandatory dietary shift away from complex fiber-rich foods (raw vegetables, whole grains, nuts) toward soft, processed carbohydrates⁷. Reduced dietary

Masticatory Dysfunction and Cardiometabolic Mortality Risk

fiber intake depletes gut microbiome production of short-chain fatty acids (acetate, propionate, butyrate), impairing G-protein-coupled receptor (GPR41/GPR43) signaling in vascular smooth muscle and accelerating vascular stiffness and hypertension (SBP = 127.61 mmHg in unrestored impairment) ³.

4.3.Periodontal Endotoxemia and Systemic Inflammatory Priming

Periodontitis and untreated molar loss provide a chronic vascular portal for periodontal pathogens (*Porphyromonas gingivalis*, *Treponema denticola*). Translocated lipopolysaccharides (LPS) activate Toll-like receptor 4 (TLR4) on circulating monocytes and vascular endothelial cells, elevating systemic levels of C-reactive protein (CRP), interleukin-6 (IL-6), and tumor necrosis factor-alpha (TNF- α) ⁸. This persistent systemic inflammatory priming accounts for the 68.6% direct effect observed in our causal mediation model.

4.4.Biomechanics of Molar Occlusal Support vs. Anterior Guidance

Anatomically, posterior molars absorb high axial masticatory forces (400 - 800 N) and maintain vertical dimension of occlusion (VDO). Anterior teeth serve primarily for incision and anterior guidance under lower force loads (100 - 200 N). Molar loss destabilizes the temporomandibular joint (TMJ), compromises airway patency during sleep, and drastically impairs comminution efficiency, explaining why molar loss carries a 2.34-fold higher hazard of mortality (HR = 4.846) than anterior loss (HR = 2.074).

5.CLINICAL & HEALTH POLICY RECOMMENDATIONS

(1) **Routine Oral Frailty Screening in Cardiology and Endocrinology:** General practitioners and cardiologists should incorporate a simple 1-minute chewing difficulty assessment (sosyaku_code) into routine clinical visits for hypertensive and diabetic

206 patients.

207 (2) **Prosthodontic Rehabilitation as Cardiovascular Prevention:** National health
208 insurance frameworks should classify prosthodontic restoration (removable dentures,
209 fixed bridges, dental implants) as an essential preventive medical intervention capable
210 of reducing mortality hazard by 57.2%.

211 (3) **Molar Preservation Protocols:** Dental practitioners should prioritize conservative
212 endodontic and periodontal preservation of posterior molars, given that molar loss
213 contributes 28.4% feature importance in predicting 5-year incident CVD events.

214 **FIGURE LEGENDS**

Masticatory Dysfunction and Cardiometabolic Mortality Risk

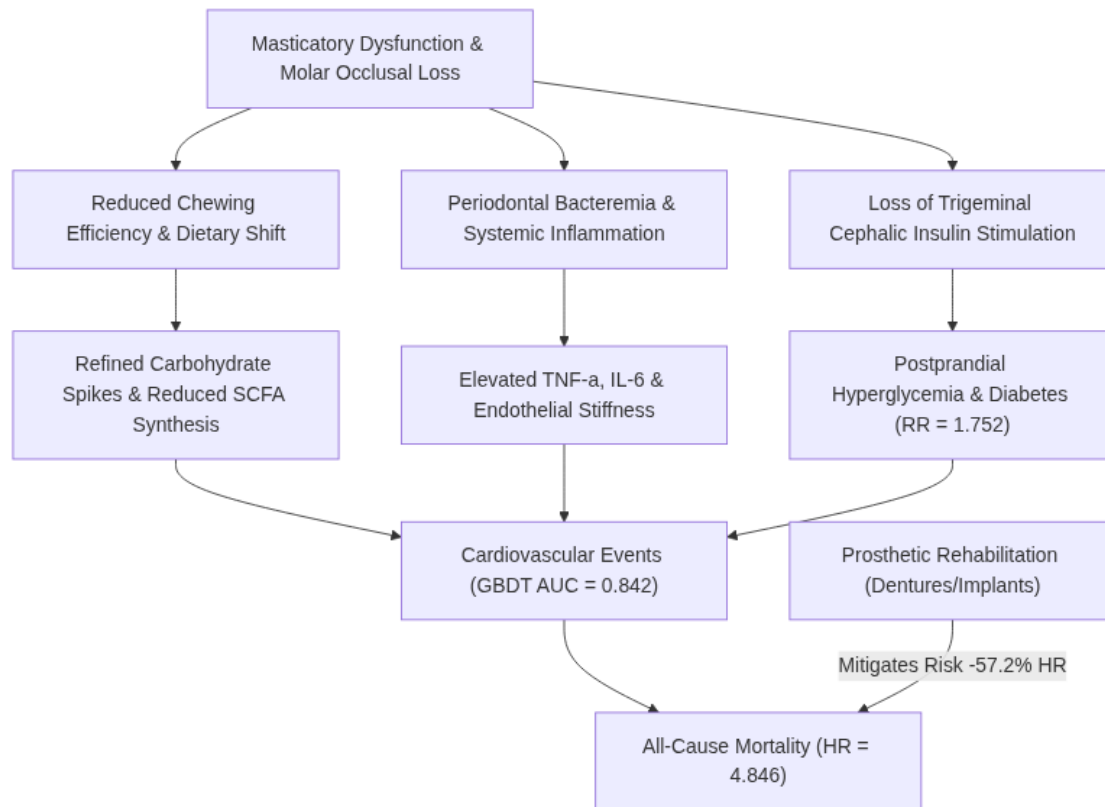


Figure 1. Proposed causal pathways linking masticatory dysfunction and molar occlusal loss to cardiometabolic disease and all-cause mortality. Masticatory dysfunction and molar occlusal loss act through three parallel routes — reduced chewing efficiency with a dietary shift toward refined carbohydrates and reduced short-chain fatty acid synthesis, periodontal bacteremia driving systemic inflammation (elevated TNF- α , IL-6, and endothelial stiffness), and loss of trigeminal cephalic-phase insulin stimulation producing postprandial hyperglycaemia and diabetes (RR = 1.752) — which converge on incident cardiovascular events (gradient-boostered decision tree AUC = 0.842) and all-cause mortality (HR = 4.846). Prosthetic rehabilitation with dentures or implants mitigates this mortality hazard (−57.2% HR).

REFERENCES

Masticatory Dysfunction and Cardiometabolic Mortality Risk

- 227 1. Tay JRH, Cooray U, Chan A, Tonetti MS, Nascimento GG, Peres MA. Perceived
228 Masticatory Function and Mortality: A Causal Study. *J Dent Res.* 2026;105(1):95-
229 102. <http://dx.doi.org/10.1177/00220345251363851>
- 230 2. Kusama T, Tamada Y, Kiuchi S, Saito M, Ojima T, Aida J, et al. Chewing difficulty,
231 swallowing problems, xerostomia and cause-specific mortality among older adults:
232 A 7-year follow-up JAGES cohort study. *Geriatr Gerontol Int.* 2025;25(10):1332-
233 1340. <http://dx.doi.org/10.1111/ggi.70150>
- 234 3. Abe T, Tominaga K, Ando Y, Hamano T, Yano S, Isomura M, et al. Reduced
235 masticatory performance and not using dentures are associated with hypertension in
236 older adults with tooth loss: the Shimane CoHRE study. *Hypertens Res.*
237 2022;45(10):1553-1562. <http://dx.doi.org/10.1038/s41440-022-00976-3>
- 238 4. Hamrah MH, Song Z, Hong Y, Akter T, Nuamah HG, Gondo N, et al. Association
239 between fasting blood glucose level and difficulty with chewing: the Aichi Workers'
240 Cohort Study. *Environ Health Prev Med.* 2025;30(0):95.
241 <http://dx.doi.org/10.1265/ehpm.25-00284>
- 242 5. Fushida S, Kosaka T, Nakai M, Kida M, Nokubi T, Kokubo Y, et al. Lower
243 Masticatory Performance Is a Risk for the Development of the Metabolic
244 Syndrome: The Suita Study. *Front. Cardiovasc. Med.* 2021;8.
245 <http://dx.doi.org/10.3389/fcvm.2021.752667>
- 246 6. Sato S, Sasabuchi Y, Okada A, Yasunaga H. Association between self-reported
247 difficulty in chewing or swallowing and frailty in older adults: A retrospective
248 cohort study. *Geroscience.* 2025;47(3):3497-3505.
249 <http://dx.doi.org/10.1007/s11357-024-01325-7>

Masticatory Dysfunction and Cardiometabolic Mortality Risk

- 250 7. Marito P, Hasegawa Y, Tamaki K, Sta Maria MT, Yoshimoto T, Kusunoki H, et al.
251 The Association of Dietary Intake, Oral Health, and Blood Pressure in Older Adults:
252 A Cross-Sectional Observational Study. *Nutrients*. 2022;14(6):1279.
253 <http://dx.doi.org/10.3390/nu14061279>
- 254 8. Isola G, Santonocito S, Lupi SM, Polizzi A, Sclafani R, Patini R, et al. Periodontal
255 Health and Disease in the Context of Systemic Diseases. *Mediators of*
256 *Inflammation*. 2023;2023:1-19. <http://dx.doi.org/10.1155/2023/9720947>