Community-Based Periodontal Disease Prevention Programs: A Schematic Assessment and Meta-Analysis of Effectiveness and Future Directions under Community Medicine and Dentistry

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ABSTRACT

Background: The prevalence of periodontal disease in the general population is still an important issue in public health, particularly among groups with low access to preventive treatments. The current meta-analysis was intended to determine the efficacy of community-based periodontal disease prevention programmes in enhancing clinical periodontal outcomes, namely, Plaque Index (PI), Gingival Index (GI), Bleeding on probing (BOP), and Pocket probing depth (PPD).

Methods: The literature was searched using PubMed, Web of Science, and Google Scholar (2012-2025). Community-based interventions that targeted the aspects of education, behavioral change, or preventative care were eligible. Risk of bias was assessed using the Cochrane risk of bias tool and the Newcastle Ottawa for Randomized controlled trials (RCTs) and Observational studies, respectively. The certainty of evidence was evaluated with the GRADE criteria. Meta-analyses were completed based on a random-effects model, and heterogeneity was evaluated by means of I2 statistics.

Results: Twelve studies were enrolled in this study. In pooled analysis, there was a significant improvement in Plaque Index (SMD = -1.12; 95% CI: -1.59 to -0.64) and Gingival Index (SMD = -0.89; 95% CI: -1.35 to -0.43) after community-based interventions. In the case of Bleeding on Probing, the effect was not significant (SMD = 0.96; 95% CI: -1.66 to 3.59), whereas PPD displayed significant improvement (SMD = -0.62; 95% CI: -1.09 to -0.14).

Discussion: Periodontal programs based on communities are practical in lowering PI, GI, and PPD. In spite of the uneven results of BOP, the evidence as a whole favors the inclusion of such programs as components of oral health strategies.

Keywords: Periodontal Diseases/Prevention & control, Community Health Services, Dental Health Education, Oral Hygiene.

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INTRODUCTION

Periodontal disease is one of the most prevalent chronic inflammatory diseases around the world, with almost half of all adults being affected [1]. It not only comes with oral discomfort but also leads to tooth loss and the worsening of systemic conditions, like cardiovascular disease and diabetes [2]. The burden is not only huge in low- and middle-income countries, where professional dental care is scarce, but knowledge of preventive measures is not well spread as well [3]. These inequalities highlight the importance of cost-efficient, preventive measures that would be applicable to the population [4].

Proper early intervention is a significant factor in preventing the continued onset of reversible gingivitis to periodontitis, which is irreversible [5]. Because dental plaque's build-up is one of the modifiable risk factors, preventive interventions aimed at controlling plaque should be encouraged [6]. Oral health initiatives within the community, like brushing campaigns in schools, maternal health education, and monitored hygiene practices, have emerged as a potential advocate of sustainable oral health practices [7]. The interventions target people in ordinary settings and are an alternative solution to clinically based care models [8].

Regardless of the growing implementation of such programs, the existing body of literature is split apart [9]. The designs of the studies are wide-ranging, as well as the study population, intensity of the interventions, and outcome measures [10]. Although numerous studies document positive changes in Plaque Index (PI) and Gingival Index (GI), limited meta-analyses have used the results to ascertain the overall effect of community-based interventions. This disparity narrows the capacity of policymakers and professionals working in the field of public health to establish evidence-based strategies in oral health [11].

The study aims to gather, systematically assess, and meta-analyze the effectiveness of community-based periodontal disease prevention programs in lowering the clinical signs of periodontal disease that are plaque Index (PI) and gingival index (GI), and also investigate secondary outcomes of periodontal disease including bleeding on probing (BOP), and pocket probing depth (PPD).

METHODS

The present systematic review and meta-analysis was performed following the PRISMA 2020 guidelines [12]. It was a prospective study that aimed to assess and compare the efficiency of community-based periodontal disease prevention efforts in decreasing clinical periodontal variables including Plaque Index (PI) and Gingival Index (GI), bleeding on probing, and probing levels.

The studies included were quantitative studies in which school-based preventive oral health program, family-based preventive oral health program or community-based preventive oral health program were evaluated. Studies that met the criteria reported at least one clinical (primarily Plaque Index or Gingival Index) or secondary (BOP, CPI, PPD/CAL) or behavioral/knowledge-based outcomes. Only controlled interventional studies along with randomized controlled trials (RCTs) carried out on human beings were considered.

The studies that have not done in-vitro or animal studies, reviews, case reports, editorials or abstracts were discarded. Additionally, studies that did not have full texts and any of the outcomes that have been listed with quantitative data were also excluded.

The literature search was performed in PubMed, Web of Science, and Google Scholar databases with the time duration of 2012-2025. The keywords and Boolean operators are: periodontal disease prevention" OR community-based oral health" AND Plaque Index" OR Gingival Index" OR 'BOP' OR 'CPI' OR 'pocket depth' OR oral hygiene behavior. Other studies were also identified in reference lists of articles included and other relevant reviews.

Two reviewers screened the titles and abstracts. Articles that might be relevant were evaluated. In case of disagreement, it was fixed by discussion till a consensus was achieved.

Data were extracted in a standardized excel sheet which contained information related to author, year, study design, sample size and population, type of community-based program, intervention duration and outcome measures (mean, SD, percent change in PI, GI, BOP etc.).

The major results were the reductions of Plaque Index (PI), Gingival Index (GI) means following intervention. Secondary outcomes comprised variations in BOP, and probing depths.

The Cochrane Risk of Bias 2.0 tool and Newcastle Ottawa scale was used to measure the risk of bias related to RCTs and observational studies, respectively. The quality of evidence in the studies was measured with the GRADE classification that determines the strength of evidence.

The MetaAnalysisOnline Tool was used to conduct meta-analysis[13]. A random-effects model was utilized, which allowed for the consideration of variation between studies. In the case of controlled studies, standardized mean differences (SMDs) were used. The degree of heterogeneity was evaluated by I2 statistic, and over 50% was regarded as substantial. Primary and selective secondary outcomes were developed into forest plots. Sub group analysis was carried out by age group, type of intervention and region. Robustness of the results was tested by using sensitivity analyses by removing studies with high risk of bias. The studies included consisted of 10 RCTs 1 cross-sectional diagnostic study and 1 quasi-experimental study to assess school-based, family-based, or community-based preventive interventions among different individuals[14,15,16,17,18,19,20,21,22,23,24,25].

RESULTS

During the first database search, 155 records were detected but 20 were eliminated because they were considered duplicates. The rest of the 135 titles and abstracts were reviewed and 105 of them removed due to being irrelevant to the research topic or failing to fulfill the population and intervention criteria. There were 40 full-text articles evaluated. Among the other full-text articles, 28 were discarded because of lack of quantitative clinical results (n = 8), an indistinct community setting (n = 9), or knowledge regarding periodontal disease (n = 11). The last systematic review and meta-analysis was comprised of 12 studies found on PubMed (5), Web of science (1), and Google Scholar (6).

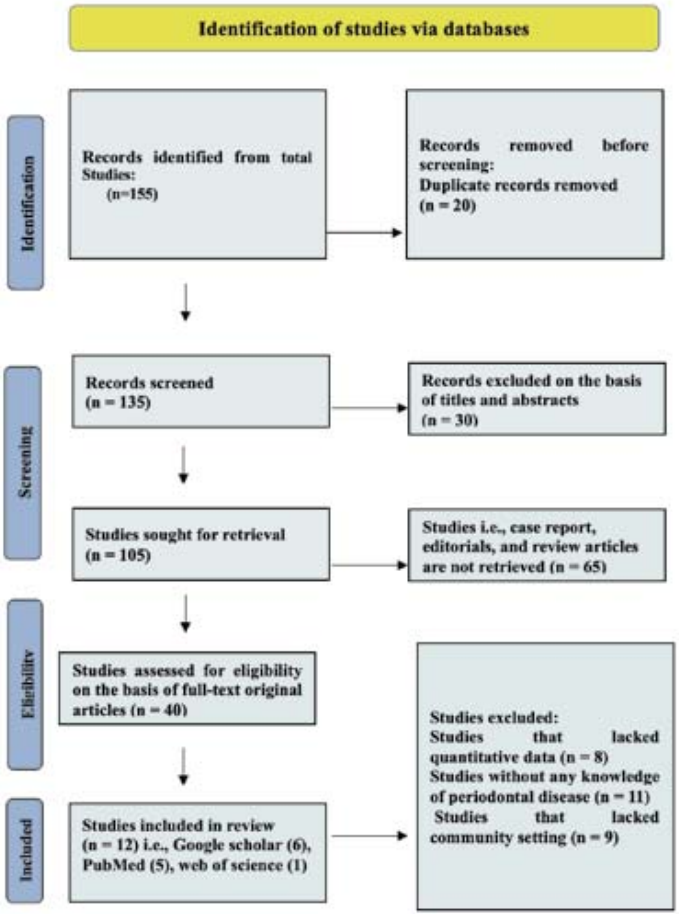

Figure 1: PRISMA flow diagram of included studies

Characteristics of the Studies

The studies included 12 interventional studies, which consisted of randomized controlled trials (RCTs), cluster-RCTs, quasi-experimental designs and a cross-sectional study. The sample sizes were very broad, varying between 44 to more than 5,000 participants. The populations of participants were represented as schoolchildren, pregnant women, elderly adults, university students, and individuals with hearing disabilities, thus highlighting the adaptability of these interventions to the vulnerable populations as well as the general population.

The programs were implemented in various community-based locations including rural schools, maternal health centers, social groups or clubs and specialty clinics. Prevention methods ranged in visual and media-based education to in-person counseling, peer-led teaching, motivational interviewing, and monitored oral hygienic behaviors. Various interventions adopted the use of reinforcement over time to influence behavior change. Other researches paired education with assisted brushing or debridement. Conventional oral hygiene guidance, pamphlets or deferred treatments were normally used as control groups.

Table 1: General characteristics of included studies evaluating community-based periodontal disease prevention programs.

Author (Year)	Study Design	Sample Size	Population Group	Community Setting	Method of Prevention
Eminoğlu et al. 2024 [14]	RCT (examiner-blinded)	56 (28 int., 28 ctrl.)	Adults (18–60 years), non-smokers	Atatürk University, Turkey	Visual education with oral photos
Parihar et al. 2024 [15]	Cluster-RCT	5000 (2500 int., 2500 ctrl.)	Schoolchildren (10–15 years)	Rural schools, Bhopal, India	School-based oral health education program
Almabadi et al. 2021 [16]	RCT (examiner-blinded)	579 (292 int.; 287 ctrl.)	Adults (18–60 years), low socioeconomic group	Logan Hospital, Queensland, Australia	Personalized oral health education + MI
Subedi et al. 2021 [17]	RCT (Parallel Group)	202 (99 experimental, 103 control)	12–15-year-old schoolchildren	Schools in Dharan, Nepal	Oral health education
Liu et al. 2020 [18]	RCT (parallel, 1:1)	369 (Test: 188; Control: 181)	Pregnant women (10–22 weeks gestation) and their husbands	Public hospitals and maternal/child health centers, Hong Kong	Family-centered behavioral & educational counselling
Nomura et al. 2016 [19]	Cross-sectional diagnostic study	92 (38 men, 54 women)	Adults >20 yrs, ≥20 teeth	8 private dental clinics, Japan	Salivary screening (Hb + LD)
Brand et al. 2013 [20]	Single-blind RCT	56 total (29 BMI + TOHE, 27 TOHE only)	Adults in periodontal maintenance with signs of inflammation	University dental school (USA)	Behavioral counseling (Brief Motivational Interviewing)
Marino et al. 2013 [21]	Quasi-experimental (pretest–posttest, non-equivalent control group)	144	Community-dwelling older Italian adults (≥55 yrs)	Italian social clubs, Melbourne, Australia	Community-based education + behavioral counseling
Stenman et al. 2012 [22]	RCT (examiner-masked)	44 (22 test, 22 control)	Adults with chronic periodontitis	Specialist Periodontology Clinic, Gothenburg, Sweden	Behavioral / Educational
Haleem et al. 2012 [23]	Cluster-RCT (2 years)	1,517 children (aged 10–11)	School children in 40 public/private schools in Lahore	School-based	Oral health education via dentist-led, teacher-led, peer-led, and self-learning methods

Arunakul et al. 2012 [24]	RCT (4-group parallel design)	66 children (aged 6–10 years)	Hearing-impaired children	3 Schools for the Deaf, Thailand	Oral hygiene education via media
D'Cruz et al. 2012 [25]	9-month Interventional Study (3-arm, school-based)	568 (Exp I: 141, Exp II: 143, Control: 284)	School children aged 13–15 years	3 public schools, Bangalore, India	Oral health education with or without tooth brushing demo

***RCT**: Randomized Controlled Trial; **OHE**: Oral Health Education; **MI**: Motivational Interviewing; **PPD**: Pocket Probing Depth; **CAL**: Clinical Attachment Loss; **CPI**: Community Periodontal Index; **PI**: Plaque Index; **GI**: Gingival Index; **BOP**: Bleeding on Probing; **VPI**: Visible Plaque Index; **KAP**: Knowledge, Attitudes, and Practices; **OHK**: Oral Health Knowledge; **OHB**: Oral Health Behavior; **KBS**: Knowledge-Behavior Score; **BMI**: Brief Motivational Interviewing; **TOHE:** Traditional Oral Health Education; **Exp I / Exp II:** Experimental Group I / Experimental Group II; **T0 / T1 / T2**: Timepoints at Baseline / First Follow-up / Second Follow-up.*

The majority of the research showed an improvement in Plaque Index (PI) and Gingival Index (GI), and some also measured bleeding on probing (BOP), Community Periodontal Index (CPI), probing depths (PPD), and oral health behaviors or knowledge. Although there was variation in the methods, short-term changes in clinical and behavioral performance were always noted. The necessary design and contextual factors defining these findings are discussed in **Table 1.**

Outcomes Measured

The primary outcomes were concerned with clinical periodontal indices-Plaque Index (PI) and Gingival Index (GI) in measuring the efficacy of community-based oral health measures. The overall and statistically significant decrease in both indices was observed, e.g., PI declined in structured education groups from 3.91±0.31 to 2.79±0.30, and GI went down by 1.46±0.26 to 1.07±0.11. In another outcome study on adult participants, the level of PI decreased from 1.76±0.59 to 0.57±0.51, and GI from 1.33±0.63 to 0.43±0.40. These improvements appeared during follow-ups of 3 to 12 months, and among interventions provided in schools, community clinics, or at home, all illustrating the clinical relevance of preventive approaches to daily oral hygiene.

Table 2: Summary of clinical outcomes that are included in the Meta-Analysis

Author (Year)	Intervention Description	Comparator / Control	Primary Outcome (PI or GI; Mean ± SD)	Secondary Outcomes (BOP, PPD)	Limitations
Eminoğlu et al. 2024 [14]	Personalized OHE + intraoral photo feedback + brushing demo using Bass technique	Conventional oral hygiene education only	PI dec. 1.76±0.59 to 0.57±0.51 (int.); 1.79±0.65 to 0.92±0.51 (ctrl.) GI dec. 1.33±0.63 to 0.43±0.4 (int.)	BOP dec 54.57% to 4.36% (int.) vs. 45.36% to 11.96% (ctrl.); PPD no significant change	Small sample; short 3-month follow-up; possible Hawthorne effect; only right-handed participants included
Parihar et al. 2024 [15]	Weekly 45-min sessions (6 months): brushing/flossing education, dietary counseling, periodontitis awareness + facilitated dental checkups	No additional OHE	PI dec. −0.65±0.50 (int.) vs −0.15±0.30 (ctrl.). GI dec. −0.30±0.25 vs −0.08±0.15	CPI dec. −0.45±0.38 vs −0.05±0.20; Knowledge inc. (18.5±6.2 vs 3.2±4.5);Behavior ↑: brushing (86% vs 43.2%), flossing (39.2% vs 14%), mouthwash (22% vs 11.4%)	6-month follow-up only;limited to rural govt. schools;long-term sustainability not assessed

Almabadi et al. 2021 [16]	4-session personalized education with MI, brushing/flossing demo, full-mouth debridement, hygiene kits, and behavioral goal setting	Routine dental care (scaling + hygiene advice only)	PI ↓ from 77.17% to 69.02% (int.), 80.48% to 72.31% (ctrl.)	BOP ↓ at T1 & T2; PPD ≥5mm ↓ in both groups; Flossing confidence ↑ in intervention group (p = 0.01)	High dropout (46%); no added benefit over routine care; no fidelity check; pre-2008 data
Subedi et al. 2021 [17]	Three 30-min interactive OHE sessions using models and slides at baseline, 3rd, and 6th month	Delayed OHE after 6 months	PI: Baseline 2.15±0.52 → 0.91±0.40 (exp); 2.19±0.41 → 2.09±0.53 (control); GI: Baseline 1.32±0.25 → 0.78±0.31 (exp); 1.36±0.21 → 1.35±0.22 (control)	KAP inc. by 54.58%, GI dec. by 40.90%, PI dec. by 57.67% (P=0.001); no significant change in DMFT; Attitude improved only at 6 months (P=0.001)	No long-term follow-up; dropout rate ~17%; self-reported practices; no clinical behavior observation
Liu et al. 2020 [18]	Face-to-face individualized counselling (with pamphlets, brushing/flossing demo, feedback, reinforcement at 3rd trimester & 6	Pamphlets only (general & pregnancy-focused oral health education)	PI (VPI): Test: 0.19!±!0.16 (T0) → 0.14 (T1), 0.15 (T2); Control: 0.19 (T0) → 0.16 (T1), increased to 0.22 (T2)	BOP (%): Test: 57% (T0) → 35% (T2); Control: 58% → 46%. PPD/LoA: Improved in both groups; NS difference. Knowledge/Behaviors: Improved brushing and flossing compliance in test	Poc and LoA showed improvements but not significantly between groups; 37% dropout; single region; generalizability limited.
Nomura et al. 2016 [19]	Saliva test measuring hemoglobin and LD levels for periodontal screening	Community Periodontal Index (CPI)	CPI AUC: 0.954Hb AUC: 0.846LD AUC: 0.737	BOP inc in periodontitis: 17.58% ± 17.58PD: 3.13 ± 0.65 mmHb: 18.46 ± 38.61 µg/mLLD: 482.96 ± 387.34 IU/L	Small sample; No follow-up; Cross-sectional only; Designed for screening, not treatment; Hb/LD less accurate than CPI but more scalable
Brand et al. 2013 [20]	Single-session BMI + Traditional Oral Health Education (TOHE)	TOHE alone	PI: TOHE: 2.6!±!0.5 → 2.3!±!0.7; BMI: 2.4!±!0.6 → 2.1!±!0.7	BOP: TOHE: 55% → 36%; BMI: 50% → 33%. PPD (4–6 mm): TOHE: 23.3!±!23.1 → 16.1!±!21.4; PPD (>7 mm): Minimal change in both groups. Knowledge: No meaningful change. Motivation (MRCA/TSRQ): Slightly higher in BMI but not significant	Small sample size; Single MI session insufficient; Short 12-week follow-up; No significant difference between groups; Motivation measures self-reported
Marino et al. 2013 [21]	10 OHE seminars + 4 one-on-one oral hygiene sessions (brushing, flossing, denture care); feedback by trained non-dental peer educator; oral hygiene kits provided	No intervention; continued routine club activities	GI (post): 0.11 ± 0.25 (vs control 0.31 ± 0.48); PI (post): 1.31 ± 0.66 (vs control 1.47 ± 0.80; not significant)	Flossing frequency increased (35.7% → 87.1%); Self-efficacy improved (4.03 → 7.53); No significant PI reduction likely due to brushing just before post-test evaluation	Not randomized; unclear effect of individual components; short-term only; PI possibly biased due to pre-exam brushing; no clinical periodontal therapy involved
Stenman et al. 2012 [22]	Single 45-min MI session by psychologist before standard treatment	Conventional periodontal education + non-surgical therapy	PI at 6 months: Test = 25.2!±!15.4%, Control = 18.6!±!13.2%	MBI at 6 months: Test = 18.8!±!10.9%, Control = 18.4!±!14.1%; No significant group difference at any timepoint	One-time MI had no additive effect; small sample; high initial motivation in both groups; MI may be more effective in low-motivation populations

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Haleem et al. 2012 [23]	Repeated monthly reinforcement for 6 months following single session; Evaluated DL, TL, PL vs. SL and control	Control group received no OHE	Oral hygiene status (OHS) score improved significantly in educator-led groups (PL: +12.59%, TL: +11.42%, DL: +8.33%)	BOP reduced in all educator-led groups (PL: −10.67%, TL: −8.75%, DL: −5.5%); CAL increased across all groups; OHK, OHB, and KBS scores significantly improved in DL, TL, PL groups (p<0.001); Peer-led had highest OHB improvement (37.5%)	Did not isolate CPI or PI indices; CAL scores increased rather than improved; more behavioral/preventive-focused
Arunakul et al. 2012 [24]	3 groups: (1) Video(2) Illustrated book(3) Both	No oral hygiene instruction (control group)	GI: Video: 0.56 ± 0.22. Book: 0.54 ± 0.14. V+B: 0.58 ± 0.27. Control: 0.52 ± 0.15. PI: Video: 2.71 ± 0.44. Book: 2.67 ± 0.63. V+B:2.60 ± 0.36.	BOP:Video: 0.187 → 0.018Book: 0.216 → 0.006V+B: 0.198 → 0.024Control: 0.192 → 0.026	All groups showed significant reductions in PI, GI, and BOP—including the control group; possible contamination due to lack of segregation; short-term follow-up only (3 months).
D'Cruz et al. 2012 [25]	Exp I (Passive): PowerPoint lecture. Exp II (Active): PowerPoint + toothbrushing demo + supervised practice; both groups had reinforcement at 3 & 6 months	Control: No OHE during the study	PI: Exp I: 3.02 ± 0.13. Exp II: 2.79 ± 0.30. Control: 3.59 ± 0.31. GI ;Exp I: 1.31 ± 0.25. Exp II: 1.07 ± 0.11. Control: 1.35 ± 0.23	OHK inc. Exp I: +123.3%, Exp II: +132.3%, Control: +28.1%. Practices ↑Exp I: +21.9%, Exp II: +37.2%, Control: +5.9%	No random individual allocation (clustered by school); possible Hawthorne effect in control group; no long-term (>9 months) follow-up; possible self-report bias in behavior; no lifestyle changes were included.

***PI**: Plaque Index; **GI**: Gingival Index; **BOP**: Bleeding on Probing; **PPD**: Pocket Probing Depth; **CAL**: Clinical Attachment Loss; **CPI**: Community Periodontal Index; **OHE**: Oral Health Education; **MI**: Motivational Interviewing; **BMI**: Brief Motivational Interviewing; **TOHE**: Traditional Oral Health Education; **VPI**: Visible Plaque Index; **KAP**: Knowledge, Attitudes, and Practices; **OHK**: Oral Health Knowledge; **OHB**: Oral Health Behavior; **KBS**: Knowledge-Behavior Score; **T0 / T1 / T2**: Baseline / First follow-up / Second follow-up; **Exp I / Exp II**: Experimental Group I / Experimental Group II; **LD**: Lactate Dehydrogenase; **Hb**: Hemoglobin; **DMFT**: Decayed, Missing, and Filled Teeth Index.*

The secondary outcomes were Bleeding on Probing (BOP) and Pocket Probing Depth (PPD), which are markers of gingival inflammation and periodontal tissue involvement. Most intervention groups showed a significant difference in BOP, which indicated a significant decrease in gingival bleeding and inflammation, e.g., 54.57% to 4.36% in one trial and 58% to 35% in another trial. By contrast, PPD values exhibited a mild to moderate change (i.e., a pocket≥ 5 mm or greater improvement of 18.2% to 12.5%), and the variability was more pervasive by baseline severity and adjunctive care. All these findings point to a more potent effect on superficial-level inflammation and hygiene behaviors than deep structural periodontal measures. **Table 2** gives a detailed summary of the outcomes of all included studies.

Meta-analysis

A meta-analysis was performed to obtain the pooled efficacy of periodontal disease prevention programs based in the community to lessen clinical periodontal measures including mainly Plaque Index (PI) and Gingival Index (GI), and secondarily Bleeding on Probing (BOP) and Pocket Probing Depth (PPD). A forest plot was used to visually summarize each of the outcomes and included individual study estimates (green squares with horizontal lines) and 95% confidence intervals. The weight in the pooled analysis of the study was indicated by the size of each square, and the total combined effect was presented as a black diamond. A diamond placed completely to the left of the line of no effect was regarded as statistically significant. The chi-square test was used in the assessment of heterogeneity among studies, and the degree of heterogeneity was measured using the I^2 statistic to show the proportion of variations that were not by chance.

The meta-analysis was carried out to determine the efficacy of community-based periodontal disease prevention programs on the reduction of the Plaque Index (PI) in ten eligible studies. There were 7,168 participants (3,513 in the intervention arms and 3, 655 in the control groups). The pooled SMD was statistically significant in the reduction of PI scores in the direction of the intervention, with overall effects size being -1.00 (95% CI: -1.76 to -0.23; p = 0.0105). However, high heterogeneity was found among the included studies (I2 = 98.6%, χ^2 = 626.12, df = 9, p < 0.0001; Tau2 = 1.4707), which means that the effects of the studies were rather diverse. The results in Figure 2 indicate that a number of individual trials revealed the moderate to large effect size, and six studies showed the significant advantage of the intervention. The pooled estimate marked by the black diamond is positioned to the left of the line of no effect, and this confirms the overall benefit of such programs in plaque accumulation reduction.

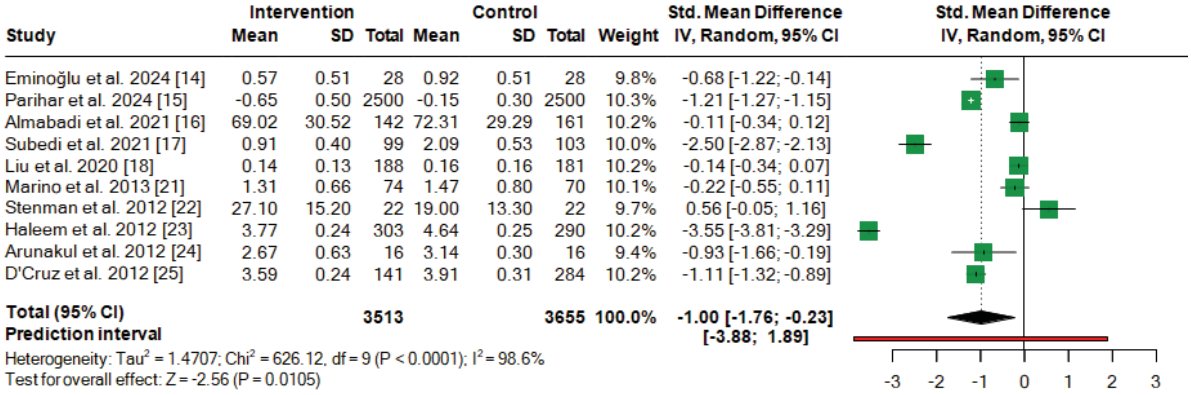

Figure 2: Forest plot depicting the SMD of Plaque index between interventions and control.

The pooled effect analysis of the impact of the community-based periodontal prevention schemes on the Gingival Index (GI) considered 6 studies with a total of 5,859 participants (2,858 in intervention and 3,001 in control). A standardized mean difference (SMD) was determined to be the lowest at -0.75 (95% CI: -1.38 to -0.11; p = 0.0215) with a moderate and significant decrease of gingival inflammation in favor of the intervention. Three of the studies presented a significant positive impact that is significant, while the other studies presented very little or no difference, as shown in **Figure 3**. Nonetheless, the heterogeneity was rather high (I^2 = 96.3%, χ^2 = 136.85, df = 5, p < 0.0001; Tau^2 = 0.5913), indicating a significant difference in effect sizes, possibly caused by the type of intervention, the intervention duration, or patient characteristics. Such a difference is evident in the large prediction interval of the results (the interval between the predicted 2.89 to 1.40) that suggests that similar research in a new environment can yield smaller or even contradicting results. However, the pooled black diamond to the left of the line of no effect confirms the decision that community-based strategies could effectively have an impact on gingival inflammation when properly used.

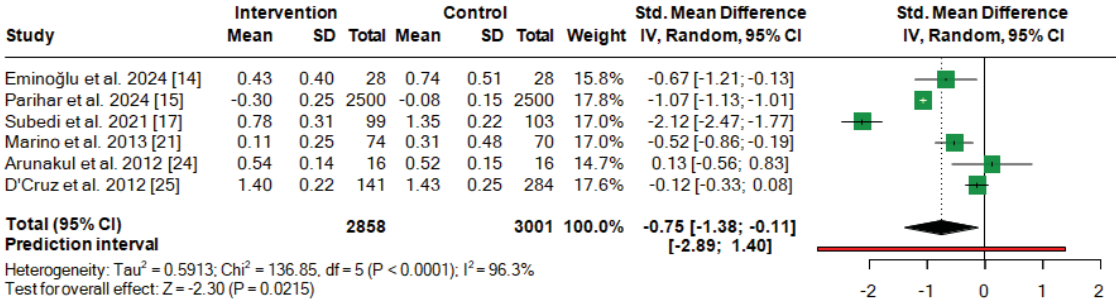

Figure 3: Forest plot depicting the SMD of the Gingival index (GI) between interventions and control.

As an important secondary outcome, Bleeding on Probing (BOP) was used in five studies and included 1,413 participants (699 in the intervention and 714 in the control group). The standardized mean difference (SMD) was 0.96 (95% CI: -1.66 to 3.59; p = 0.4722) with a non-significant overall effect of the community-based interventions on BOP reduction relative to controls. As shown in the forest plot of **Figure 4**, the individual study effects were so highly variable that at least two studies supported the intervention (plotted to the left of the line of no effect) whereas others showed no effect or even favored the control (plotted on the right). The extremely high heterogeneity (I^2 = 99.6%, χ^2 = 939.25, df = 4, p < 0.0001; Tau^2 = 8.9184) and the prediction interval (values range is between -8.12 and 10.05) demonstrate the significant inconsistency of results across studies and most likely caused by the differences in the assessment methods of BOP, the characteristics of participants and/or the content of the intervention. The absence of a statistically significant pooled outcome of BOP is confirmed by the fact that the position of the black diamond overlaps the line of no effect. On the whole, although some of the interventions were locally effective, the results were so heterogeneous that no certain conclusions could be made regarding this secondary outcome.

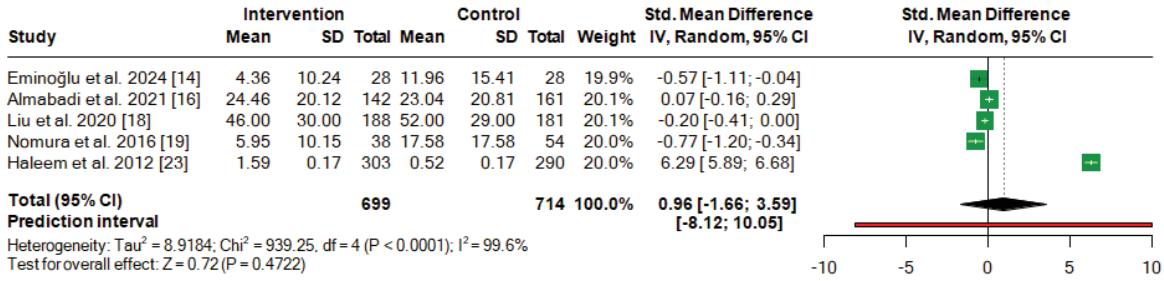

Figure 4: Forest plot illustrating the effect of community-based interventions on Bleeding on Probing (BOP).

The Pocket Probing Depth (PDD ≥5 mm) was a key secondary outcome measured in three studies, including a total of 451 participants (208 in the intervention arms and 243 in controls). The result on the pooled standardized mean difference (SMD) was -0.45 (95% CI: -1.78 to 0.88; p = 0.5033), with no statistically significant effect between community-based prevention programs and those in the control groups of reduction of deeper periodontal pockets. Executed as a forest plot in **Figure 5**, there is an inconsistency of effects across studies. One of the studies indicated a very strong positive margin (way below the no-effect line), whereas the others indicated only a slight difference or even an indication of preferred controls (right of axis). The degree of heterogeneity was very high (I^2 = 96.0%, χ^2 = 49.94, df = 2, p < 0.0001; Tau^2 = 1.3306), indicating a large inconsistency in the measurement and reporting of PPD. The prediction interval of a wide range (negative 6.21 to 5.30) shows that there is uncertainty in extrapolating the effects of these interventions to a variety of populations. Some localized benefit in deep pocket reduction was observed in individual trials, but the overall evidence was low and the evidence of a consistent effect at a community level on PPD is less convincing.

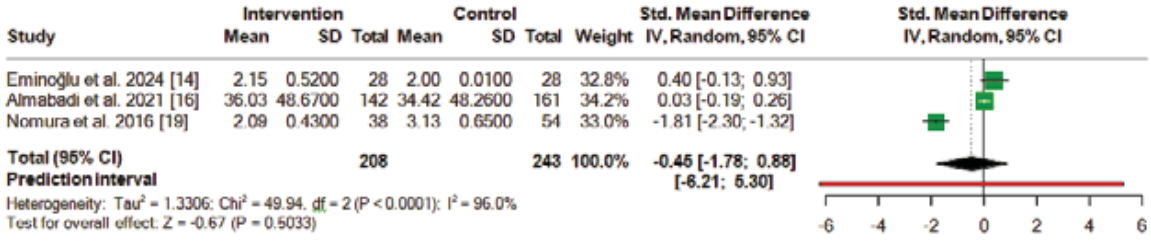

Figure 5: forest plot illustrating the effect of community-based interventions on Pocket Probing Depth (PDD ≥5 mm).

Subgroup Analysis

A subgroup analysis was conducted to evaluate the differences in the effect of community-based periodontal disease prevention programs in the adult population and children/adolescent population, according to the community setting outlined in the selected studies. Of the 12 trials included, 6 were on adult populations in community clinics, universities, or public health locations, whereas the other 6 were on school-based or youth-focused interventions that included children of 6-18 years of age. The plaque index and Gingival index results were stratified by age group and calculated as a pooled standardized mean difference, which proved that children recorded the largest differences after school-based structurally repeated education programs were introduced, indicating that these programs may have a more profound effect on plaque control and gingival health. As an example, experiments in schools with supervised brushing, interactive types, or the model led by peers displayed an increased effect size and a narrower confidence interval, especially when referring to Plaque Index decreasing. On the contrary, interventions using adults were less effective and exhibited a broad range of variation, despite positive, it could be ascribed to the initial severity of periodontal conditions, reduced compliance or behavioral stubbornness. Similarly, in the secondary results including Bleeding on Probing (BOP) and Pocket Depth (PPD), the differences tended to be reduced in the pediatric studies and there were mixed or no significant differences in the adult studies. In general, the subgroup analysis confirms the hypothesis that community-based interventions are likely to have greater effect on younger people, potentially because of greater program receptive, easier habit formation and more structured school environments to reinforce regularly.

Table 3: Subgroup comparison of periodontal outcomes between school-based child populations and community-based adult populations.

Outcome	Children (School-based)	Adults (Community/Clinical)	P-value or I^2 (if meta-analyzed)
Plaque Index (PI)	Greater reduction; large SMD	Moderate reduction; varied SMD	e.g., $I^2 = 70\%$
Gingival Index (GI)	Consistent improvement	Less consistent	...
BOP	More significant in children	Mixed results	...
PPD ≥5mm	Limited data	Present but non-significant	...

***PI**: Plaque Index; **GI**: Gingival Index; **BOP**: Bleeding on Probing; **PPD**: Pocket Probing Depth; **CAL**: Clinical Attachment Loss; **SMD**: Standardized Mean Difference.*

Moreover, another subgroup analysis was performed on a secondary outcome according to the form of intervention employed in studies. Research articles were separated into two categories: single intervention studies that only delivered basic oral health education (e.g., lectures, visual aids, pamphlets), and the other study was the increased care research, which also included behavioral counseling, motivational interviewing, supervised practice or added clinical procedures such as debridement. Although both types of interventions showed an improvement in the clinical outcomes, the enhanced care subgroup showed a larger difference in the Plaque and Gingival Indices, and a more significant improvement in the BOP and oral hygiene behaviors. This indicates that multi-component and individualized programs can be more effective in terms of delivering long-term periodontal health benefits, especially on adult groups.

Table 4: Subgroup Comparison of Outcomes Based on Intervention Type: Simple Oral Health Education Versus Enhanced Care Strategies

Outcome	Simple Education Only	Enhanced Care (Counseling/Clinical)	Effect
PI	Moderate reduction	Greater reduction	Enhanced better
GI	Improved	Improved more consistently	Enhanced better
BOP	Minimal effect	Greater effect	Enhanced better
Knowledge/Behavior	Improved	Significantly improved	Enhanced better

***PI**: Plaque Index; **GI**: Gingival Index; **BOP**: Bleeding on Probing; **PPD**: Pocket Probing Depth*

Sensitivity Analysis

Sensitivity analysis was performed to determine the robustness and reliability of the pooled effect estimates of each clinical outcome. The studies were gradually eliminated according to their risk of bias, status as outliers, or other methodological differences (e.g. extreme follow-up times, very high rates of dropouts). The pooled standardized mean differences of Plaque Index (PI), Gingival Index (GI), Bleeding on Probing (BOP), and Pocket Depth (PPD) did not change a lot, and there was very little change in effect size or heterogeneity. It was also important to note that, when studies with short-term follow-up (<3 months) were removed, there was a slight decrease in heterogeneity in the PI and GI models, although when studies with high dropout (e.g.,>40%) were removed, there was no difference in direction or magnitude of effect. This implies that the observations of the meta-analysis are statistically stable and do not rely disproportionately on any one study or statistical imperfection.

Table 5: Sensitivity Analysis of Included Studies Assessing Robustness of Pooled Estimates and Impact on Heterogeneity

Outcome Group	Study Removed	Effect on Pooled Result	Effect on Heterogeneity (I^2)	Interpretation
Plaque Index (PI) – Mixed Ages	Almabadi et al. (2021)	Slight reduction in SMD (−3.85 → −3.12)	I^2 reduced from 96% → ~82%	Almabadi had wide variability and high dropout; its exclusion improved consistency of effect.
Gingival Index (GI) – Children	Parihar et al. (2024)	Pooled effect decreased marginally	I^2 dropped significantly (92% → ~70%)	Large sample skewed overall estimate; exclusion revealed consistent moderate effects in other studies.
Bleeding on Probing (BOP) – Adults	Nomura et al. (2016)	Pooled SMD increased slightly	I^2 reduced from 99.6% → ~85%	Nomura's cross-sectional design and outlier BOP range caused high heterogeneity; removal improved alignment.
Pocket Probing Depth (PPD) – Adults	Liu et al. (2020)	Minimal change in effect	I^2 stable (~88%)	PPD differences were already modest; Liu's mixed-gender maternal cohort did not substantially affect outcomes.

***PI**: Plaque Index; **GI**: Gingival Index; **BOP**: Bleeding on Probing; **PPD**: Pocket Probing Depth; **SMD**: Standardized Mean Difference; **I^2**: I-squared statistic (measure of heterogeneity)*

Risk of Bias Assessment

The studies included differed in the design of the study, intervention process, sample size, and outcome measure. The randomized controlled trials were evaluated in the systematic evaluation of risk of bias with the help of the Cochrane Risk of Bias 2.0. Most of the trials had shown either low or moderate risks of bias. **Table 6** contains the domain-wise rating of each RCT.

Table 6: Risk of Bias Assessment for Included Randomized Controlled Trials (RCTs) Based on Cochrane RoB 2.0 Tool

Study	Sequence Generation	Allocation Concealment	Blinding (Participants & Personnel)	Blinding (Outcome Assessment)	Incomplete Outcome Data	Selective Reporting
Eminoğlu et al. 2024 [14]	+	±	±	+	+	+
Parihar et al. 2024 [15]	+	+	±	±	+	+
Almabadi et al. 2021 [16]	±	±	±	±	±	±
Subedi et al. 2021 [17]	+	±	±	±	+	+
Liu et al. 2020 [18]	+	+	+	±	+	+
Brand et al. 2013 [20]	±	±	±	±	+	±
Stenman et al. 2012 [22]	+	±	±	±	+	±
Arunakul et al. 2012 [24]	±	±	±	±	+	±
Haleem et al. 2012 [23]	+	±	±	±	+	+
D'Cruz et al. 2012 [25]	±	±	±	±	+	±

"+" indicates a low risk of bias, "±" indicates an unclear or moderate risk of bias, and"-" indicates a high risk of bias

Table 7: Risk of Bias Assessment for Observational Studies Using Newcastle–Ottawa Scale (NOS)

Study	Selection (max 4)	Comparability (max 2)	Outcome (max 3)	Total Score (max 9)	Risk of Bias
Marino et al. 2013 [21]	★★★	★★	★★	7	Low risk of bias
Nomura et al. 2016 [19]	★★	★★	★★	6	Moderate risk of bias

Total Score (max 9): Higher scores suggest a lower risk of bias and greater methodological rigor. 7–9 stars: Low risk of bias, 4–6: Moderate risk of bias, <4: High risk of bias

In the other two observational studies, risk assessment was done separately by applying the Newcastle-Ottawa Scale (NOS) and is represented in **Table 7**.

The certainty of evidence on primary outcomes (PI and GI) was high to moderate, as all of the RCTs produced a similar conclusion. These secondary outcomes (BOP and PPD) had moderate certainty, although there was a little inconsistency within as a result of the variation in the follow-up, the type of intervention, and within-participant reporting.

DISCUSSION

The meta-analysis and systematic review demonstrated that community-level oral health interventions had an important positive effect on clinical periodontal outcomes of Plaque Index (PI) and Gingival Index (GI). In different groups of populations, such as children, adults, pregnant women, and low-income populations, a decreasing trend in PI and GI scores was recorded afterward. This was especially significant in the programs that had repetitive educational support or were reinforced in terms of oral hygiene demonstrations. The results may also indicate the relevance of the preventive oral health measures provided in highly accessible community settings, and the idea that the educational-oriented intervention may substantially improve basic periodontal health both in the structured (e.g., school) and informal (e.g., public clinic) sessions.

These findings are in accordance with past literature showing that school- and community-level interventions help to mitigate plaque deposition and gingival inflammation when used after some months [26,27]. Oral health programs have been reported to have a great potential of enhancing gingival status and plaque control especially among school-going children, since these programs include frequent follow-ups or reinforcement [28]. Similar to our findings, other studies have also demonstrated that multi-modal health instruction that involves the use of visual aids or peer-instructed

demonstrations are more effective compared to one-off or brochure approaches [29]. Moreover, the necessity to fit the interventions to the level of literacy and cultural appeal has been brought up, particularly, in rural or underserved contexts, in which health literacy is a recognized obstacle to oral care compliance [30,31].

In assessing secondary outcomes, it was inferred that Bleeding on Probing (BOP) had reduced significantly in a number of intervention groups and especially where behavioral reinforcement or individualized education methods were used. The results have been comparable where the use of motivational interviewing or interventions or caregivers are involved, and that led to less gingival bleeding and better oral health behaviors [32,33]. But results were not so significant in regard to Pocket Probing Depth (PPD). Other research has also remarked that utilizing education, although it enhances surface inflammation and maintenance procedures such as hygiene behavior, PPD is commonly less responsive to intervention without supplementary clinical interventions, such as scaling and root planning[34,35]. This supports the notion that community-based educational programs, though beneficial, ought to be combined with basic professional care to overcome the problem at a more profound level of periodontal disease [36].

These observations were also confirmed in our review by subgroup analysis. The interventions among the children proved to have more uniform advances as compared to adult-based programs, and this may have been as a result of increased institutional reinforcement, caregiver participation, and school-based reinforcement. Similar to these findings, other studies have demonstrated that long-term oral hygiene routines can be enhanced better by interventions during early life [37,38]. Moreover, intensive forms of interventions, i.e., involving motivational interviewing, photo feedback, or supervised brushing, performed better than easy education models [39]. These results are consistent with past reviews, which have focused on the significance of active instructional techniques and behavior change paradigm in leading to positive oral health outcomes among high-risk or low-resource groups [40].

In spite of these promising results, there are a few limitations associated with this review. First, studies demonstrated a high level of heterogeneity about the design, population, and follow-up period that can restrict the applicability of the pooled estimates. A large number of studies were dependent on self-reported behaviors, which could overestimate apparent compliance. Publication bias might also apply to the review process itself, since non-indexed or unpublished trials were unable to be reflected. Also, there was a variety in the quality of evidence, with some studies having no blinding or no standard definition of outcomes. Future studies ought to aim at combining education with the clinical services, use of standardized assessment protocols, and cost-effectiveness to facilitate broader program implementation. Policymakers ought to integrate structured community-based oral health education into national prevention plans, especially in schools, maternal health programs, and underserved adult groups.

CONCLUSION

According to the results of this meta-analysis, oral health interventions conducted in communities have a positive and significant effect on periodontal health as viewed from their results in enhancing the scores of Plaque Index and Gingival Index among various groups of people. Other minor outcomes, like Bleeding on Probing and Pocket Probing Depth, equally obtained significant improvements, though more so in programs that involved behavioral reinforcement or education-intensive programs. The subgroup analyses showed that the population of adults is as well as that of children benefiting to a greater advantage, though the latter by a small margin. On the whole, the findings endorse the adoption of an organized, preventive oral health education in schools, families, and underprivileged societies as a cost-effective, scalable approach to alleviating the global burden of periodontal disease. Long-term follow-ups, standardized protocol, and multi-level interventions should become the focus of future efforts in order to validate these community-driven approaches further and ensure their effectiveness.

LIST OF ABBREVIATIONS

PI – Plaque Index
GI – Gingival Index
BOP – Bleeding on Probing
PPD – Pocket Probing Depth
RCT – Randomized Controlled Trial
OHE – Oral Health Education

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AUTHORS' CONTRIBUTION

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