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ORIGINAL RESEARCH

ASSESSMENT OF ORAL HEALTH STATUS, KNOWLEDGE AND BEHAVIOUR OF PATIENTS WITH CARDIOVASCULAR DISORDERS- A CROSS-SECTIONAL STUDY

[1] Shamimul Hasan, [1] Samiya Kulsoom, [2] Shazina Saeed, [1] Mandeep Kaur, [1] Virender Gombra, [1] Rahnuma Masood, [3]Mambakkam Jayakanth

[1]Department of Oral Medicine and Radiology, Faculty of Dentistry, Jamia Millia Islamia, New Delhi, India

[2]Amity Institute of Public Health & Hospital Administration, Amity University Noida, Uttar Pradesh, India

[3]Department of Internal Medicine Patiala Heart Institute Patiala, India

Corresponding Author: Shamimul Hasan; shasan1@jmi.ac.in

Author Contribution: *Shamimul Hasan* (S.H.): contributed to conceptualizing, methodology, writing the original draft, data collection, editing, and corresponding the manuscript. *Samiya Kulsoom* (S.K.): contributed to conceptualizing, data collection, and editing the manuscript. *Shazina Saeed* (S.S.): contributed to the methodology, data analysis, and manuscript editing. *Mandeep Kaur* (M.K.): contributed to methodology and data collection. *Virender Gombra* (V.G.): contributed to data collection and editing the manuscript. *Rahnuma Masood* (R.M.): contributed to data collection. *Mambakkam Jayakanth (M.J.):* contributed to the methodology.

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ABSTRACT

Background: Cardiovascular disorders (CVDs) make up the most prevalent category of systemic illness in developed as well as developing countries because of changes in lifestyles and dietary habits. Emerging evidence suggests a significant association between poor oral health and CVDs, with individuals affected by periodontal disease exhibiting an increased risk of developing atherosclerotic CVDs. CVDs share inflammatory pathways with periodontal disease, yet oral health assessment is seldom integrated into cardiometabolic care. This study evaluated oral health status and treatment needs in adults with CVDs and assessed patient knowledge, behaviors, and service utilization, while exploring links between poor oral health and CVD risk.

Materials and Methods: In a cross-sectional study at the Outpatient Department of Oral Medicine and Radiology, Jamia Millia Islamia, 175 adults (20–70 years) with physician-diagnosed CVDs underwent standardized examinations for decayed-missing-filled teeth (DMFT), the Silness-Loe Plaque Index (PI), and Russell's Periodontal Index (RPI) using a WHO probe. A structured questionnaire assessed knowledge, attitudes, and practices. Data were entered in Microsoft Excel and analyzed in SPSS v20.

Results: The mean age was 52.9 ± 9.7 years; 57.1% were female. Caries experience was high (mean DMFT 3.00 ± 2.01; 72.2% DMFT > 0). Mean PI was 1.59 ± 0.63, with ~85% classified as fair–poor. Mean RPI was 1.82 ± 1.63, and nearly two-thirds were in destructive categories, indicating a substantial periodontal burden. Behaviors were sub optimal: 55% brushed once daily and 43% twice daily; with limited use of adjunctive aids (mouthwash 24%, floss 19.4%). Dental service utilization was low (67.1% visited a dentist < once/year). Knowledge gaps were marked: low awareness of infective endocarditis (25.1%), the oral-cardiac link (13.7%), and antibiotic prophylaxis for cardiac conditions (6.3%). The most frequent treatment need was periodontal therapy (72.0%), followed by prosthodontic (49.7%), restorative/endodontic (34.8%), and surgical (15.4%) care; 23.4% required no treatment.

Conclusions: Patients with CVDs exhibited considerable oral disease burden with significant knowledge and care-seeking gaps. Integrating routine periodontal screening, targeted education, and structured referral pathways into cardiometabolic care may reduce oral disease and potentially mitigate systemic inflammation.

***Keywords*:** Behaviour, Cardiovascular disease, Knowledge, Oral health, Periodontal disease

INTRODUCTION

A report by the surgeon general in America says that the mouth serves as a mirror of health or disease, acting as a sentinel or early warning system, and providing an accessible model to analyze other tissues and organs with certain pathologies [1] . Cardiovascular disease (CVD) is one of the leading causes of chronic disease morbidity and mortality in industrialized countries [2] . According to the Global Burden of Disease study, CVDs account for 24.8% of mortalities in India [3] . Familial history, hypercholesterolemia, hyperlipidemia, obesity, sedentary lifestyle and cigarette smoking are the important risk factors for CVDs. Published literature has established periodontal disease as a potential risk factor for CVDs [4] .

Periodontitis is a chronic inflammatory disease due to bacterial colonization, and causes tissue destruction between the tooth surface and gingiva, loss of connective tissue attachment, alveolar bone erosion and loss of the tooth [5] . The American Academy of Periodontology defines periodontitis to be typified by bleeding on probing, gingival recession, pocket formation, and alveolar bone loss [6] .

The possible linkage between periodontal disease and the prevalence of CVDs has been well-established, with growing evidence suggesting that periodontal disease is a risk factor for atherosclerotic cardiovascular disease (ASCVD) [7] . The suggested pathophysiological basis between chronic periodontitis and atherosclerotic cardiovascular disease includes the interaction between periodontal microbes, vascular endothelial damage, and atherogenesis.

Systemic inflammation, with chronically raised inflammatory markers, appears common to both disease processes [8] . Periodontal bacteremia leads to host-mediated immune response and results in atheroma formation, maturation, and exacerbation [9] . Horder, in 1909, was the first to emphasize that “oral sepsis” was the primary cause for infective endocarditis (IE) [10] .

Bacteria from oral foci of infection enters the systemic circulation and lead to transient bacteremia, thus, promoting microbial adhesion to previously compromised cardiac tissues [3] .

Although the effect of periodontal therapy in ameliorating the cardiovascular outcomes has still not been confirmed, there is international consensus regarding regular dental visits and enhancing the awareness of meticulous oral health in CVD patients [4] .

Published literature has established a cause-to-effect relationship between poor oral hygiene and cardiovascular disorders. Despite the alarming increase in the burden of CVDs in India, regular oral health evaluation of cardiovascular patients is not in routine clinical practice.

Moreover, individual knowledge, behaviour, and attitude related to poor oral health as a potential risk factor for CVDs and their treatment needs remain an unexplored subject [3] .

Our study aims to evaluate the oral health status of cardiovascular patients. The study also aims to assess the behavioral aspects and attitudes of cardiovascular patients regarding oral health and their treatment needs.

2. MATERIAL AND METHODS

A cross-sectional study was carried out among 175 patients with confirmed cardiovascular diseases (CVDs) who visited the Outpatient Department of Oral Medicine and Radiology at Jamia Millia Islamia. The study protocol received approval from the Institutional Ethics Committee (Ref. No. 17/12/308/JMI/IEC/2020), and written informed consent was obtained from all participants. Participants were selected based on the following criteria:

Inclusion criteria

1. Patient’s in the age range of 20-70 years of age (both male and female)
2. Patient’s with a confirmed diagnosis of CVDs (hypertension, myocardial infarction, ischemic heart diseases, Coronary artery disease, and valvular diseases) for at least 2 years.
3. Patient’s willing to participate in the study.

Exclusion criteria

1. Patient’s not willing to participate in the study.
2. Patient’s less than 20 years of age and more than 70 years of age.
3. Pregnant and lactating females
4. Patient’s with coexisting systemic diseases (diabetes mellitus, endocrine disorders, musculoskeletal disorders, cancer, etc.)

Sample size: The sample size was calculated using the formula (Naing et al.) [11].

n = Z2 P (1-P)/d

n =Sample size,

Z = Z statistic for Confidence level at 95% (standard value of 1.96), P = Estimated prevalence of measure (in proportion of 1) Prevalence of cardiovascular diseases in urban India is known to be around 13.2% or 0.132 d = Precision or margin of error (in proportion of 1; 5% = 0.05), n = ~175 patients

The clinical examination was conducted following infection control measures and included scores for dental caries (decayed, missing and filled teeth DMFT index), oral hygiene (plaque index) and periodontal status using a standard probe.

DMFT index was calculated from the number of decayed, missing and filled teeth. All permanent teeth, excluding third molars, were examined under adequate

illumination using a mouth mirror and a community periodontal index (CPI) probe [12] . A tooth was considered "decayed" when there was a cavity, undermined enamel, or softened surfaces. Teeth missing due to caries were recorded as "M," while those with permanent restorations and no recurrent decay were recorded as "F." The DMFT score for each participant was calculated as the sum of decayed, missing, and filled teeth. The mean DMFT and standard deviation (SD) were computed for the study population, along with the component means (DT, MT, FT) and their respective ranges. The prevalence of caries experience was defined as the proportion of participants with a DMFT score greater than zero.

The oral hygiene status of the participants was assessed using the Silness and Loe Plaque Index (PI) [13] . The plaque index assessed the accumulation of plaque to the naked eye, without using plaque disclosing agents. The examination was conducted under adequate natural light using a mouth mirror and WHO probe. Six index teeth (16, 12, 24, 36, 32, and 44) were selected as per WHO guidelines, and four surfaces (buccal, lingual, mesial, distal) of each tooth were examined. Where an index tooth was missing, the adjacent tooth was substituted. The score ranged from 0 (no plaque) to 3 (Abundant plaque within the gingival pocket and/or covering the gingival margin and tooth surface). Each tooth was examined at four points and the highest score was determined. The individual PI score was obtained by calculating the mean of the surface scores for all examined teeth. Based on these values, participants were categorized as having: Excellent oral hygiene: PI = 0; Good oral hygiene: PI = 0.1–0.9; Fair oral hygiene: PI = 1.0–1.9; Poor oral hygiene: PI = 2.0–3.0. For each participant, the plaque index was recorded, and the mean values and distribution across categories were calculated.

The periodontal status of the participants was assessed using Russell's Periodontal Index (RPI),
which evaluates both the prevalence and severity of periodontal disease [14] . All teeth, excluding
third molars, were examined under adequate illumination using a mouth mirror and WHO
probe. Each tooth was scored according to the following criteria:

0 = Negative (healthy periodontium)
1 = Mild gingivitis involving only a portion of the tooth
2 = Gingivitis circumscribing the tooth without pocket formation
6 = Gingivitis with pocket formation, tooth firm and without loss of function
7 = Advanced destruction with tooth mobility, drifting, or loss of function; missing teeth due to periodontal disease were also recorded as score 7.

For each participant, the total score was obtained by summing the values of all examined teeth
and dividing by the number of teeth present. The resulting index value was then interpreted as
follows:

0–0.2 = Clinically normal
0.3–0.9 = Simple gingivitis
1.0–1.9 = Beginning destructive periodontal disease
2.0–4.9 = Established destructive periodontal disease
5.0–8.0 = Terminal disease

The enrolled participants were asked to complete a structured questionnaire for assessing their knowledge, attitude, and practices towards oral health and oral hygiene measures. The study questionnaire was adapted from an existing validated instrument which was developed to assess the oral health status, behaviour and knowledge patients with cardiovascular diseases [7] .

Patient recruitment and evaluation was done for a duration of six months, followed by data analysis and report writing. The data obtained were tabulated using Microsoft Excel sheet and further statistical tools were applied using SPSS 2.

A discrete-time forecast model was also developed to project 15-year trajectories in public awareness that "poor general health" is a cardiac risk factor. The modeled cohort was initialized using the study's observed baseline awareness, with the remainder classified as "not aware." A two-state Markov structure (Aware vs Not Aware) updated annually with fixed
transition probabilities captured (i) acquisition of awareness and (ii) decay of awareness (small
but non-zero to reflect message fade-out) [15] .

Two scenarios were evaluated: a status-quo condition (no targeted program) and a sustained education condition simulating recurring, multi-channel public-health messaging; the latter increased the probability of becoming aware and reduced decay. Transition parameters were calibrated to reproduce the observed baseline and the pre-specified end-of-horizon targets, with face validity checked by expert review. Core assumptions included a closed cohort, stable demographics, no competing mass campaigns in the status-quo, and constant annual effects within scenarios. Uncertainty was explored through one-way sensitivity (varying intervention uplift, decay rate, and baseline awareness) and, if required, simple probabilistic analysis using beta-distributed transitions. Primary outputs were annual awareness percentages by scenario
and absolute/relative gains at year 15; implementation used spreadsheet formulas (or equivalent
R/Python code) to ensure transparency and replicability.

3. RESULTS

(Table 1) depicts the sociodemographic characteristics of the study cohorts. The mean age of the participants was 52.9 ± 9.7 years, with the majority falling in the 51–60 years age group (40.5%), followed by those aged 41–50 years (34.2%). A smaller proportion of participants were aged 61–70 years (15.4%), while only 2.8% were aged 71–80 years. The study population comprised 57.1% females and 42.9% males. In terms of occupation, homemakers represented the largest group (35.4%), followed by skilled or manual workers (30.3%), educators (19.4%), and those in clerical, sales, or service roles (14.9%). Regarding educational status, half of the participants (50.0%) had received school-level education, 20.0% had no formal education, while 10.0% and 20.0% had attained undergraduate and postgraduate or higher qualifications, respectively. (Table 2) details the oral health status and behaviour related to maintaining oral hygiene. At least 56.6% of the patients reported the presence of at least one oral or more oral symptoms.

Table 1. Sociodemographic characteristics of Study Participants.

Variables	Frequency (%)
AGE	
Age, mean (SD) in years	52.9 ±9.7
Age group 21-30	0 (0.0%)
Age group 31-40	12 (6.9%)
Age group 41-50	60 (34.2%)
Age group 51-60	71 (40.5%)
Age group 61-70	27 (15.4%)
Age group 71-80	5 (2.8%)
GENDER	
Male	75 (42.9%)
Female	100 (57.1%)
OCCUPATION	
Homemakers	62 (35.4%)
Educators	34 (19.4%)
Skilled/Manual Workers	53 (30.3%)
Clerical/Sales/Service	26 (14.9%)
EDUCATION	
No Formal Education	35 (20.0%)
School Education	88 (50.0%)
Undergraduate (UG)	17 (10.0%)
Postgraduate & Higher	35 (20.0%)

Table 2. depicts the Oral health status and behaviour related to maintaining oral hygiene.

VARIABLES	Frequency	Percentage
Self-Reported Problem ** Few patients presented with more than one self-reported problem*		
Decayed	49	62
Sensitivity	40	50.1
Food Lodgement	20	25.3
Missing Teeth	25	31.7
Dry Mouth	10	13.7
Tooth Mobility	16	20.3
Bleeding Gums	17	21.5
Filled teeth	10	12.7
Ill-fitting denture	2	2.5
Self-reported oral health problems		
One or more oral problem		56.6%
Brushing Frequency per Day		
Once	96	55
Twice	75	43
Never	4	2
Oral Hygiene Products Used ** Few patients presented with more than one oral hygiene product*		
Mouthwash	42	24.0
Dental Floss	34	19.4
Toothpaste	142	81.0
None	33	19.0
Cigarette/Bidi Usage per Day		
None	82	46.9
Less than 5	63	36.0
More than a packet	30	17.1
Dentist Visit Frequency		
Less than once/ year	117	67.0
More than twice/year	51	29.0
Never	7	4.0
Oral Health Status		
Good	26	14.8
Moderate	89	50.8
Poor	60	34.3

The most commonly self-reported dental problems were decayed teeth (62%), followed by sensitivity (50.1%), missing teeth (31.7%), and food lodgement (25.3%). Other reported problems included bleeding gums (21.5%), tooth mobility (20.3%), dry mouth (13.7%), filled teeth (12.7%), and ill-fitting dentures (2.5%). Perceived oral health status varied among the cohorts, with 50.8% rating their oral health as moderate, 34.3% as poor, and only 14.8% as good. In contrast, the majority of participants valued oral health, with 78.3% rating it as important to highly important for general health, while 21.7% considered it less important.

Regarding oral hygiene behaviour, the majority brushed their teeth once daily (55%), while 43% brushed twice daily, and 2% reported never brushing. The use of oral hygiene aids was variable: toothpaste was the most commonly used product (81%), followed by mouthwash (24%) and dental floss (19.4%), whereas 19% reported not using any oral hygiene products. 46.9% were non-users, while 36.0% smoked fewer than five cigarettes/bidis per day and 17.1% reported smoking more than a packet per day. While 67% of participants reported visiting a dentist less than once a year, roughly one-third attended more than twice annually, whereas 4.0% had never sought dental services.

Table 3 Cardiovascular disease (CVD) status and Knowledge of people with CVDs.

VARIABLES	Frequency	Percentage
Cardiovascular Disease Distribution		
Hypertension (only)	124	70.9
Coronary Artery Disease (CAD)	24	13.7
Arrhythmia	18	10.3
Valvular Heart Disease	9	5.1
Years since diagnosis of CVD		
6 to 10	64	36.6
11 to 15	58	33.1
15 to 20	42	24.0
21 and more	11	6.3
Participant Awareness on Poor oral Health as a risk factor for cardiac complications		
Yes	80	45.7
Don't know	64	36.6
No	31	17.7
Participant Awareness of Infective Endocarditis		
Yes	44	25.1
No	131	74.9
Awareness of Oral and Cardiac Disease Link		
Yes	24	13.7
No	151	86.3
Awareness of Dry Mouth from Anti hypertensives		
Yes	47	26.9
No	128	73.1
Awareness of Tooth Loss from Anti hypertensives		
Yes	16	9.1
No	159	90.9
Awareness of Gum Enlargement from Anti hypertensives		
Yes	13	7.4
No	162	92.6
Awareness of Visiting Cardiologist Before Dental Procedure/knowledge regarding cardiac clearance before invasive dental procedure		
Yes	11	6.3
No	164	93.7
Awareness of Oral Health Linked To General Health		
Yes	137	78.3
No	38	21.7

(Table 3) depicts the cardiovascular disease (CVD) status and Knowledge of people with CVDs. With respect to cardiovascular conditions, hypertension alone was the most prevalent diagnosis, observed in 70.9% of the participants. Coronary artery disease (CAD) was reported in 13.7%, followed by arrhythmias in 10.3%, and valvular heart disease in 5.1% of the study population. With regard to the duration since cardiovascular disease diagnosis, 36.6% of participants had been diagnosed for 6-10 years, 33.1% for 11-15 years, 24.0% for 15-20 years, and 6.3% for more than 21 years. When asked whether poor oral health is a risk factor for cardiac complications, 45.7% responded affirmatively, 36.6% reported not knowing, and 17.7% responded negatively. Knowledge of infective endocarditis was notably low; only 25.1% of participants were familiar with the condition, while 74.9% reported no awareness. Similarly, knowledge of the relationship between oral and cardiac health was limited, with only 13.7% acknowledging a possible link and 86.3% reporting no such knowledge.

Knowledge of oral complications related to antihypertensive medications was also poor. While 26.9% recognized dry mouth as a side effect, only 9.1% were aware of its association with tooth loss, and 7.4% identified gum enlargement as a possible complication. Knowledge of antibiotic prophylaxis before dental procedures was minimal, with only

6.3% aware that cardiologists may recommend it, whereas 93.7% were unaware.

Table 4 . Details the DMFT scores among the study cohorts.

Variables	
DMFT (mean ± SD)	3.00 ± 2.01
DT (mean, range)	1.19 (0–3)
MT (mean, range)	0.63 (0–2)
FT (mean, range)	1.18 (0–3)

DMFT = number of decayed, missing, and filled teeth (caries index); DT = decayed teeth; FT = filled teeth; MT = missing teeth

The dental caries experience of the study population was assessed using the DMFT index, as depicted in (Table 4). The mean DMFT score was 3.00 ± 2.01, indicating that, on average, each participant presented with approximately three teeth affected by caries experience. When analyzed by component, the mean number of decayed teeth (DT) was 1.19, with a range of 0-3. The mean number of missing teeth due to caries (MT) was 0.63 (0-2), while the mean number of filled teeth (FT) was 1.18 (0-3). Overall, 72.2% of participants had a DMFT score greater than zero, demonstrating the prevalence of caries experience within this population. These findings reflect a moderate burden of untreated caries and restorative needs within the population, highlighting the continuing importance of preventive and therapeutic oral healthcare interventions.

Table 5. Distribution of plaque index scores in the study cohorts.

S.no.	Rating	Score	No. of patients
1	Excellent	0	None
2	Good	0.1–0.9	27 (15.42%)
3	Fair	1.0–1.9	105 (60.00%)
4	Poor	2.0–3.0	43 (24.57%)

The mean plaque index score of the study population is illustrated in (Table 5). The mean plaque index score of 1.59 ± 0.63 corresponds to the fair oral hygiene category. Distribution analysis revealed that the majority of participants (60.0%) exhibited fair plaque scores, followed by 24.6% with poor oral hygiene and 15.4% with good oral hygiene. Notably, none of the participants were classified as having excellent plaque control. Overall, nearly 85% of the population demonstrated fair to poor oral hygiene status, underscoring the need for improved oral hygiene practices and preventive care interventions.

Table 6. Distribution of periodontal index scores in the study cohorts.

Sno.	Score	Interpretation	N (%)
1	0 – 0.2	Clinically normal	8 (4.6%)
2	0.3 – 0.9	Simple gingivitis	63 (36.0%)
3	1.0 – 1.9	Beginning destructive periodontal disease	56 (32.0%)
4	2.0 – 4.9	Established destructive periodontal disease	37 (21.1%)
5	5.0 – 8.0	Terminal disease	11 (6.3%)

The periodontal status of the study population, as assessed using the Russel's periodontal Index (RPI) in (Table 6), revealed that only 4.6% of participants were clinically normal. The mean RPI score of 1.82 ± 1.63 indicates a predominance of destructive periodontal conditions. Notably, destructive changes were observed in nearly two-thirds of participants, highlighting the substantial burden of periodontal disease within the study cohort.

Table 7. Distribution of dental treatment needs among the study cohorts.

S. no.	Dental treatment needs	Number of patients (%)
1	No treatment required	41 (23.4%)
2	Periodontal therapy	126 (72.0%)
3	Prosthodontic rehabilitation	87 (49.7%)
3	Restorative and endodontic treatment	61 (34.8%)
4	Exodontia and other surgical treatment	27 (15.4%)

(Table 7) details the distribution of dental treatment needs in the study population. The findings suggests that a significant proportion of participants required professional intervention. Periodontal treatment was the most common need, reported in 126 participants (72.0%). Prosthodontic rehabilitation was required in 87 participants (49.7%), while 61 participants (34.8%) required restorative and endodontic treatment. Exodontia or other surgical management was indicated for 27 participants (15.4%). Notably, 41 participants (23.4%) did not require any treatment.

A binary logistic regression was performed to assess whether awareness of infective endocarditis, knowledge of the oral–cardiac disease link, recognition of dry mouth as a side effect of antihypertensive medications, and awareness of the oral–general health link predicted participants' perception of poor general health as a cardiac risk factor. Awareness of infective endocarditis (OR = 2.25, p = 0.499) and the oral–cardiac link (OR= 2.23, p = 0.297) both showed positive but non-significant associations. Similarly, awareness of dry mouth as a side effect of anti hypertensives (OR = 1.62, p = 0.498) demonstrated a non-significant positive association. Interestingly, awareness of the oral–general health link showed a negative, though non-significant, association (OR = 0.24, p = 0.206), indicating that those aware of this link were less likely to report poor general health as a cardiac risk factor.

A forecast model was developed to estimate changes in awareness regarding poor general health as a cardiac risk factor over a 15-year period. In the absence of targeted interventions, awareness is projected to increase modestly from 45.6% to 51.6%. However, with sustained public health education efforts, awareness levels could rise significantly, reaching approximately 69.6% by year 15 (Figure 1).

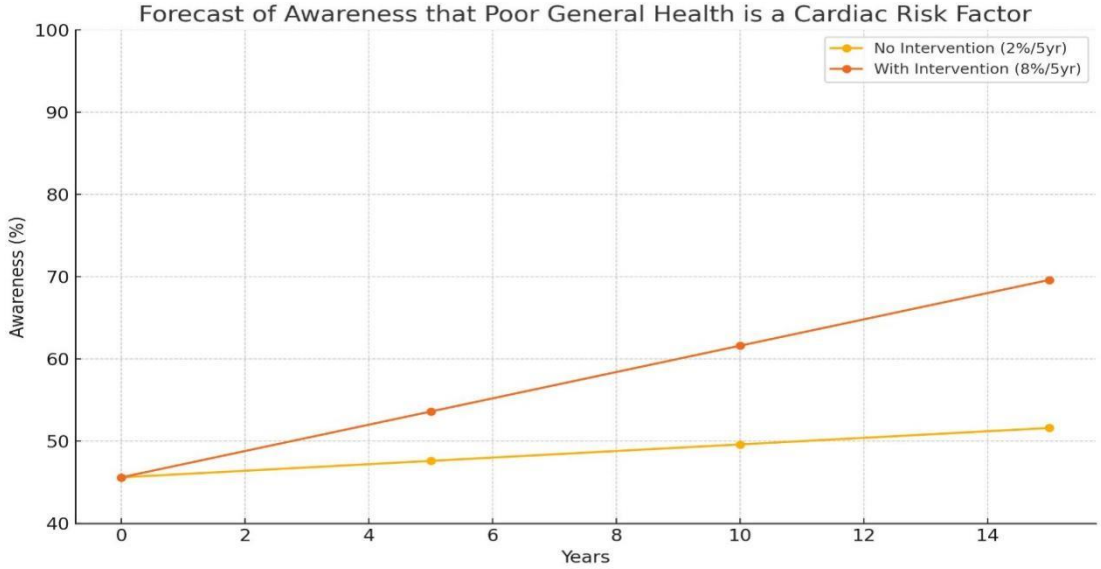

Figure 1. Forecast model estimating changes in awareness of poor general health as a cardiac risk factor.

We further synthesized patient pathways from three source tables (Tables 5-7) to link plaque status, periodontal stage, and treatment needs. Plaque categories were retained as reported. Periodontal status was harmonized into five ordered bands (Normal, Simple gingivitis, Beginning destructive, Established destructive, Terminal disease), and treatment needs were mapped a priori into four composite classes (Periodontal, Restorative, Prosthodontic, Exodontia); rare unclassifiable items were grouped as "Other" and omitted if negligible. To preserve comparability, each table's marginal totals was rescaled to a common grand total NNN (the median of the three), maintaining relative proportions. We then estimated the joint plaque × periodontal × treatment distribution using Iterative Proportional Fitting (RAS), yielding the maximum-entropy three-way contingency table consistent with the three one-way marginals. Non-integer

fitted counts were converted to integers using the largest-remainder method while preserving the grand total NNN. Flow weights for visualization were derived as (i) plaque→periodontal by summing across treatment categories and (ii) periodontal→treatment by summing across plaque categories, thereby reproducing the observed marginals by construction. Two vector, Sankey-style alluvial panels were rendered with band widths proportional to marginal totals and ribbon widths scaled to flow magnitudes; labels were centered on bands, and ribbon values were displayed only above a size threshold to minimize overlap.

Quality checks confirmed exact recovery of the input marginals and stability to alternative positive starting values for the IPF procedure; a brief sensitivity analysis varying initializations produced identical solutions within numerical tolerance. Because these flows are reconstructed from marginals rather than observed cross-tabulations, they should be interpreted as plausible, maximum-entropy allocations. If row-level data become available, the figure can be recomputed to show observed transitions.

Overall, the pathways succinctly illustrate how patients progress from plaque status to periodontal stage and, subsequently, to likely treatment needs, using a standard method that ensures agreement with the totals reported in (Tables 5–7).

In Panel A (Plaque → Periodontal), the highest plaque band (2.0–3.0) accounts for ~61.5% of all flows and predominantly progresses to terminal disease (≈50% of its own outflow) or to established destructive periodontitis. The intermediate band (1.0–1.9) contributes ~30.8%, again mainly feeding terminal disease, while the lowest band (0.1–0.9) contributes ~7.7%, almost entirely to terminal disease. Collapsing across plaque, the receiving periodontal distribution is ~61.5% terminal disease, ~30.8% established destructive disease, and ~7.7% beginning destructive disease.

Panel B (Periodontal → Treatment need) shows that outflows from terminal disease (~61.5% of periodontal outflow) go chiefly to extractions (≈37.5% of the terminal-disease outflow), with smaller proportions to prosthodontic and restorative care. Established destructive disease (~30.8%) splits across extractions, prosthodontics, and restorative needs, whereas beginning destructive disease funnels almost entirely to extractions. Combining panels yields an estimated treatment mix of ~46.2% extractions, ~23.1% prosthodontics, ~23.1% restorative care, and ~7.7% periodontal therapy. Overall, worse plaque status is associated with more advanced periodontal disease, shifting treatment demand toward more invasive services, particularly tooth extractions and subsequent prosthodontic rehabilitation (Figure 2).

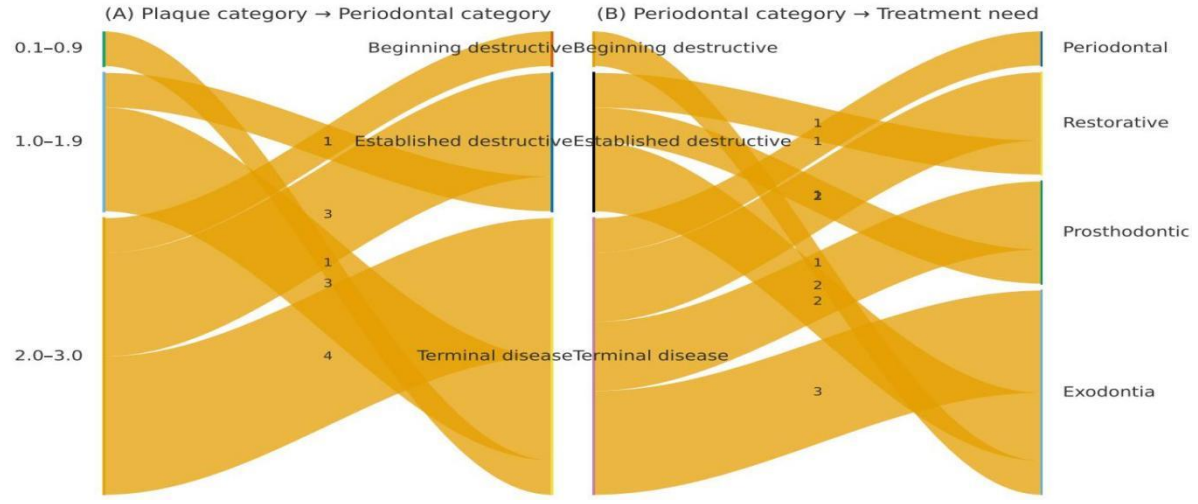

Figure 2. Depicts the alluvial visualization of oral-health pathways.

4. DISCUSSION

This cross-sectional study assessed oral health status, behaviors, and awareness among patients with cardiovascular disease, highlighting significant gaps in knowledge and preventive practices. Despite the high CVD burden, many participants lacked understanding of the bidirectional relationship between oral and cardiac health, reinforcing the link between poor oral hygiene and cardiovascular risk.

The study population had a mean age of 52.9 ± 9.7 years, with most participants aged 51–60 years (40.5%) and 41–50 years (34.2%), consistent with previous studies [4,16-19], though some reported younger cohorts [20,21]. This mid-to-late adult age group (40–70 years) represents a

critical period for targeted cardiovascular and oral health interventions, given their heightened vulnerability to both systemic and oral diseases. Nevertheless, awareness of the link between these conditions remains limited [22].

The study observed a slight female predominance (57.1%), contrasting with previous epidemiological studies of higher CVD prevalence in males, [4,7,16-18], though some studies reported equal gender distribution [20]. Recent trends suggest a narrowing gender gap, particularly in low- and middle-income countries, where women increasingly exhibit comparable cardiovascular risk profiles and disease burdens. These trends are driven by epidemiological transitions, increasing prevalence of shared modifiable risk factors, and persistent disparities in healthcare access and quality [23].

Most participants (70%) had not completed university education, with half having only school-level education and 20% lacking formal schooling. These findings align with previous studies demonstrating that higher educational attainment is linked to improved oral hygiene, greater dental care utilization, and enhanced awareness of oral–systemic health links [7,18,24,25].

The study population was primarily composed of homemakers (35%) and skilled/manual laborers (30%). Low socioeconomic status, often linked to such occupations, negatively impacts oral health through limited oral health literacy, restricted healthcare access, and financial constraints. Previous studies have reported poorer oral health outcomes and lower utilization of preventive dental services among lower-skilled occupational groups, underscoring the need for targeted community- or workplace-based oral health interventions [7,16,26].

Most participants (70.9%) reported hypertension, followed by coronary artery disease (13.7%), arrhythmias (10.3%), and valvular heart disease (5.1%). These patterns align with national data, where hypertension is the predominant cardiovascular risk factor in Indian adults, contributing substantially to stroke and coronary heart disease mortality and conferring a six- to eight-fold increased risk of cardiovascular death [27].

Around 2/3^{rds} of the patients had cardiovascular disease for 6-15 years, reflecting a significant chronic disease burden and a need for preventive oral healthcare, consistent with Sanchez et al., who reported a mean duration of 7.8 years [7].

Most participants with CVDs perceived their oral health as sub-optimal, with the majority reporting moderate or poor oral health status, consistent with previous reported evidences linking periodontal and cardiovascular health [3,9,28].

In this study, only 45.7% of participants recognized poor oral health as a risk factor for cardiac complications, while 36.6% were uncertain. This highlights persistent gaps in patient education and interdisciplinary care [3,7,20], likely driven by limited oral health knowledge among patients and clinicians, inadequate training on oral-cardiovascular links, insufficient cardiovascular-specific resources, and time constraints faced by cardiac care professionals [4,7].

Infective endocarditis (IE) is a life-threatening infection of the endocardial lining, typically affecting the valves, caused when oral bacteria enter the bloodstream during invasive dental procedures and colonize damaged endocardial tissues or prosthetic valves. In CVD patients, IE carries high risks of heart failure, embolic events, and mortality, highlighting the importance of preventive oral care and antibiotic prophylaxis in high-risk individuals, as recommended by the American Heart Association (AHA) and the European Society of Cardiology (ESC) [29,30].

Our study reported a low knowledge regarding infective endocarditis (25.1%), aligning with recent evidence indicating that only 28–45% of high-risk patients can accurately define the condition, and over half are unaware of the necessity for antibiotic prophylaxis prior to dental procedures. These gaps highlight a critical vulnerability, as inadequate awareness may increase the risk of severe complications, including heart failure, in susceptible individuals [31-33].

Knowledge of oral complications associated with antihypertensive medications was limited, with only 26.9% identifying dry mouth, 9.1% recognizing tooth loss, and 7.4% acknowledging gingival enlargement as possible side effects. These results are consistent with prior evidence that xerostomia and gingival overgrowth are common yet under recognized adverse effects of calcium channel blockers and diuretics [7,34,35]. The observed limited awareness regarding infective endocarditis and oral complications of antihypertensive therapy may be partly attributed to the low educational attainment of the study population.

In the present study, although a majority of participants (78.3%) acknowledged the importance of oral health for overall well-being, knowledge of its specific association with CVDs was limited, with only 13.7% demonstrating awareness of this link. This reflects a superficial understanding of health and limited knowledge of the systemic implications of oral disease, aligning with findings from other national and international studies that report poor patient knowledge of oral–systemic links. Kumar et al. study findings revealed that 33% of participants were aware of the association [3], though none were aware of the potential risk of related complications. Sanchez et al. reported that 50% of the cohort had

adequate knowledge of the oral health-CVD relationship [7], whereas Hollatz et al. observed that approximately 73% of participants exhibited little or no awareness of this connection [20].

These findings highlight the necessity for integrated health promotion initiatives across clinical and community settings, fostering collaboration between dental and medical professionals to improve patient education on the oral complications of antihypertensive therapy and the systemic impact of poor oral health. The poor knowledge observed in this study may be attributable to the limited oral health resources and educational information provided within the cardiac care setting [3,7,20,36].

Our study found that only 6.3% of patients were aware of the need for cardiac clearance before undergoing dental treatment. These findings align with recent evidence indicating limited awareness among cardiovascular patients, highlighting the urgent need for enhanced patient education and strengthened interdisciplinary collaboration[4,7,30].

In the present study, 56.6% of patients reported one or more oral symptoms. Comparable findings have been reported previously, with Kumar et al. documenting a prevalence of 45% [3], and Sanchez et al. observing such symptoms in 81.8% of their cohorts [7]. A significant proportion of participants reported oral health problems such as dental caries (62%), sensitivity (50.1%), and missing tooth (31.7%). Comparable results were observed in other studies [3,27,37].

Oral hygiene behaviour among study cohorts demonstrated considerable scope for improvement. Over half (55%) reported brushing only once daily, 43% brushed twice daily, and 2% brushed infrequently or not at all, indicating a persistent gap between recommended oral hygiene guidelines and actual practices.

Brushing frequency among patients with CVDs showed marked variability across different populations. In Australian and German cohorts, the majority of patients (60.4% and 84%, respectively) reported brushing twice or more daily, reflecting comparatively better adherence to recommended oral hygiene practices [7,20]. Conversely, only 15.5% of Iranian patients brushed once daily [18], while in India 67% did not brush at all on a daily basis and only 10.4% reported brushing once per day [3]. These findings underscore pronounced disparities in oral hygiene behaviors, with poorer practices observed in low- and middle-income countries.

Notably, evidence from large population-based studies and systematic reviews also demonstrates that infrequent tooth brushing (<2 times/day) is associated with increased risks of cardiovascular events, metabolic disorders, and mortality, underscoring the critical role of meticulous oral hygiene in CVDs prevention and management [3,7,38].

Fluoridated toothpaste was the most commonly used oral hygiene product among participants (81%), while the use of adjunctive aids such as mouthwash (24%) and dental floss (19.4%) was limited, indicating the need to reinforce comprehensive oral hygiene practices. These findings are consistent with recent studies reporting limited utilization of adjunctive oral hygiene aids, with only 6-13% of cardiovascular patients engaging in regular flossing and 14-36% using mouthwash daily, highlighting inadequate oral hygiene practices [3,18,39].

C-reactive protein (CRP) serves as a biomarker of systemic inflammation, with elevated levels associated with an increased risk of cardiovascular disease. Evidence indicates that regular tooth brushing and flossing contribute to reduced circulating CRP levels [40].

In the present study, more than two-thirds of participants reported visiting a dentist less than once per year, indicating limited utilization of preventive dental services. Variable patterns have been reported in several other studies, with annual dental visits ranging from 8.7% to 58.8%. Furthermore, over one-fourth of participants delayed their most recent dental consultation for more than two years, while 38.1% had never visited a dentist and 46.2% had not sought dental care for over a year [7,16,18].

These findings underscore persistent disparities in dental service utilization, highlighting the need for targeted interventions to improve oral health-seeking behaviors. Findings from both population-based and clinical studies suggest that individuals who delay or neglect routine dental care are more prone to develop coronary heart disease, stroke, and heart failure compared with those who attend regular preventive visits. Meticulous oral hygiene markedly reduces systemic inflammation and cardiovascular risk, highlighting the importance of integrating oral healthcare into comprehensive cardiovascular disease prevention and management strategies [40-42].

Poor oral hygiene and untreated periodontal disease contribute to an increased systemic inflammatory burden, as evidenced by elevated levels of biomarkers such as C-reactive protein (CRP), interleukin-6 (IL-6), and tumor necrosis factor-alpha (TNF-α). This increased inflammatory state facilitates the progression of atherosclerosis, promotes thrombotic activity, and impairs endothelial function, thereby significantly increasing the risk of adverse cardiovascular events [32].

In this study, 72.2% of participants demonstrated caries experience, with a mean DMFT score of 3.00 ± 2.01, reflecting a moderate caries burden. While direct comparisons with other investigations are limited by

variations in age distribution, socioeconomic background, and methodological variations, comparable caries patterns have been reported across diverse cohorts. Epidemiological evidence consistently indicates a high prevalence of dental caries among individuals with systemic conditions, including cardiovascular disease, with mean DMFT values commonly between 2.5 and 4.5 [3,43]. Notably, several other studies have documented even higher DMFT scores among CVD patients[17,20,27,37,44].

The mean plaque index (PI) of our study cohort was 1.59 ± 0.63, indicative of predominantly fair oral hygiene, with the majority of participants presenting fair to poor scores. These results are consistent with previous literature demonstrating that individuals with CVDs typically exhibit higher plaque indices (average PI-1.2-1.4) than non-CVD controls, underscoring the substantial burden of inadequate oral hygiene in this population [3,17,19].

In our study, the mean Russell's Periodontal Index (RPI) was 1.82 ± 1.63, indicating a high prevalence of destructive periodontal disease. This pattern mirrors prior evidence of greater periodontal burden among individuals with cardiovascular comorbidities (particularly hypertension and coronary artery disease), supporting a plausible cardiometabolic-periodontal link [45-4]. However, a higher RPI was reported in other studies. Sanikop et al. found the highest RPI in the chronic periodontitis group (mean 3.62) with significant between-group differences [48], and Gor et al. reported that patients with congenital heart diseases (CHD) and generalized periodontitis had a higher mean RPI (5.01 ± 0.18) than those without CHD (3.72 ± 0.13), an ~1.35-fold increase, indicating more advanced destructive disease in cardiovascular cohorts [49].

In the present study, self-perceived oral health did not align with actual treatment needs, as only 23.4% of patients required no dental intervention. These findings, consistent with previous reports, highlight limited awareness of oral health problems among participants [3,50]. This underscores the limited awareness of dental problems among the study participants, which may be partly explained by their tendency to overlook oral health concerns in the context of a life-threatening cardiac condition.

The forecasting model provided projections that align with findings from similar health promotion modeling studies, such as those using the PRECEDE–PROCEED framework for planning behavior change interventions and microsimulation models assessing long-term outcomes of oral health campaigns [51.52]. Additionally, diffusion of innovation models have demonstrated that strategic communication can accelerate adoption of preventive behaviors in cardiovascular health [53]. These trends underscore the critical role of structured and sustained educational interventions in improving cardiovascular health literacy and closing knowledge gaps in at-risk populations.

Strengths, Limitations and Future Directions

The study concurrently evaluated clinical oral status, treatment needs, and knowledge and behaviour, offering a holistic picture of oral health among adults with CVDs. The examinations followed WHO-recommended instruments and validated indices with explicit scoring criteria and category thresholds, improving reproducibility and cross-study comparability. Further, including patients with confirmed CVDs strengthens clinical applicability for cardiometabolic care pathways and oral-systemic integration. The detailed treatment-need profiling (periodontal, prosthodontic, restorative, surgical) provides directly implementable guidance for service planning and referral within cardiac clinics. However, the cross-sectional design, single-center sampling, reliance on self-report for knowledge and behaviour, and modeled (rather than observed) pathway flows temper causal interpretation and generalizability. Future research should employ longitudinal or cohort designs with multicenter sampling and collect individual-level cross-tabulations (plaque × periodontal × treatment) to directly estimate observed flows.

5. CONCLUSION

Adults with cardiovascular disease (CVD) in this cohort exhibited a substantial oral disease burden with a moderate caries experience (mean DMFT ≈ 3), predominantly fair-to-poor plaque control, and a high frequency of destructive periodontitis. Awareness of oral-cardiac links and everyday preventive practices was low; dental attendance was infrequent, and self-perceived oral health underestimated actual treatment needs, indicating missed opportunities for prevention and timely care.

Although multivariate analyses did not show a significant association between specific knowledge items and recognizing "general health" as a cardiac risk factor, a 15-year forecast suggests that sustained, structured education could raise awareness from ~46% to ~70%. This highlights education as a realistic, scalable lever for improvement.

Practice and policy should prioritize: integrating routine oral screening, prevention, and referral pathways within cardiac clinics; delivering co-designed, culturally tailored education that addresses infective endocarditis prevention, medication-related oral effects, and daily

hygiene; and institutionalizing dentistry-cardiology collaboration to guide antibiotic prophylaxis and align periodontal care with cardiovascular risk reduction.

Given the single-center, cross-sectional design and reliance on self-reported knowledge and behaviour, future multicenter longitudinal studies with individual-level plaque–periodontal–treatment cross-tabulations are warranted to quantify observed pathways and evaluate the impact of integrated oral-cardiac care on outcomes.

To conclude, bridging oral and cardiovascular care is both necessary and feasible, as CVDs continue to be the leading causes of global mortality and significantly contribute to diminished health and increased healthcare expenditures [54] . Targeted education, systematic screening, and timely periodontal/restorative treatment can lower inflammatory burden, preserve dentition, and plausibly contribute to improved cardiovascular trajectories in this high-risk population.

DECLARATIONS

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Competing Interests

The author declares no competing or conflicting interests.

Ethical approval and consent to participate

Ethical permission was granted by the Institutional Ethics Committee of the Faculty of Dentistry, JMI University (Ref. No.:17/12/JMI/IEC/2020;18/2/21).

All patient identifiers were anonymized for confidentiality *with the ethical principles outlined in the Declaration of Helsinki.*

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