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Original Article

A New Multidimensional Oral Health Indicator (MOHi): Construction, Distribution, and Predictive Validity in a Large Clinical Cohort

Michael J. Harris[1]*, Emily R. Stone[1], Ahmed S. Farouk[1]

[1]Department of Oral and Maxillofacial Surgery, School of Dentistry, University of Michigan, Ann Arbor, United States

*E-mail ✉ michael.harris@gmail.com

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ABSTRACT

To create a novel multidimensional oral health indicator (MOHi) capable of determining and describing overall oral health conditions. MOHi was formulated using data from first-time attendees (N = 1,034) at a university dental service over an 18-month window. Participants completed the Oral Health Value Scale (OHVS), the Oral Health Impact Profile-14 (OHIP-14), and self-reported periodontal questionnaires. Caries experience was assessed via the Decayed, Missing, and Filled Teeth (DMFT) index, together with radiographic evaluation. The MOHi score was constructed as a linear combination of normalized OHVS, OHIP-14, and DMFT values, expressed on a continuous 0–3 scale, where higher numbers reflect poorer oral health. MOHi performance was examined across sociodemographic and behavioral variables, as well as periodontal self-report. Group differences in mean MOHi were tested using Student's t-test and one-way ANOVA. Predictors were identified using stepwise multivariate logistic regression, and model accuracy was assessed through ROC/AUC analysis. MOHi demonstrated suitable normal distribution characteristics (range: 0.29–2.47), with a mean of 1.22 (±0.41). Elevated MOHi values occurred among individuals reporting periodontitis ($p < 0.001$), active or former smokers ($p < 0.001$), those with elementary or middle-school education ($p < 0.001$), employed or retired participants ($p < 0.001$), individuals aged ≥ 45 years ($p < 0.001$), and those who were married/divorced/widowed ($p < 0.001$). The final simplified logistic model identified the following predictors of poorer oral health: age (OR = 1.05), self-reported periodontitis (OR = 1.94), female sex (OR = 1.80), smoking status—active/former (OR = 3.12 / OR = 1.62), and lower education—elementary/middle (OR = 2.94 / OR = 2.27). The model achieved an AUC of 0.81. MOHi appears to be an effective and comprehensive tool for evaluating overall oral health.

Keywords: Multidimensional oral health indicator, Clinical cohort, AUC, Dental

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Introduction

Health-related behaviors are shaped by multiple influences, including psychological traits, socioeconomic conditions, emotional factors, beliefs, education, cultural context, health policy, and access to dental care [1]. Within oral health, community norms and care quality influence how people perceive oral health and engage with dental services [2]. Central to this are oral health values (OHV), which reflect how individuals prioritize and allocate attention or resources toward oral care. These values vary widely and affect how people decide on health behaviors [3]. Oral health–related quality of life (OHRQoL) describes the degree to which dental conditions interfere with daily activities, social relationships, and well-being [4]. Deteriorating oral health contributes to poorer OHRQoL [3], capturing the self-reported impact of oral problems on life satisfaction [5, 6]. However, defining OHRQoL remains complex [6], and traditional frameworks often emphasize clinician perspectives while undervaluing patient OHV [7]. This underscores the need to integrate OHV to better reflect

each individual's interpretation of their oral health experience. Growing literature indicates OHV significantly influences care-seeking behavior, alongside other health indices [8]. Furthermore, oral health disparities disproportionately affect low-income populations, minority groups, people with disabilities, women (despite higher dental attendance), edentulous individuals, and older adults [8, 9]. These disparities suggest that lower OHV may be linked to worsening oral health outcomes.

Combining patient-reported outcome measures (PROMs)—such as OHRQoL and OHV—with clinical information in a unified framework offers a more holistic assessment by capturing both subjective perceptions and objective oral health indicators. The ability to use such an index across various clinical environments may strengthen public health surveillance, facilitate identification of vulnerable groups, and support targeted interventions. A multidimensional approach ensures oral health assessment accounts for clinical findings as well as personal values and lived experiences, promoting more equitable, patient-centered care.

Therefore, the goal of this study was to construct a new multidimensional oral health indicator (MOHi) that integrates OHRQoL, OHV, and clinical metrics to provide a comprehensive evaluation of an individual's oral health status.

Materials and Methods

Study design, setting, and participants

This investigation relied on information obtained from a cohort of individuals attending a Portuguese academic dental center (Egas Moniz Dental Clinic, Almada, Portugal). Participants were enrolled through consecutive intake from January 2022 to June 2024 during their first scheduled visit. Ethical approval was granted by the Egas Moniz Ethics Committee (1050/2022), and written informed consent was secured from every participant. The study is presented following the TRIPOD recommendations for developing multivariable prognostic or diagnostic models [10].

Eligibility criteria and sampling

Inclusion required individuals to be at least 18 years old, capable of understanding and signing consent, and presenting for an initial triage assessment at the university clinic. Participation was voluntary and anonymous. Due to the absence of prior work combining clinical oral indicators with patient-reported measures, a specific sample size was not predetermined; instead, an 18-month consecutive sampling framework was used to obtain a random series of eligible attendees.

Variables

Outcome variables

Caries burden was assessed via the Decayed, Missing, and Filled Teeth (DMFT) index. Dental examinations were performed clinically, and findings were digitally recorded to compute the DMFT value. This index is commonly applied in population-level oral health research to benchmark conditions and appraise preventive or therapeutic interventions [11]. Periodontal assessment employed a previously validated self-reported instrument containing thirteen questions, including two items with an AUC of 0.8 for predictive performance [12], along with the clinically confirmed count of lost teeth. The remaining questions captured perceptions about gum and tooth health, mobility, bone loss, esthetics, and hygiene practices such as flossing and mouthwash use [12, 13].

Exposure variables

Information on sociodemographic and behavioral aspects was obtained through a self-administered survey completed before panoramic imaging and clinical examination. Variables included sex, age, marital status (single, married/cohabiting, divorced, widowed), and education categorized as "elementary" (9 years of schooling), "middle" (secondary or vocational training), and "higher" (college/university). Employment status was classified as student, employed, unemployed, or retired, alongside medical history. Smoking status followed NHANES definitions [14]: non-smoker (never or <100 cigarettes lifetime), ex-smoker (≥100 cigarettes lifetime, not currently smoking), and active smoker (≥100 cigarettes lifetime and currently smoking). Participants also reported daily cigarette consumption and duration of smoking.

To evaluate the perceived importance of oral care, the Portuguese version of the OHVS was applied [3, 15]. The Oral Health Value Scale contains 12 statements spanning professional dental care (items 4, 8, 11), appearance and health (items 3, 7, 12), flossing behaviors (items 2, 5, 10), and preservation of natural teeth (items 1, 6, 9). Responses are scored on a 5-point Likert format from "strongly disagree" to "strongly agree," enabling detailed insight into participants' attitudes and assisting clinicians in recognizing areas needing attention.

The Portuguese-adapted Oral Health Impact Profile (OHIP-14) [16] was employed to assess how oral conditions influenced each individual's day-to-day well-being. This tool contains 14 items designed to

capture how oral issues affect several life domains, such as physical symptoms, functional limitations, psychological strain, and social interactions [5]. For every item, participants indicated how frequently they faced the described situation using a 5-point response format (never, hardly ever, occasionally, often, very often) [5, 16].

Data analysis and statistical procedures

The construction of the proposed composite metric (MOHi) followed the methodological framework outlined in the *Handbook on Constructing Composite Indicators* [17]. MOHi was conceptualized as a multi-component index, created by assigning equal weights to the normalized values of OHVS, OHIP-14, and DMFT. Its final form is a continuous measure ranging from 0 to 3, where higher scores reflect progressively poorer oral health. Once developed and validated, MOHi's distributional behavior, variation, and responsiveness were examined in relation to demographic and behavioral patterns, as well as participants' self-declared periodontal status.

Analyses included descriptive summaries, inferential testing, and statistical modeling, performed using IBM SPSS Statistics v.30 (Armonk, NY, USA). Continuous variables were summarized with means and standard deviations (SD), and categorical variables with counts and percentages (%). Normality checks preceded between-group comparisons for continuous data (using Student's t-tests and one-way ANOVA when appropriate). Stepwise multivariable logistic regression was applied to explore predictors of deteriorated oral health, defined as MOHi $\geq$ 1.5. A second model using DMFT alone (cutoff: 14) [18] was generated for comparison. Both reduced models were evaluated in terms of predictor coverage and diagnostic performance through ROC curves and AUC metrics. A 5% significance threshold ($p < 0.05$) guided all inferential testing.

Results and Discussion

Study sample and general profile

From the initial 1,127 individuals invited, 63 declined, and 30 provided incomplete data, leaving a final sample of 1,034 participants **(Figure 1)**. A detailed overview appears in **Table 1**. The cohort consisted mostly of women (58.1%)**,** with a mean age of 46.8 ± 18.6 years. Most were employed (67.9%)**,** and had either middle (33.5%) or higher (33.8%) education levels; 24.7% reported active smoking. The mean DMFT score was 12.8 ± 8.4**,** and participants had on average 6.3 ± 7.5 missing teeth. Roughly 9.0% showed substantial tooth loss. Based on self-reports, 42.0% indicated having periodontitis. For oral health values, the mean OHVS score was 31.1 ± 6.3**,** corresponding to 64.8% ± 13.2**.** The mean OHIP-14 score was 12.1 ± 12.0**,** with 57.8% noting that their daily life was frequently affected. **Figure 1.**

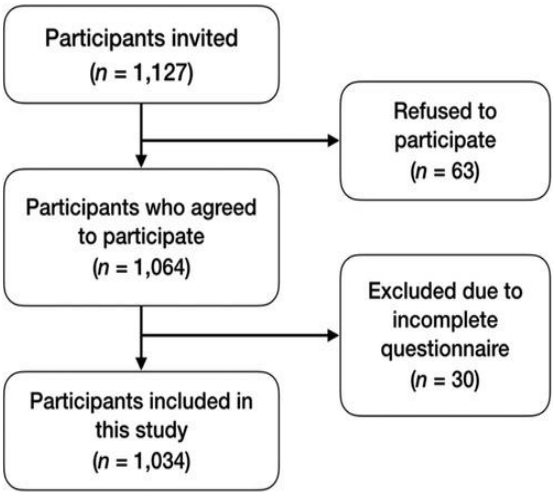

Figure 1. Flow diagram illustrating recruitment and reasons for exclusion.

Table 1. Sociodemographic and behavioral characteristics of the sample (N = 1,034).

Characteristic	Overall (N = 1,034)
Age (years), mean ± SD	46.8 ± 18.6
Sex, n (%)	
Female	601 (58.1%)
Male	433 (41.9%)
Employment status, n (%)	
Student	116 (11.2%)
Employed	702 (67.9%)
Unemployed	41 (4.0%)
Retired	175 (16.9%)
Marital status, n (%)	

Single	401 (38.8%)
Married	466 (45.1%)
Divorced	120 (11.6%)
Widowed	47 (4.5%)
Educational attainment, n (%)	
Elementary school	338 (32.7%)
Middle/high school	346 (33.5%)
Higher education (university/college)	350 (33.8%)
Smoking status, n (%)	
Never smoked	210 (55.3%)*
Former smoker	76 (20.0%)*
Current smoker	94 (24.7%)*
DMFT index, mean ± SD	
Total DMFT	12.8 ± 8.4
Decayed teeth (D)	3.2 ± 3.6
Missing teeth (M)	6.3 ± 7.5
Filled teeth (F)	3.4 ± 3.9
Severe tooth loss (fewer than 10 remaining teeth), n (%)	93 (9.0%)
Self-reported periodontitis, n (%)	434 (42.0%)
Oral Health Value Scale (OHVS), mean ± SD	31.1 ± 6.3
OHVS (percentage score), mean ± SD	64.8 ± 13.2
Oral Health Impact Profile-14 (OHIP-14), mean ± SD	12.1 ± 12.0

Patient-reported outcomes (PROs) and caries profile

Distributional analysis showed that OHVS and DMFT displayed near-symmetric patterns with slight platykurtosis **(Table 2)**. In contrast, OHIP-14 demonstrated a marked positive skew, indicating that a considerable portion of participants reported relatively low levels of impairment in oral-health-related quality of life.

Table 2. Descriptive distribution parameters for OHVS, OHIP-14, and DMFT (N = 1,034).

Measure	Mean ± SD	Median	Minimum-Maximum	Skewness	Kurtosis
Oral Health Value Scale (OHVS)	31.1 ± 6.3	30.0	15–48	0.361	−0.497
Oral Health Impact Profile-14 (OHIP-14)	12.1 ± 11.9	9.0	0–54	1.026	0.242
Decayed, Missing, and Filled Teeth (DMFT) Index	12.8 ± 8.4	12.0	0–32	0.292	−0.763

Creation and refinement of the MOHi

The composite indicator was assembled from three standardized numerical elements **(Table 3)**. The resulting MOHi values display an overall balanced distribution with a mild shift to the right **(Figure 2 and Table 4)**, indicating that while most individuals cluster around the midpoint, a subset reports noticeably elevated scores.

Table 3. Structure of the MOHi metric (a), based on its three standardized numerical components.

Component	Calculation Formula
(A)	1 - [(OHVS score - 12) / 48]
(B)	(OHIP-14 score) / 56
(C)	(DMFT) / 32
MOHi	(A) + (B) + (C)

aMOHi interval: 0–3; minimum MOHi: 0 (corresponding to OHVS = 60; OHIP-14 = 0; DMFT = 0); maximum MOHi: 3 (corresponding to OHVS = 12; OHIP-14 = 56; DMFT = 32).

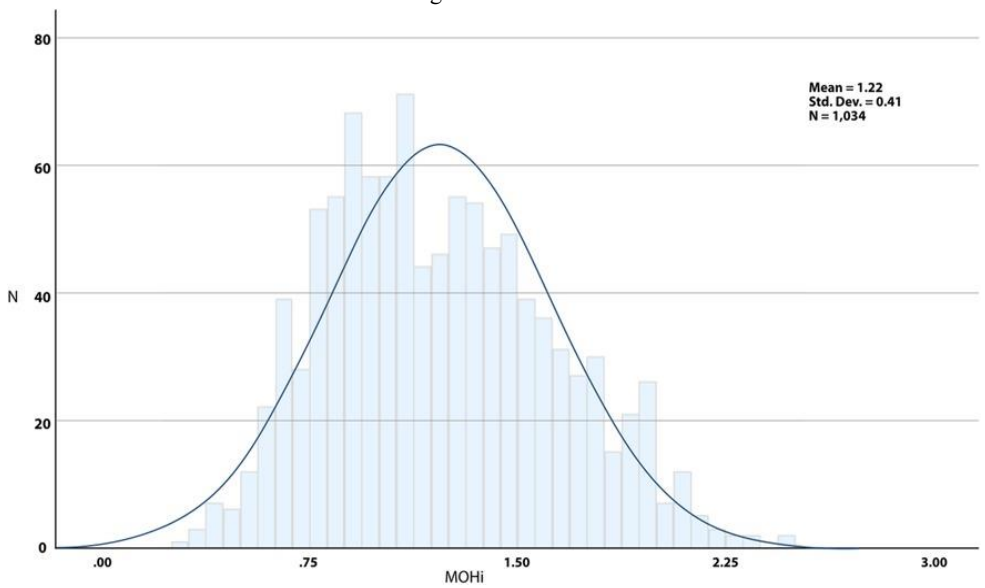

Figure 2. Distribution profile of MOHi scores across the sample.

Table 4. Summary statistics for the MOHi distribution (N = 1,034).

Descriptive Statistic	Value
Mean (Standard Deviation)	1.22 (0.41)
Median	1.18
Minimum – Maximum	0.29 – 2.47
Skewness	0.351
Kurtosis	−0.482
Variable	MOHi score

MOHi in relation to sociodemographic/behavioral traits and self-reported periodontal health

Clear differences in MOHi scores were observed across periodontal categories as well as multiple demographic and lifestyle variables **(Table 5).** Higher MOHi values—indicating poorer oral health—were noted among those reporting periodontitis, older participants, individuals with less schooling, smokers, those retired from employment, and persons who were divorced or widowed (all $p < 0.001$). A marked age gradient appeared, with the mean score increasing from 1.02 in the 18–44 group to 1.47 among participants aged 65+. Lower educational backgrounds and current tobacco use were also associated with worse outcomes. Although women showed slightly higher scores than men, this did not reach statistical significance ($p = 0.066$). Collectively, these data emphasize the impact of socioeconomic vulnerability, aging, and smoking behaviors on overall oral health status.

Table 5. Comparison of mean MOHi scores by periodontal self-report and sociodemographic/behavioral variables (N = 1,034).

Variable	Category	n	MOHi Mean (SD)	95% CI for Mean	p-value
Self-reported periodontitis	No	600	1.12 (0.38)	1.09 – 1.15	<0.001**
	Yes	434	1.35 (0.41)	1.31 – 1.39	
Sex	Female	601	1.24 (0.42)	1.21 – 1.27	0.066*
	Male	433	1.19 (0.39)	1.15 – 1.23	
Age group	18–44 years	454	1.02 (0.35)[a]	0.99 – 1.05	<0.001**
	45–64 years	367	1.32 (0.38)[b]	1.28 – 1.36	
	65+ years	213	1.47 (0.36)[c]	1.42 – 1.52	
Education level	Elementary	338	1.36 (0.41)[a]	1.32 – 1.41	<0.001**
	Middle	346	1.24 (0.39)[b]	1.20 – 1.28	
	Higher	350	1.06 (0.37)[c]	1.02 – 1.10	
Smoking status	Never smoked	550	1.13 (0.39)[a]	1.10 – 1.16	<0.001**
	Former smoker	245	1.29 (0.39)[b]	1.24 – 1.34	
	Current smoker	239	1.35 (0.42)[b]	1.29 – 1.40	
Professional status	Employed	702	1.20 (0.39)[a]	1.18 – 1.23	<0.001**
	Student	116	0.83 (0.25)[b]	0.79 – 0.88	
	Retired	175	1.49 (0.34)[c]	1.44 – 1.54	
	Unemployed	41	1.39 (0.36)[c]	1.28 – 1.51	
Marital status	Married	466	1.30 (0.38)[a]	1.27 – 1.34	<0.001**

	Divorced	120	1.40 (0.39)[a,b]	1.33 – 1.47
	Widowed	47	1.45 (0.40)[b]	1.37 – 1.60
	Single	401	1.04 (0.37)[c]	1.00 – 1.07

Significant p-values ($p < 0.05$) appear in bold.
t-test.
One-way ANOVA (distinct letters signal statistically different means).

Predictive modelling of risk for compromised oral health using MOHi

The multivariable logistic regression indicates that age, reported periodontitis, female sex, lower schooling levels, and smoking behavior are all significant determinants of an impaired oral health profile (MOHi ≥ 1.5) **(Table 6).** Current smoking and reduced educational attainment were the most influential predictors, underscoring the importance of lifestyle factors and social context. In contrast, the simplified model assessing high caries burden (DMFT ≥ 14) identified only age, sex, and smoking as associated variables, demonstrating a narrower predictive span relative to the MOHi-based analysis.

Table 6. Final multivariate (reduced) model (a) predicting elevated risk of deteriorated oral health (MOHi ≥ 1.5) (N = 1,034).

Predictor	Category / Reference	Odds Ratio (95% CI)	p-value
Age	(per 1-year increase)	1.05 (1.04 – 1.06)	< 0.001
Self-reported periodontitis	No (reference)	–	–
	Yes	1.94 (1.39 – 2.69)	< 0.001
Sex	Male (reference)	–	–
	Female	1.80 (1.28 – 2.54)	< 0.001
Education level	Higher (reference)	–	–
	Middle	2.27 (1.47 – 3.50)	< 0.001
	Elementary	2.94 (1.91 – 4.54)	< 0.001
Smoking status	Never smoked (reference)	–	–
	Former smoker	1.62 (1.08 – 2.45)	0.020
	Current smoker	3.12 (2.07 – 4.70)	< 0.001

aDerived through stepwise logistic regression; final model significant with $\chi^2(7) = 249.978$, $p < 0.001$; explains 31.9% of variance (Nagelkerke R^2) and accurately classifies 77.9% of cases; AUC = 0.81 (95% CI: 0.78–0.84).

This investigation introduces a newly assembled composite measure designed to categorize individuals according to their likelihood of poorer oral health, integrating three major components: cumulative caries experience, OHVS results, and oral health–related quality of life. The MOHi framework brings these dimensions together into a single evaluative system and showed notable associations with age, gender, self-declared periodontal conditions, schooling level, and tobacco use.

By embedding both oral health values and quality-of-life aspects into its structure, the MOHi supplies a broader perspective of oral well-being, reflecting disease presence, its perceived consequences, and the importance individuals assign to oral health. This multi-angle formulation is consistent with contemporary health paradigms emphasizing the interplay of physical, emotional, and social elements in planning effective interventions [19, 20]. Earlier attempts to combine clinical findings with subjective patient input have been reported [21–23], but these lacked the OHV dimension, which only became available following its creation in 2021.

Since the 1970s, numerous PROM tools have been introduced to quantify how oral disorders influence daily functioning, social participation, and psychological states [20, 24]. Classic assessment strategies often prioritized specific clinical outcomes—such as decay or periodontal status—without considering how such measures align with patient experiences. Early investigations indicated inconsistent and weak links between clinical severity and subjective burden [24]. Later reductions in PROM length, such as the transition from OHIP-49 to OHIP-14 [5], may have contributed to stronger relationships with clinical markers [25], partly due to less respondent fatigue associated with shorter instruments [26].

The present findings further illustrate how the MOHi can uncover differences between subgroups. Including OHV and OHRQoL helps reveal vulnerabilities that may be masked when relying solely on clinical diagnostics. For example, people with low OHV scores might delay seeking care even when substantial disease is present, while those reporting poorer OHRQoL may experience greater psychosocial consequences. These insights emphasize how the MOHi could support more

individualized care and guide targeted outreach for populations at greater risk.

The MOHi also shows promise for use in dental services and population-level planning. In clinical workflows, it may help classify patients by priority level and highlight those requiring earlier or more intensive intervention. From a public health perspective, the tool could support decision-making related to program development and resource distribution. Its reliance on both objective and subjective dimensions reinforces the role of patient participation in managing oral health, which aligns with ongoing movements toward person-centered care.

Strengths and limitations

Although the MOHi appears to be a valuable addition to oral health assessment strategies, several constraints should be acknowledged. First, reliance on self-reported elements introduces the possibility of misclassification due to inaccurate recall or reporting. Also, the relationship with self-reported periodontal status should be interpreted carefully, as this screening approach has about 80% predictive performance and cannot replace a clinical periodontal examination [12]. Subsequent investigations should explore whether clinically confirmed periodontal disease maintains similar associations with MOHi scores. Second, further work is needed to determine whether MOHi performs similarly across heterogeneous populations, as cultural attitudes toward oral health and differences in service accessibility may affect generalizability. Third, although MOHi aids in risk differentiation, it does not incorporate several broader influences, such as other oral pathologies (e.g., xerostomia, bruxism, temporomandibular issues), systemic health factors, environmental exposures, or genetic predispositions. Future refinements could enhance predictive strength by adding such variables.

Conclusion

The MOHi contributes a noteworthy advancement in evaluating oral health from a multidimensional standpoint. Ongoing research should aim to validate the tool in external populations and assess its utility within various clinical and public health environments.

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Ethics Statement: The studies involving humans were approved by Egas Moniz Ethics Committee, Egas Moniz School of Health and Science. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

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