The association between oral hygiene and periodontitis:

A systematic review and meta-analysis

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ABSTRACT

Objective: Accumulation of dental plaque and improper personal oral hygiene are risk factors of periodontitis, but their effects have never been pooled. Therefore, this systematic review aimed to estimate magnitudes of association between oral hygiene and periodontitis. **Material and methods**: MEDLINE and SCOPUS databases were searched up to May 2016. Observational studies that assessed association between oral hygiene and periodontitis in adults were eligible. A multivariate random-effect meta-analysis was applied for pooling effects of fair and poor versus good oral hygiene on periodontitis across studies. In addition, association between oral care habits and periodontitis were also assessed. **Results**: From a total of 50 eligible included studies, 15 studies were pooled effect of fair and poor versus good oral hygiene on periodontitis, with the pooled ORs of 2.04 (95% CI: 1.65, 2.53) and 5.01 (95% CI: 3.40, 7.39), respectively. Pooling effects of oral care habits by regular tooth brushing and visiting dentist, based on 10 and 6 studies, indicated protective effects with pooled ORs of 0.66 (95% CI: 0.47, 0.94) and of 0.68 (95% CI: 0.47, 0.98), respectively. **Conclusions**: Fair to poor oral hygiene increases risk of periodontitis. This risk can be reduced by regular tooth brushing and dental visits once a year.

INTRODUCTION

Periodontitis is the common oral disease with the prevalence of 11.2% age-standardized in severe form across the world[1]. It is a multi-factorial disease, which is differently susceptible depending on individual factors[2], e.g., age, gender, diabetes mellitus (DM), smoking, as well as, oral hygiene (OH)[3]. Poor OH or accumulation of dental plaque and calculus is usually caused by improper tooth brushing technique, ignoring interdental cleaning and irregular dental visits. Dental plaque deposition is recognized as the etiology of gingivitis. Then, persistent gingival inflammation is a key risk-predictor for breakdown of periodontal attachment apparatus. As a result, OH is usually considered as one important risk factor of periodontitis. However, the magnitude of OH that is associated with periodontitis has never been explored. Therefore, we conducted a systematic review and meta-analysis which primarily aimed to estimate and pool the effects of OH measured by oral hygiene index (OHI), plaque index (PI) and plaque score (PSc) on periodontitis. In addition, we secondarily aimed to pool the magnitude of association between oral care habits (i.e., regular tooth brushing, interdental cleaning and dental visit) and periodontitis.

METHODS

The PRISMA guidelines for meta-analysis were followed[4]. The checklist was provided in *Supplement information A*. (PROSPERO registration number: CRD42015019036)

Search strategy

MEDLINE and SCOPUS databases were used to identify relevant studies with standardized methodological filters up to May 2016. Search strategies were mainly constructed based on the primary objective with 3 domains (i.e., periodontitis, oral hygiene, and general aspects for observational studies) as follows: ("periodontitis" OR "periodontal") AND ("poor oral hygiene" OR "plaque index" OR "oral hygiene index" OR "plaque score") AND ("relation" OR "association" OR "risk factor"). The search terms and search strategies were described in *Supplement Table S1*.

Inclusion criteria

Studies were screened based on titles and abstracts. Full papers were reviewed if a decision could not be made. Any type of observational study (e.g. cohort, case-control, or cross-sectional studies) was included if it met the following criteria: (i) assessed associations between OH and periodontitis in either general or specific types of adult population (ii) had at least 2 groups of outcome, periodontitis versus non-periodontitis, or mild, moderate, severe periodontitis versus normal periodontium (iii) assessed OH by standard tools such as Oral Hygiene Index (OHI) or Simplified Oral Hygiene Index (OHI-S)[5], Plaque Index (PI)[6], Plaque control record / Plaque Score (PSc)[7], or questionnaire including frequency of brushing, interdental cleaning

and dental visits and (iv) reported/possibly calculated mean and standard deviation (SD) of OH scores between periodontitis groups, or frequency data of contingency table between non-periodontitis/periodontitis and OH groups. Only English studies were eligible. Studies were excluded if they had insufficient data for pooling after 2-3 attempts in contacting authors for requesting additional data.

Two of three reviewers (AL, SR, and SA) independently evaluated the studies for each eligibility, extracted data, and assessed risk of bias among included studies. Any discrepancies between reviewers were discussed and resolved by consensus.

Studied factors

The primary studied factor was OH which could be objectively measured by performing oral examination and using OHI, PI or PSc. The secondary study factors were oral care habits, which were subjectively assessed using questionnaires including tooth brushing, interdental cleaning, and dental visits.

Outcome

The interested outcome was periodontitis, which was defined according to original studies by any measures such as periodontal probing depth (PPD), clinical attachment level (CAL) or radiographs without restriction of periodontitis definition.

Data extraction

Study characteristics including study design (cohort, case-control or cross-sectional study), type of population (general population or specific disease), and study based (community-based

or hospital-based) were extracted. Characteristics of subjects (i.e., percentage of male, percentage of smoking and DM) and clinical data (i.e., periodontitis definition and details of OH assessments) were also extracted.

Risk of bias assessment

The quality of studies was assessed using the modified Newcastle-Ottawa Quality Assessment Scale[8], see *Supplement information B*, which considers 3 domains: *representativeness* of studied subjects, *comparability* between groups, and ascertainments of *outcome and exposure*. Each domain was graded by giving stars if it was low risk of bias. Individual studies were categorized according to stars as low, moderate, and high risk of bias, if stars were □75%, 50-74% and <50%, respectively.

Statistical analysis

Data were pooled if there were at least 2 studies reporting the same outcomes and studied factors. Data analysis was performed separately by type of OH data (i.e., categorical and continuous data) as follows:

For categorical data, the odds ratio (OR) of having periodontitis for fair versus good OH (OR_1), and poor versus good OH (OR_2) along with their 95% confidence intervals (CI) for each study were estimated. Given included studies had 2 or more groups of OH, the multivariate random-effect meta-analysis was applied for pooling ORs. This method takes into account for within-study variation using Riley's method[9, 10] via 'mvmeta' command in STATA. For those studies where OH > 2 groups and reported ORs without frequency data the variance-covariance were assumed as zero.

For continuous data, the mean difference in OH scores between periodontitis and non-periodontitis groups was estimated and pooled using a standardized mean difference (SMD). If mean and standard deviation (SD) were not reported, but correlation coefficients of logistic model were reported instead, the beta coefficients were then pooled using pooling mean method.

Heterogeneity and degree of heterogeneity of effect sizes were assessed by Cochrane's Q test and I^2 statistic, respectively. If heterogeneity was present (Q test < 0.1 or I^2 □ 25%), the random-effect model (Dersimonian & Laird) was used, otherwise the fixed-effect model with inverse variance method was applied.

Sources of heterogeneity were explored by Galbraith plot to identify outlier studies. Co-variables (i.e., type of population, age, gender, smoking, DM, use of indexes, periodontitis definitions) were then fitted one by one into a meta-regression model. If there was a suggested trend of association, a sensitivity analysis by excluding the outlier studies and/or a subgroup analysis according to that factor was performed.

Finally, exploration of potential publication bias was performed using the Egger test and a funnel plot. If any of these indicated asymmetry, a contour enhanced funnel plot was constructed to identify the cause of asymmetry of the funnel. All analyses were performed using STATA software version 14. Two-sided $P < 0.05$ was considered statistically significant except for the heterogeneity test, in which $P < 0.10$ was used.

RESULTS

Identifying studies

A total of 2763 studies were identified from MEDLINE and SCOPUS, and 1934 studies were left after removing duplicates. Among them, 1878 studies were not eligible with reasons described in *Figure 1*, leaving 56 studies[11-66] which were eligible for review. Six studies[11, 44, 45, 48, 49, 54] were excluded due to insufficient data after contacting authors. Among 50 studies, 45 studies[12-15, 17-28, 30, 32-36, 39-43, 46, 47, 50-53, 55-66] objectively assessed OH by oral examination. Fifteen[12, 14, 19, 23-26, 28, 32-36, 43, 62] analyzed OH as categorical data. Thirty-one studies[13, 15, 17-22, 27, 30, 39-42, 46, 47, 50-53, 55-61, 63-66] as continuous data, while one study[19] analyzed OH as both. Eleven studies provided the association between periodontitis and oral care habits which were brushing[26, 29-31, 33, 34, 37, 38, 41, 53], interdental cleaning[26, 38, 41, 53] and dental visits[16, 30, 31, 33, 37, 53].

Characteristics of subjects

Characteristics of 50 included studies are described in *Table 1*. The majority of study designs were cross-sectional studies. Most of them investigated in general population and 33 studies were hospital-based. The mean age ranged from 15 to 65 years. Percentage of male, smoker and DM were also shown in *Table1*. Criteria for defining periodontitis varied across the studies, but most studies (92%) used PPD and/or CAL with different details.

Risk of bias assessment

Most studies (72%) were inadequate in sample selection in which representativeness may be questioned. For example, they did not mention sampling method or clearly describe about selection of cases and controls. In comparison domain, 27 studies (46%) were potentially

biased from improper statistical adjustment for confounding factors. Almost all measured periodontitis according to oral examination which was more objective and valid. However, 16 studies (32%) used partial-mouth examination protocols, 16 studies (32%) diagnosed periodontitis without details of CAL, and 25 studies (50%) did not mention about intra/inter-examiners agreements. The number of studies with low, moderate and high risk of bias were 23, 19 and 8, respectively (see *Supplement Table S2*).

Oral hygiene

For 15 studies with categorical data of OH, 6 studies[12, 26, 32, 35, 43, 62] categorized OH as good and poor OH, whereas 9 studies[14, 19, 23-25, 28, 33, 34, 36] categorized OH as good, fair, and poor OH. Criteria used for classifying OH were presented in *Supplement Table S3*. Pooled ORs using a multivariate meta-analysis gave 2.04 (95% CI: 1.65, 2.53) and 5.01 (95% CI: 3.40, 7.39) which indicated that fair and poor OH increased risk of periodontitis by approximately 2 and 5 times when compared to good OH with the I^2 of 40% and 78%, respectively (*Figure 2*). Details of each individual study were shown in *Supplement Table S4*.

Exploring sources of heterogeneity indicated that types of population might be the main source of heterogeneity. Subgroup analysis in community-based studies yielded lower heterogeneity, i.e., the I^2s were respectively 4% and 0% for fair and poor versus good OH with the corresponding pooled ORs of 2.23 (95% CI: 1.85, 2.69) and 4.78 (95% CI: 4.10, 5.58). In addition, a sensitivity analysis focusing on general population decreased the degree of heterogeneity to 22% and 49% for fair and poor versus good OH with the pooled ORs of 2.10 (95% CI: 1.76, 2.49) and 4.21 (95% CI: 3.21, 5.51), respectively. Moreover, definitions of

periodontitis, type of indexes used and smoking behavior also contributed to heterogeneity (see *Supplement Table S5*).

Among 31 studies with continuous data of OH, 25 studies[15, 21, 22, 30, 39-42, 46, 47, 50-53, 55-61, 63-66] compared OH as mean scores between periodontitis and non-periodontitis groups. SMDs were highly heterogeneous (I^2 = 95.6%) with a pooled SMD of 2.04 (95% CI: 1.59, 2.50), see *Supplement Table S6*. From this could be interpreted that periodontitis subjects had significantly higher OH score of 2.04 standardized units than non-periodontitis subjects.

Six[17, 19, 22, 27, 30, 39] and 3[13, 18, 20] studies reported the effects of PI and PSc on periodontitis as coefficients (i.e., ln(OR)) of logistic regression models. Pooling these corresponding effects yielded the pooled ORs of 2.25 (95% CI: 1.43, 3.54) and 1.02 (95% CI: 1.01, 1.03) with high heterogeneity for both poolings (*Figure 3*). From this, it could be interpreted that every one-unit-increase of PI and PSc would respectively increase odds of having periodontitis by 2.25 and 1.02, respectively.

Oral health care habits

Ten[26, 29-31, 33, 34, 37, 38, 41, 53], 4[26, 38, 41, 53], and 6 studies[16, 30, 31, 33, 37, 53] assessed effects of brushing, dental floss, and dental visits on periodontitis (*Supplement Table S7*). The pooled ORs were estimated (see *Figure 4*) and suggested that the tooth brushing and dental visits were significantly associated with periodontitis. Their effects were high and moderate heterogeneous with the I^2 of 94.5% and 60.4%, respectively. Subjects who brushed their teeth regularly had approximately 34% significantly lower odds of periodontitis (pooled OR = 0.66;

95% CI: 0.47, 0.94). Smoking, definition of regular brushing and definition of periodontitis might be sources of heterogeneity, see *Supplement Table S8*.

For dental visits, the sensitivity analysis was performed by considering 4 of 6 studies that had clearly defined a regular dental visit as least once a year[16, 30, 33, 53]. This yielded a significant effect size of 0.56 (95% CI: 0.37, 0.83) with the I^2 of 0%, indicating subjects who had professional dental care once a year were about 44% lower risk of periodontitis than those who did not visit regularly. However, the homogenous effect (I^2 of 5%) of interdental cleaning on periodontitis from 4 studies was borderline non-significant with the pooled OR of 0.87 (95%CI: 0.75, 1.00)

Publication bias

Publication bias was assessed for all poolings using funnel plots (*Supplement Figure S1*) and Egger test (*Supplement Table S9*). These suggested symmetry except for mean difference of OH score, PSc, and dental visits. Contour enhanced-funnel plots were further constructed (*Supplement Figure S2*), which indicated that asymmetry of funnels might be due to heterogeneity and publication bias.

DISCUSSION

We have comprehensively performed a systematic review and meta-analysis of OH effect on periodontitis. Our results suggest dose-response relationship between OH and periodontitis, which is fair and poor OH significantly increase the risk of having periodontitis 2 and 5 times

when compared to good OH. Contrastingly, regular tooth brushing and regularly visiting dentist could protect periodontitis around 34 and 32%, repectively. The pooled effects of OH and oral care habits were summarized in *Table 2* and *Figure 5*.

The effect of OH on periodontitis is higher when compared with the effects of other risk factors such as DM[67] (OR = 2.6; 95% CI: 1.0, 6.6), smoking[68] (OR = 2.82; 95% CI: 2.36, 3.39) or obesity[69] (ORs = 2.13; 95% CI: 1.40, 3.26). Our results showed protective effects of regular brushing, which were consistent to the previous meta-analysis[70] which reported the significant risk effect of infrequent brushing on severe periodontitis (OR = 1.44; 95% CI: 1.21, 1.71) by pooling 14 studies. The results on interdental cleaning were pooled from 4 studies which used dental floss as the representation of interdental cleaning. The non-significant effect of dental floss also agreed with the previous meta-analysis[71] which showed little benefit from self-performed flossing on plaque or periodontal parameters.

Although use of OH assessments were varied among included studies, about a half of them commonly used PI with approximate cutoff points similar to others, and thus, they could be applied to clinical circumstances. The use of cutoff was defined as *poor OH* if PI > 2 or having moderate accumulation of soft deposit seen by naked eyes; *fair OH* if PI ranged from 1 to 2, or having film of plaque adhering to the tooth which was detected by disclosing solution or probe.

To concern about the different qualities of individual studies, the sensitivity analysis was also done by including only studies with low risk of bias[19, 23-26, 32-34, 43, 62]. The results showed little differences when compared to overall pooling, and interestingly, they gave very much more reduction of heterogeneity.

The results showed protective effects of oral care habits, thus the effects of OH and personal oral care should be emphasized as part of a health conscious lifestyle. Repeated and individually tailored OH instruction is the key element in achieving gingival health. Health care providers should regularly educate, motivate, and assess patients' perception for improving oral health behaviors. The use of goal setting, self-monitoring and planning are effective interventions for improving OH related behavior in periodontitis patients. Recognizing the benefits of behavior change, their own susceptibility and the harmfulness of periodontitis are important messages of periodontitis prevention[72].

Patients should be able to regularly access to dental care for professional cleaning alongside customising and monitoring their OH[72]. They should be also taught how to efficiently self-perform plaque removal. In general, mechanical plaque control by twice daily tooth brushing with a fluoride-based dentifrice is the accepted recommendation. The proper duration of tooth brushing is also mentioned as the important determinant of plaque removal, therefore, it should be stressed during tooth brushing instruction sessions[73]. However, with the current scientific data, dental floss is a less effective tool which requires instruction in the skill for the user in order to be effective. The interdental brushes have been proven as the most effective method for inter-dental plaque removal[74], although it has to be a clinician's decision based on patient needs, dexterity and characteristics of the inter-dental spaces.

This study has some strengths. We have extensively and systematically determined the effects of OH considering both objective and subjective assessments. Magnitude of effects were pooled and reported. The results of subgroup analyses (i.e., type of population, study-basis, periodontitis definition and smoking) were also provided. To improve the validation of

analysis, we used the multivariate random effects meta-analysis which took into account the variance-covariance between the studies.

However, this study also has some limitations. Our pooled ORs were based on summary data of observational studies. Some data were reported without adjusting for confounding effects and thus pooling results might be prone to bias. In addition, there might be some missing studies in pooling of oral care habits, because identifying relevant studies was based on the primary objective of this review, hence the results might be under/over estimation. Moreover, uses of periodontitis definitions were varied, which resulted in high heterogeneity. Attempts in exploring sources of heterogeneity were done, but it was still present. . Furthermore, the assessments of publication bias using funnel plot and Egger tests with the low numbers of included studies in some meta-analyses may not be valid. Failure to detect asymmetry cannot rule out a reporting bias, or vice versa. Therefore, the interpretation should still be done with caution.

In conclusion, poor OH increases risk of periodontitis approximately 2 to 5 times when compared with good OH. Oral care habits including brushing and regular dental visits can decrease risk of periodontitis, and thus should be promoted more in public health concerns.

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Figure legends

Figure 1: Flow chart of identifying and selecting studies

Figure 2: Pooling effects of fair and poor versus good oral hygiene on periodontitis

Figure 3: Pooling ORs of Plaque index and Plaque score on periodontitis

Figure 4: Pooling effect of oral care habits on periodontitis

Figure 5: Summary of pooled effect of oral hygiene and oral care habits on periodontitis

Table 1 Characteristics of included studies

Authors	Type of study	Study-based	Population	OH Measurement	Age	Male (%)	Smoking (%)	DM (%)	Periodontitis definition
Imaki[12]	Cross-sectional	Community based	General population	PI	38.1	100	56.1	N/A	CPITN: 3-4
Norderyd[13]	Cross-sectional	Community based	General population	PSc	48	48.7	20	4	bone loss more than 1/3 of root length
Wakai[14]	Cross-sectional	Hospital based	General population	PI	51.1	82.1	34.4	N/A	CPITN: 3-4
Papapanou[15]	Case-control	Hospital based	General population	PSc	50.9	47.3	32.2	N/A	□ 1 site with PPD □ 5 mm AND CAL □ 3 mm
Hashim[16]	Cohort	Community based	General population	OHI, Dental visit	15	54.2	33.3	N/A	□ 1 site with CAL increase 4 mm
Tezal[17]	Cross-sectional	Community based	General population	PI	48.7	48.2	61.8	N/A	Mean CAL □ 2 mm
Hugoson[18]	Cross-sectional	Community based	General population	PSc	65.0	52.7	42.9	N/A	bone loss more than 1/3 of root length
Do[19]	Cross-sectional	Community based	General population	PI	40	40.3	28.9	N/A	□ 2 sites with CAL □ 5 mm AND □ 1site with PPD □ 4 mm
Meisel[20]	Cross-sectional	Community based	General population	PSc	51.0	46.6	49.5	6	4th-5th quintiles of % CAL > 4 mm
Alpagot[21]	Cohort	Hospital based	HIV patients	PI	34.1	57.9	N/A	0	□ 1 site with PPD □ 4 mm OR CAL □ 2 mm
Solis[22]	Cross-sectional	Hospital based	General population	PI	37.4	35.3	23.5	0	□ 2 sites with CAL □ 6 mm AND □ 1 site with PPD □ 5 mm
Wickholm[23]	Cross-sectional	Community based	General population	PI	36.7	49.2	44.7	N/A	□ 3 teeth with PPD □ 5 mm
Natto[24]	Cross-sectional	Community based	General population	PI	36.4	64.9	70	N/A	□ 10 sites with PPD □ 5 mm
Torrungruang[25]	Cross-sectional	Community based	General population	PSc	60	74.4	14.3	15.8	Mean CAL > 2.5 mm

Table 1 *Characteristics of included studies (Continued)*

Authors	Type of study	Study-based	Population	OH Measurement	Age	Male (%)	Smoking (%)	DM (%)	Periodontitis definition
de Macedo[26]	Cross-sectional	Community based	General population	PSc, Floss, Brushing	N/A	33.8	31.4	N/A	□ 4 teeth with PPD □ 4 mm AND CAL □ 3 mm at the same site
Khader[27]	Cross-sectional	Hospital based	General population	PI	39.4	44.8	N/A	N/A	Khader's risk score
Vandana[28]	Cross-sectional	Hospital based	Dental fluorosis	OHI	25.36	68.6	N/A	0	CPITN: 3-4
Wang[29]	Cross-sectional	Community based	General population	Brushing	N/A	45.7	27.7	0	Mean CAL □ 3 mm
Akhter[30]	Case-control	Hospital based	General population	PI, Brushing, Dental visit	38.5	50	45.7	N/A	□ 2 sites with CAL □ 6 AND □ 1 site with PPD □ 5 mm
Kumar[31]	Cross-sectional	Community based	General population	Brushing, Dental visit	33.9	100	N/A	N/A	CPITN: 3-4
Benguigui[32]	Cross-sectional	Community based	General population	PI	58	54.9	19.2	6.7	CDC-AAP
Saxlin[33]	Cohort	Community based	General population	PI, Brushing, Dental visit	41.86	27	0	0	new teeth with PPD □ 4 mm
Bawadi[34]	Cross-sectional	Hospital based	General population	PI, Brushing	36.4	49.4	20.3	17.9	□ 4 teeth with PPD □ 4 mm AND CAL □ 3 mm at the same site
Carrilho Neto[35]	Cross-sectional	Hospital based	Inpatients	OHI	45.7	59.7	42.7	N/A	□ 1 site with PPD > 4 mm
Mathur[36]	Cross-sectional	Hospital based	General population	OHI	N/A	57.3	N/A	N/A	N/A
Teng[37]	Cross-sectional	Hospital based	Psychiatric inpatients	Brushing, Dental visit	41	62.5	42.5	N/A	CPITN: 3-4
Crocombe[38]	Cross-sectional	Community based	General population	Brushing, Floss	N/A	50	15	4.3	□ 1 site with CAL □ 4 mm
Mannem[39]	Cross-sectional	Hospital based	General population	PI	52.5	44.1	34.2	N/A	□ 4 teeth with PPD □ 4 mm AND CAL □ 3 mm at the same site

Table 1 Characteristics of included studies *(Continued)*

Authors	Type of study	Study-based	Population	OH Measurement	Age	Male (%)	Smoking (%)	DM (%)	Periodontitis definition
Raja[40]	Cross-sectional	Hospital based	General population	PI	36.5	53.3	96.7	0	□ 4 sites with CAL □ 4 mm
Vogt[41]	Cross-sectional	Hospital based	Pregnancy	PSc, Floss Brushing	27.2	0	15.87	0	□ 4 teeth with PPD □ 4 mm AND CAL □ 4 mm at the same site
Fiyaz[42]	Case-control	Hospital based	General population	OHI	N/A	N/A	0	0	□ 1 site with PPD > 4 mm OR CAL > 1.5 mm
Palle[43]	Cross-sectional	Hospital based	CVD	OHI	57.2	84.1	32.3	52.2	□ 5 sites with CAL □ 5 mm
Cakmak[46]	Case-control	Hospital based	General population	PI	38.3	49.1	0	0	□ 1 site with PPD □ 5 mm AND CAL □ 4 mm
Develioglu[47]	Case-control	Hospital based	General population	PI	46.7	N/A	0	33.3	□ 30% sites with PPD □ 5 mm AND CAL □ 3 mm
Jacob[50]	Case-control	Hospital based	General population	PI	37.3	75.6	33.3	0	CDC/AAP
Kaur[51]	Case-control	Hospital based	General population	PI	N/A	66.7	25	0	N/A
Koseoglu[52]	Case-control	Hospital based	General population	PI	34.0	50	0	0	□ 4 teeth with PPD □ 5 mm AND CAL □ 4 mm in each jaw
Kovačević[53]	Cross-sectional	Hospital based	General population	OHI, Brushing, Floss, Dental visit	38.9	77.2	31.7	N/A	CPITN 3-4
Lavu[55]	Case-control	Hospital based	General population	OHI	33.6	50.4	0	0	CAL > 1 mm at least 30% sites
Lutfioglu[56]	Case-control	Hospital based	General population	PI	33.1	53.3	51.1	0	□ 1 site with PPD □ 5 mm with radiographic evidence of bone loss
Meenawat[57]	Case-control	Hospital based	General population	PI	43.2	100	41.4	0	□ 4 teeth with PPD > 4 mm AND CAL > 2 mm

Mesa[58]	Case-control	Hospital based	General population	PSc	46.3	40.3	46.8	N/A	□ 4 teeth with PD □ 4 mm AND CAL □ 3 mm at the same sites

Table 1 Characteristics of included studies *(Continued)*

OH, oral hygiene; DM, diabetes; OHI, oral hygiene index; PI, plaque index; PSc, plaque score; CPITN, the Community Periodontal Index of

Authors	**Type of study**	**Study-based**	**Population**	**OH Measurement**	**Age**	**Male (%)**	**Smoking (%)**	**DM (%)**	**Periodontitis definition**
Perayil[59]	Case-control	Hospital based	General population	OHI	43.1	43.3	0	0	□ 5 teeth with PPD □ 5 mm AND CAL □ 3 mm
Pereira[60]	Case-control	Hospital based	General population	PSc	38.4	33.7	0	0	□ 4 teeth with PPD □ 4 mm AND CAL □ 3mm
Petrović[61]	Case-control	Hospital based	General population	PI	36.1	38.8	22.4	0	□ 3 quadrants with □ 3 sites with PPD □ 3 mm AND CAL □ 2mm
Pranckeviciene[62]	Cross-sectional	Hospital based	Type I & II DM	PI	43.86	N/A	25.9	100	□ 1 site with CAL > 5 mm
Puri[63]	Case-control	Hospital based	General population	OHI	39.78	N/A	0	0	AAP 1999
Singh[64]	Case-control	Hospital based	General population	PI	43.5	52.5	0	0	□ 1 site with PPD □ 5 mm AND CAL □ 2 mm
Toyman[65]	Case-control	Hospital based	General population	PI	34.6	51.2	0	0	□ 6 teeth with PPD □ 5 mm with radiographic evidence of bone loss
Varghese[66]	Case-control	Hospital based	General population	PI	N/A	65.3	0	0	□ 30% sites with PPD □ 6 mm AND CAL □ 5 mm

Treatment Needs

PPD, periodontal pocket depth; CAL, clinical attachment loss; CDC-AAP, Periodontitis definition of the Centers for Disease Control and Prevention in collaboration with the American Academy of Periodontology, CVD, cardiovascular disease; N/A, not available

Table 2 Overview meta-analysis

	No. studies	Pooled OR (95% CI)	I^2
Oral hygiene			
(a) Categorical data			
- Fair versus Good OH	9	2.04 (1.65, 2.53)	40%
- Poor versus Good OH	15	5.01 (3.40, 7.39)	78%
(b) Continuous data			
- PI: 1-unit-increasing	6	2.25 (1.43, 3.54)	81.1%
- PSc: 1-unit-increasing	3	1.02 (1.01, 1.03)	74.2%
- Oral hygiene score	25	2.04 (1.59, 2.50)*	95.6%
Oral health care habits			
- Tooth brushing	10	0.66 (0.47, 0.94)	94.5%
- Interdental cleaning	4	0.87 (0.75, 1.00)	5.1%
- Dental visits	6	0.68 (0.47, 0.98)	60.4%

OH, oral hygiene; PI, plaque index; PSc, plaque score

* *Pooled Standard Mean Difference (SMD)*

Supplement legends

Supplement Tables

Table S1: Search terms and search strategy

Table S2: Risk of bias assessment

Table S3: Categorization of oral hygiene level

Table S4: Pooling effects of fair and poor versus good oral hygiene on periodontitis

Table S5: Subgroup and sensitivity analysis according to sources of heterogeneity of fair and poor versus good oral hygiene

Table S6: Pooling standardized mean difference of oral hygiene scores between periodontitis and non-periodontitis

Table S7: Pooled effect size of oral care habits on periodontitis

Table S8: Sources of heterogeneity of tooth brushing meta-analysis

Table S9: Publication bias assessment by Egger test

Supplement information

Supplement information A: PRISMA checklist

Supplement information B: Modified Newcastle-Ottawa Quality Assessment Scale

Supplement Figures

Figure S1: Funnel plots of publication bias assessment

Figure S2: Contour enhanced funnel plots