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Review article

Association between periodontal disease and osteoporosis in postmenopausal women: A systematic review and meta-analysis

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ABSTRACT

Objective: To evaluate the relationship between periodontitis and postmenopausal osteoporosis.
Methods: This research was carried out according to the principles laid down by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guideline statement. We searched the Web of Science, Embase, PubMed, The Cochrane Library, CNKI, VIP, and WanFang databases from inception to July 1, 2023 to collect all relevant publications, with no restrictions on publication date or Languages. Cochrane's tool for assessing RoB was used to evaluate the RoB for RCTs. The Newcastle-Ottawa Scale was used to assess the RoB for cohort studies and case-control studies. Mean differences (MD) with 95 % confidence intervals (CI) were used for analysis of continuous data. Heterogeneity was measured using the I^2 statistic. Revman 5.4 software was used for the meta-analysis.
Results: 28 observational studies with 19611 patients, including 5813 cases in the postmenopausal osteoporosis group and 13798 cases in the non-osteoporosis group. The studies showed that the degrees of clinical attachment loss (CAL), probing depth (PD), gingival recession (GR), simplified oral hygiene index (OHIS), and percentage of sites with bleeding on probing (BOP) in the postmenopausal osteoporosis group were higher than those in the non-osteoporosis group[CAL(MD = 0.89(mm), 95 % CI [0.48,1.30], $p < 0.00001$), PD (MD = 0.27(mm), 95 % CI [0.13, 0.41], $p = 0.0001$), GR (MD = 0.28(mm), 95 % CI [0.20, 0.35], $p < 0.00001$), OHIS (MD = 1.32,95 % CI [1.12,1.51], $p < 0.00001$), BOP(MD = 12.71(%), 95 % CI [3.24,22.18], $p = 0.009$)]. Eleven studies found that bone mineral density (BMD) in the postmenopausal osteoporosis group was lower than that in non-osteoporosis group (MD = −0.41(U/cm^2), 95 % CI [-0.77,-0.05], p = 0.03). The combined analysis results of the studies in the two groups showed that there were no significant differences in the loss of alveolar crestal height (ACH)[(MD = −1.76(%),95%CI [-3.64,0.12], $p = 0.07$)].

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Conclusion: Postmenopausal osteoporosis patients are more likely to suffer from periodontitis, and the condition is easily aggravated.

1. Introduction

Oral illnesses affecting the periodontal tissue, or the tissue that supports the teeth, are referred to as periodontal disease. These include gum disease that solely affects the gingival tissue and periodontitis that affects deep periodontal tissues such the alveolar bone, periodontal ligament, and cementum [1]. Postmenopausal osteoporosis (PMO) is a metabolic disease caused by the significant decrease in estrogen resulting from postmenopausal ovarian decline, and leads to disorders of bone metabolism, as well as reductions in bone mass and bone mineral density [2]. Previous studies have not observed a significant correlation between osteoporosis and periodontal disease, attributed to the fact that osteoporosis is a systemic disease and periodontal disease is a local disease [3]. In recent years, however, studies have suggested that postmenopausal women are at high risk of both osteoporosis and periodontal disease [4], and that osteoporosis is related to the occurrence and development of periodontal disease [5], suggesting that PMO is a risk factor for periodontitis [6]. Senile bone loss is a common feature of the two diseases. The common risk factors for both diseases include smoking, age, sex, menopause, and drugs [7]. The previous systematic review and meta-analysis, published in 2017, investigated the relationship between low BMD in postmenopausal women and periodontal attachment loss [4]. The only result of the meta-analysis, which focused on periodontal attachment loss, was the clinical attachment level (CAL). There is substantial variation among the research since the definition of periodontitis and CAL cutoff levels vary between investigations. However, the clinical measures of periodontal condition still place a high priority on the loss of alveolar crestal height (ACH), oral hygiene index simplified (OHIS), probing depth (PD), and percentage of sites with bleeding on probing (BOP).

Therefore, we undertook the first thorough investigation of the relationship between periodontal disease and osteoporosis in postmenopausal women with this systematic review and meta-analysis. The information could close a gap in this area.

2. Materials and methods

The protocol was registered at the International Prospective Register of Systematic Reviews (PROSPERO) under registration number CRD42021225746. The protocol for systematic review and meta-analysis was published on the BMJ Open [8].

2.1. Objectives

The goal of this review was to evaluate the relationship between periodontitis and postmenopausal osteoporosis.

2.2. Eligibility criteria according to PICO framework

A Participants, Interventions, Comparators, and Outcomes (PICO) framework was used to answer the focused question using the following approach elements: (1) Population: The participants were postmenopausal women, with no restrictions on ethnicity or health status. The WHO-recommended diagnostic criteria for osteoporosis were accepted [9], especially bone mineral density (BMD) as determined by dual energy X-ray absorptiometry. poor bone mass density (BMD) is defined as bone density that is lower than the bone peak of healthy persons of the same sex and race. Low BMD is considered acceptable if it falls within one standard deviation (SD); drops of 12.4 SD or more indicate poor bone mass, and decreases of 2.5 SD indicate osteoporosis. One or more fractures are likely to occur concurrently with BMD declines that match the diagnostic criteria for OP. The diagnosis of periodontitis refers to the diagnostic criteria of periodontitis, evaluated through clinical oral and whole-mouth curved section X-ray examination; the periodontal probing depth (PPD) should be less than 4 mm, the clinical attachment loss (CAL) should be less than 2 mm, and there should be horizontal or angular absorption of the alveolar bone [10]. (2) Comparator: variations in postmenopausal women's periodontal health between those with and without osteoporosis. (3) Results Clinical attachment loss (CAL), probing depth (PD), gingival recession (GR), percentage of sites with bleeding on probing (BOP) [11], bone mineral density (BMD), loss of alveolar crestal height (ACH), and the simplified oral hygiene index (OHIS) were the outcomes [12]. The distance from the cement-enamel junction (CEJ) to the bottom of the pocket was used to calculate CAL [13,14]. The distance from the gingival edge to the bottom of the pocket was used to measure PD decrease [13,14]. ACH was defined as the distance from the CEJ to the most coronal point of the alveolar crest immediately adjacent to the root surface, and in the case of a vertical defect, ACH was defined as the distance from the CEJ to the point immediately adjacent to the root surface at the base of the defect [13,14]. GR stood for the distance from the gingival margin to the CEJ [15].

2.3. Exclusion criteria

Studies were disqualified if one or more of the following criteria were met: (1) qualitative studies, case reports, case series, reviews, letters, comments, notes, animal studies, editorials, (2) incomplete research data, or (3) studies not written in Chinese or English.

In addition, the research with the biggest sample size and the longest follow-up period was chosen for studies using the same sample.

2.4. Search strategy

We systematically searched the Medline/PubMed, Embase, Cochrane Central Register of Controlled Trials, Web of Science, CNKI, CBM, VIP, and Wanfang databases from inception to July 1, 2023, to identify publications related to the association between periodontal disease and osteoporosis in postmenopausal women. The search strategy was conducted using medical subject headings with text words. The search terms for each database included ("periodontal diseases [MeSH]" OR "parodontosis" OR "parodontoses" OR "pyorrhea alveolaris") AND ("osteoporosis, postmenopausal [MeSH]" OR "perimenopausal bone loss*" OR "post-menopausal osteoporoses" OR "post-menopausal osteoporosis" OR "postmenopausal osteoporosis" OR "postmenopausal osteoporoses" OR "perimenopausal bone losse*"). The online supplemental Table 1 describes the full search strategies in detail.

2.5. Study selection

Data were extracted from the included studies using a standardized manner. The data extraction was carried out separately by two qualified reviewers. Discussion or a third reviewer were used to settle disagreements amongst the reviewers.

2.6. Data extraction

Using a specified data extraction table, two reviewers separately extracted the data. The information that was extracted fell into four categories: (1) study characteristics (first authors, year of publication, country of participants, length of study, number of participants); (2) participant information (age, ethnicity, periodontal disease status); (3) methods (study design, measures of exposure, outcomes, and the criteria of periodontal disease and osteoporosis); and (4) outcomes (CAL, GR, PD, BOP,BMD, ACH, OHIS).

2.7. Data synthesis and statistical analysis

The analyses were carried out with the Revman 5.4 program. The data were analyzed using the odds ratio (OR). The data was measured using the statistic of weighted mean difference (WMD), and the findings were presented with a 95 % confidence interval (CI). The chi-square test was used to analyze the degree of heterogeneity among the included study results (the test threshold was $\alpha = 0.1$), and its combination with I^2 was used to quantitatively assess the degree of heterogeneity. The fixed-effects model was employed to

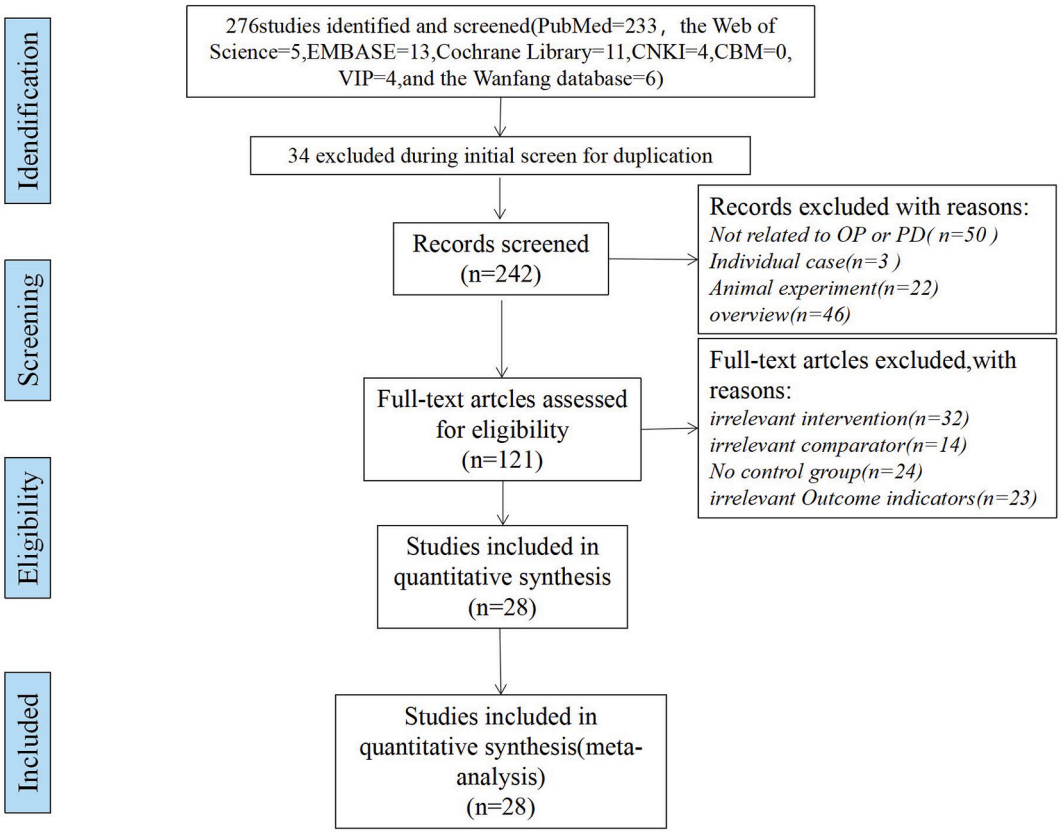

Fig. 1. Flow diagram of the selection process.

integrate the data if no statistically significant heterogeneity was seen ($I^2 \leq 50$ %, $p \geq 0.1$). When statistical heterogeneity was determined to be substantial (I^2>50 %, $p < 0.1$), the data were combined using the random effects model.

The risk of bias (RoB) for each included study was assessed independently by two researchers. Each query was answered by a third reviewer or through dialogue. Using Cochrane's method for assessing RoB, the RoB for RCTs was evaluated [16]. The Newcastle-Ottawa Scale was used in case-control and cohort studies to assess the RoB [17]. When the included literature score was less than 6 [18] or the age or sex of the two groups did not match, studies were classified as class B (inferior). Other research, in contrast, were labeled as class A studies.

When at least 10 studies had reported the main results, publication bias in the included studies was evaluated. To identify publication bias, funnel plots were visually inspected, and statistical analyses utilizing the Begg-Mazumdar rank correlation [19] and Egger's regression test [20] were performed.

3. Results

3.1. Search results

A total of 276 relevant publications were identified in the initial survey and after reviewing the title and authors, 34 were excluded due to duplications. After reading the abstracts, 50 articles that were not related to OP or periodontal disease, 3 individual case reports, 22 animal studies, and 46 overviews were excluded. After reviewing the full text articles, 93 publications were excluded due to irrelevant intervention (32 studies), irrelevant comparators (14 studies), irrelevant outcome indicators (23 studies), and lack of a control group (24 studies). Finally, 28 studies were included after layer-by-layer screening [15,21–47]. The specific screening process is shown in Fig. 1.

3.2. Patient characteristics

Twenty-eight observational studies involving 19611 patients, including 5813 cases in the postmenopausal osteoporosis group and 13798 cases in the non-osteoporosis group. The research was conducted over four continents, including 12 in Asia, 9 in Europe, 5 in South America, and two in North America, covering a total of 15 countries. In all, there were 19611 patients, including 5813 cases in the experimental group (postmenopausal osteoporosis group) and 13 798 cases in the control group (non-osteoporosis group), with an

Table 1
Main characteristics of the 28 studies included in the meta-analysis.

Study	Year	Country	Research type	Patients	average age		Outcomes
				Exp/Con	Exp	Con	
Nina von Wowern [21]	2001	Denmark	–	12/14	68.3 ± 1.8	68.1 ± 1.5	⑥
E-Chin Shen [22]	2004	China	retrospective analysis	18/16	50–59	50–59	①②③
Jean Wactawski-Wende [23]	2005	USA	cross-sectional study	316/358	53–85	53–85	⑤
K. Inagaki [24]	2005	Japan	cross-sectional study	87/98	63.8 ± 7.5	62.8 ± 7.8	⑥
Gomes-Filho [25]	2007	Brazil	case-control study	48/91	59.2 ± 6.9	58.6 ± 6.1	①②④
Fernanda Ferreira Lopes [26]	2008	Brazil	longitudinal, observational study	15/8	45–77	45–77	①
Rola Al Habashneh [27]	2010	Jordan	cross-sectional study	136/94	62.5 ± 6.4	62.5 ± 6.4	⑥
Jabbar S [28]	2011	UK	RCT	185/185	62.06 ± 14.53	62.56 ± 13.24	③
Maestre [29]	2012	Spain	cross-sectional study	19/23	55–70	55–70	①②④
E Pepelassi [30]	2012	Greece	multicentre research	35/45	55.4 ± 6.12	55.4 ± 6.12	①②③④
Passos J S [31]	2012	Brazil	case–control study	94/427	60.6 ± 7.3	60.9 ± 7.4	①②④
J. Darcey [32]	2013	UK	cross-sectional observational study	91/257	61.3 + 4.7	59.3 + 5.3	②
Masanori Iwasaki [33]	2013	Japan, USA	cross-sectional study	100/161	55–74	44–74	②④⑥
E. J. Marjanovic [34]	2013	UK	cross-sectional study	98/282	58 ± 4.7	56 ± 5.6	②
Ioana Duncea [35]	2013	Romania	–	62/35	62.42 ± 7.852	56.80 ± 7.003	③
Wei-Pin Chang [36]	2014	China	sampling survey	2527/7575	70.18 ± 10.75	70.16 ± 10.72	⑥
Anuradha Singh [37]	2014	India	single blinded cross-sectional study	31/22	46–54	46–54	①②⑤
F. M. B. G. Pereira [38]	2014	Brazil	longitudinal, observational study	6/15	45–77	45–77	①②
L. Sachelarie [39]	2015	Romania	RCT	54/33	35–75	35–75	⑥
Ravichandra Juluri [40]	2015	India	double-blind, case-control study	50/50	50–65	50–65	①②⑦
D. C. Penoni [41]	2016	Brazil	cross-sectional study	86/48	65–80	65–80	①②⑥
Soyeon Ji [42]	2016	Korea	cross-sectional study	740/1148	67.3 ± 0.4	59.6 ± 0.3	⑥
A. Temmerman [43]	2018	Sweden	long-term controlled trials	20/28	59–83	60–74	①②
Sanutm Mongkornkarn [44]	2019	Thailand	cross-sectional study	782/2500	45.7 ± 10.4	55.7 ± 11.9	①②
GUO Rui-sheng [45]	2020	China	retrospective analysis	32/32	–	–	②⑥
Zhu Jie [46]	2020	China	a retrospective case-control study	60/135	57.8 ± 4.3	57.8 ± 4.3	④⑦
Gil-Montoya José Antonio [47]	2021	Spain	cross-sectional study	61/70	45–72	45–72	①②
Saba Zaman [48]	2022	Iran	cross-sectional study	48/48	61.9 ± 5.87	58.55 ± 5.48	①

Notes:Exp: experimental group(postmenopausal osteoporosis group); Con: control group(non osteoporosis group).
Outcomes:①CAL②PD③GR④BOP⑤ACH⑥BMD⑦OHIS.

Table 2
Methodological quality evaluation included in the study.

Study	Object selection				Comparability	expose			score	Grade
	Clearly defined cases	Case representativeness	Control selection	Cross reference definition	Comparability of cases and controls in trial design or analysis	Confirm exposure	Case and control were confirmed in the same way	No response rate		
Nina von Wowern [21]	1	1	1	1	2	0	1	0	7	A
E-Chin Shen [22]	1	1	1	1	1	0	1	0	6	A
Jean Wactawski-Wende [23]	1	1	1	1	2	0	1	0	7	A
K. Inagaki [24]	1	1	1	1	1	0	1	0	6	A
Gomes-Filho [25]	1	1	1	1	2	0	1	0	7	A
Fernanda Ferreira Lopes [26]	1	1	1	1	1	1	1	0	8	A
Rola Al Habashneh [27]	1	1	1	1	2	0	1	0	7	A
Maestre [29]	1	1	1	1	1	0	1	0	6	A
E Pepelassi [30]	1	1	1	1	2	0	1	0	7	A
Passos J S [31]	1	1	1	1	2	0	1	0	7	A
J. Darcey [32]	1	1	1	1	2	0	1	0	7	A
Masanori Iwasaki [33]	1	1	1	1	2	0	1	0	7	A
E. J. Marjanovic [34]	1	1	1	1	1	0	1	0	6	A
Ioana Duncea [35]	1	1	1	1	1	0	1	0	6	A
Wei-Pin Chang [36]	1	1	1	1	1	1	1	0	7	A
Anuradha Singh [37]	1	1	1	1	2	1	1	0	8	A
F. M. B. G. Pereira [38]	1	1	1	1	1	0	1	0	6	A
Ravichandra Juluri [40]	1	1	1	1	1	0	1	0	6	A
D. C. Penoni [41]	1	1	1	1	1	0	1	0	6	A
Soyeon Ji [42]	1	1	1	1	2	0	1	0	7	A
A. Temmerman [43]	1	1	1	1	2	0	1	0	7	A
Sanutm Mongkornkarn [44]	1	1	1	1	2	0	1	0	7	A
GUO Rui-sheng [45]	1	1	1	1	2	0	1	0	7	A
Zhu Jie [46]	1	1	1	1	1	0	1	0	6	A
Gil-Montoya José Antonio [47]	1	1	1	1	2	0	1	0	7	A
Saba Zaman [48]	1	1	1	1	2	1	1	0	8	A

average age of over 45 years. Detailed information on the trials and patients included in the analysis is presented in Table 1.

3.3. Quality assessment

The Newcastle Ottawa Scale was used to evaluate the quality of the 26 included studies, with all included studies classified as Class A. Two articles [25,36,47] scored 8 stars, sixteen articles [15,21,24,26,29–32,35,37,41–44,46] scored 7 stars, and eight articles [22,

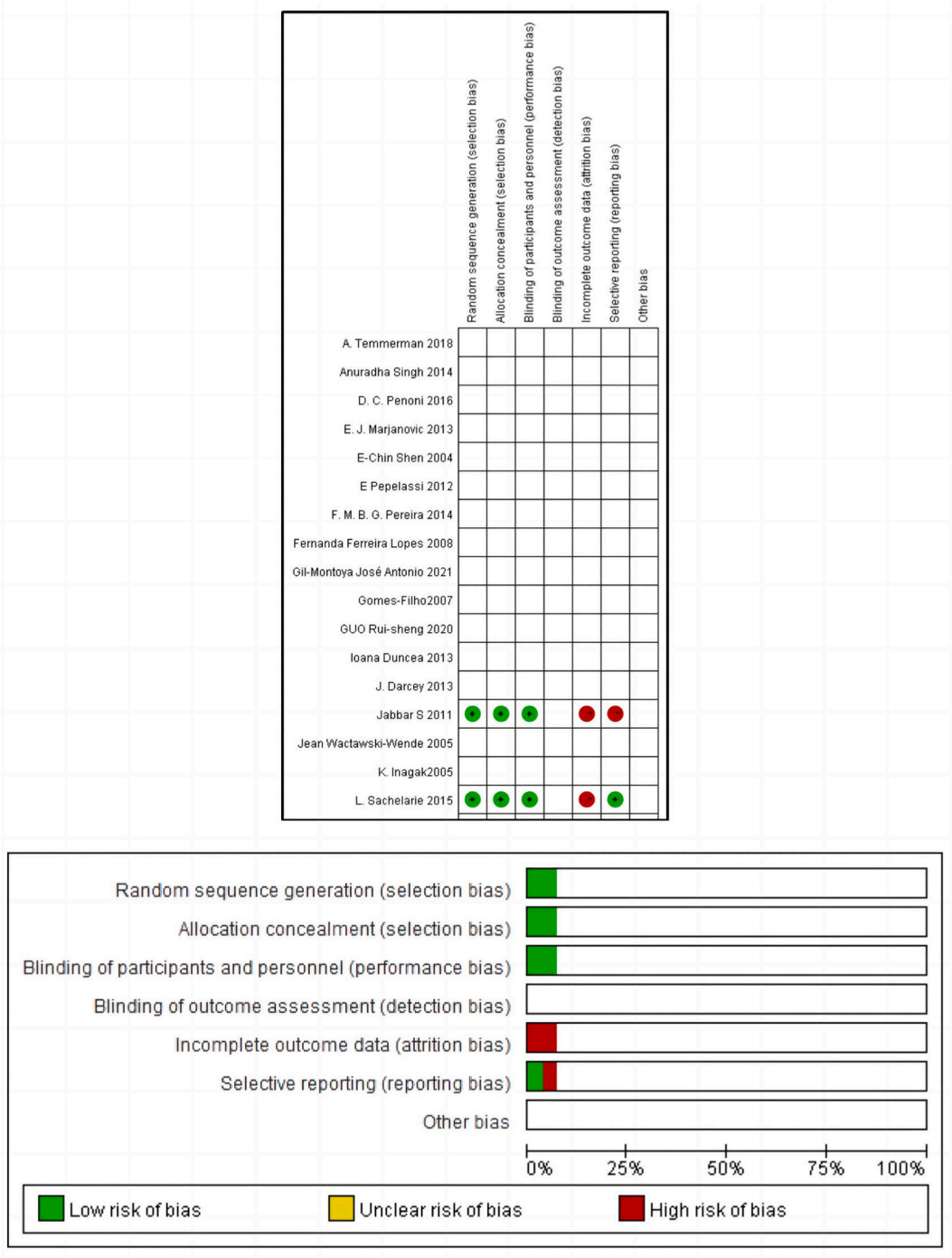

Fig. 2. Risk of bias summary: review of the authors' judgments about each risk of bias item for the included studies, risk of bias graph: review of the authors' judgments about each risk of bias item presented as percentages across all included studies. Note: Each color represents a different level of bias: red for high risk, green for low risk, and yellow for unclear risk of bias.

23,28,33,34,39,40,45] scored 6 stars (Table 2). Cochrane's tool for assessing RoB was used to evaluate the RoB for 2 RCTs [27,38], according to the criteria of Cochrane guidelines, each trial was classified as low bias, unclear (the risk of bias is undefined or unknown), or high bias. The assessment of the risk of bias is shown in Fig. 2. This suggested that the quality of the included studies was good.

3.4. Meta-analysis results

3.4.1. Clinical symptoms

The results of clinical symptoms such as CAL [22,24,25,28–30,33,36,37,39,40,42–44,46,47], PD [22,24,28–31,33,34,36–39,42–44,46], GR [22,27,29,34,36,39], BMD [21,23,26,32–35,38,41,44,46], ACH [15,36], OHIS [39,45] and BOP [25,28,30,32,36,45] were reported in various literatures. The heterogeneity test results of the included literature were as follows: CAL ($I^2 = 99$ %, $p < 0.00001$), PD ($I^2 = 92$ %, $p < 0.00001$), GR ($I^2 = 17$ %, $p = 0.30$), BMD ($I^2 = 100$ %, $p < 0.00001$), ACH ($I^2 = 100$ %, $p < 0.00001$), OHIS ($I^2 = 99$ %, $p < 0.00001$) and BOP ($I^2 = 99$ %, $p < 0.00001$). There was significant heterogeneity among the CAL, PD, BMD, OHIS, ACH, BOP. A random effect model was used for analysis. However, it was found that the results from the random effect model and the fixed effect model on the pooled data from the studies were consistent.

The results from the random effect model were as the following: CAL(MD = 0.89(mm), 95 % CI [0.48,1.30], $p < 0.00001$), PD (MD = 0.27(mm), 95 % CI [0.13, 0.41], $p = 0.0001$), BMD (MD = −0.41(U/cm^2), 95 % CI [−0.77,-0.05], p = 0.03), OHIS (MD = 1.32,95 % CI [1.12,1.51], $p < 0.00001$), ACH (MD = −1.76(%),95%CI [−3.64,0.12], $p = 0.07$) and BOP(MD = 12.71(%), 95 % CI [3.24,22.18], $p = 0.009$). The results from the fixed effect model was as the following: GR (MD = 0.28(mm), 95 % CI [0.20, 0.35], $p < 0.00001$), There were significant differences between the treatment group and the control group regarding CAL, PD, BMD, OHIS, BOP and GR ($p < 0.05$). There were no significant differences in the loss of alveolar crestal height (ACH). The results are shown in Figs. 3–9.

3.4.2. Subgroup analysis

We also thoroughly perform subgroup analyses in order to assess the research' repeatability in light of various parameters. Patients with periodontitis may be found in case-control studies with an MD of 0.71 and a 95 % CI of 0.18–1.24, as well as cross-sectional studies with an MD of 1.22 and a range of 0.51–1.92. Retrospective analysis shows a reduced risk (MD, 0.27; 95 % CI, 0.19–0.34). Overall, the findings from the subgroup analysis indicated that those with osteoporosis had a greater chance of developing periodontitis. The results is shown in Fig. 10.

3.4.3. Sensitivity analysis

The sensitivity analysis method of exclusion one by one was adopted for 24 studies included in the meta-analysis. In the case of the 10 papers reporting CAL, it was found that when the studies of Fernanda Ferreira Lopes [25], Maestre [26], Passos J S [30], E. J. Marjanovic [33], F. M. B. G. Pereira [37] and D. C. Penoni [40], assessed as having poor quality, were excluded, the heterogeneity was eliminated ($I^2 = 17$ %, p = 0.02), and the fixed effects model showed no significant difference between the combined results of the remaining studies and the original combined results (MD = 0.29, 95 % CI [0.23,0.34], $p < 0.00001$), indicating that the results were generally consistent. Fourteen studies describing PD were assessed and excluding the studies by Gomes-Filho [24], Passos J S [30], E. J. Marjanovi [33], and Anuradha Singh [36], D. C. Penoni [40], eliminated the heterogeneity ($I^2 = 0$ %, $p = 0.99$); however, there was a significant change in the combined results of the remaining studies (MD = 0.02, 95 % CI [−0.03, 0.06], $p = 0.51$), indicating that the stability of the original combined results was poor. In terms of the five studies that described BOP, exclusion of the study by Maestre [28] eliminated the heterogeneity ($I^2 = 41$, $p = 0.17$), with the combined results of the remaining studies changing significantly (MD = −7.46, 95 % CI [−8.04, −6.88], $p < 0.00001$), indicating that the stability of the original combined results was poor. Although the heterogeneity of studies describing ACH and OHIS was also very high, there were only two studies on each, preventing sensitivity analysis on these two indices.

3.4.4. Publication bias

The scattered point distribution was relatively symmetrica, as could be observed from the chart. The findings revealed that the

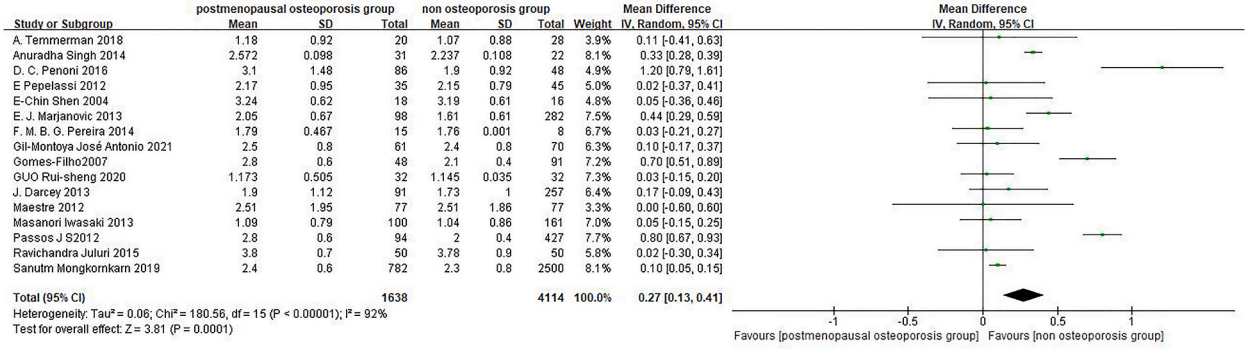

Fig. 3. Forest plot of the comparison of the PD between the experimental and control group.

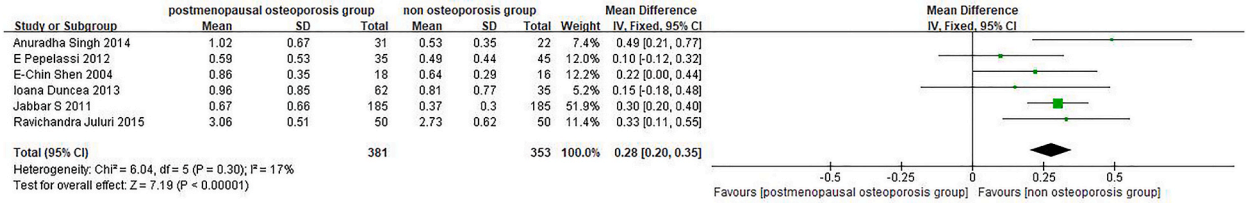

Fig. 4. Forest plot of the comparison of the GR between the experimental and control group.

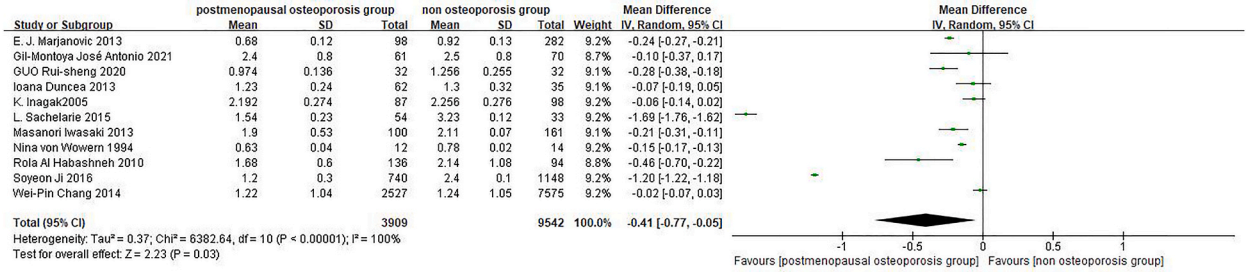

Fig. 5. Forest plot of the comparison of the BMD between the experimental and control group.

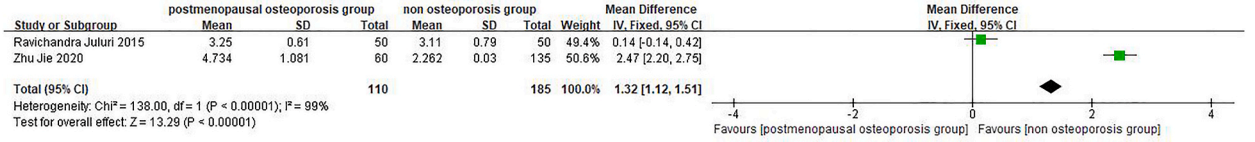

Fig. 6. Forest plot of the comparison of the OHIS between the experimental and control group.

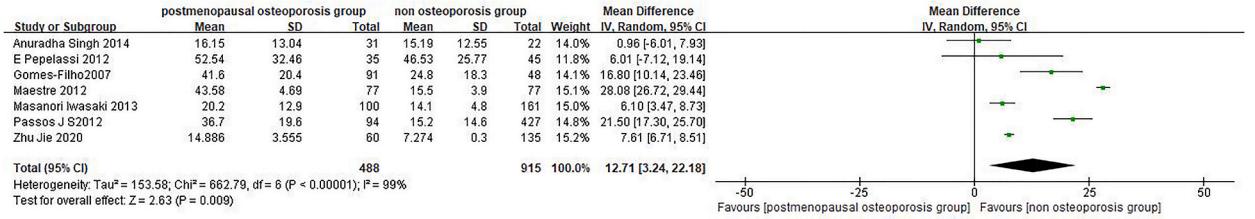

Fig. 7. Forest plot of the comparison of the BOP between the experimental and control group.

included research did not exhibit any discernible publication bias. However, due to the small number of included papers, it was unable to determine whether there was publication bias using the other outcome variables. The meta-analysis's findings need to be carefully interpreted and confirmed.

The plot result for CAL is presented in Fig. 11.

4. Discussion

4.1. Principal findings

Menopausal ladies are high-risk businesses for osteoporosis and periodontal disease, while OP is associated to the occurrence of periodontal sickness [48]. They are all age-related, chronically unfavorable diseases. The longer the onset time, the higher the harm to the human body [49–51]. At present, the clinical assessment of periodontal disease is mainly based on the degree of CAL. Wang et al. [52] conducted periodontal examinations and bone density measurements on 521 postmenopausal ladies and determined osteoporosis and bone mass, the threat of periodontal ailment in the reduced population is twice that of the normal population. From the medical empirical research posted in latest years, 23 studies [53] showed that there is a enormous correlation between CAL and OP, which is consistent with the consequences of this study. The PD, CAL,GR, number of missing teeth, and gingival bleeding can be used as

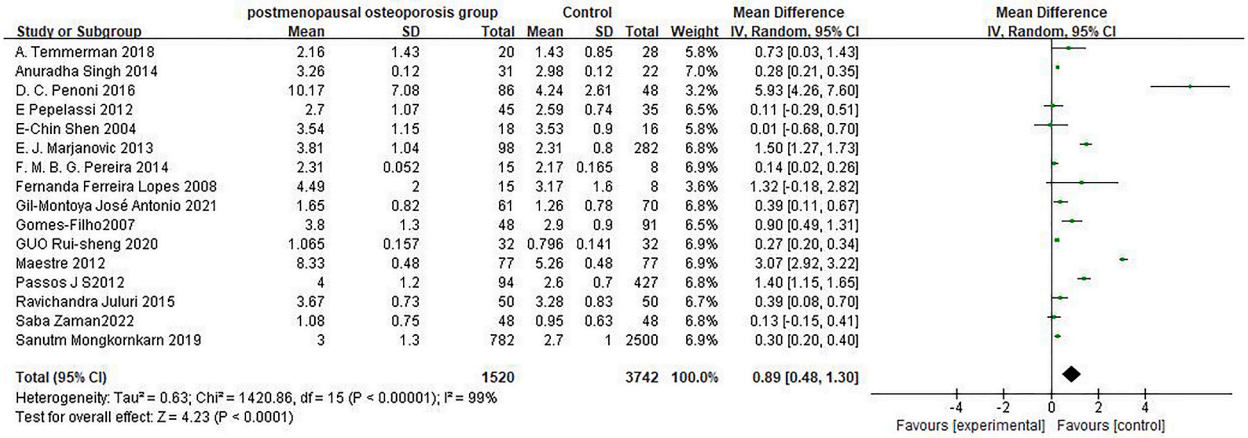

Fig. 8. Forest plot of the comparison of the CAL between the experimental and control group.

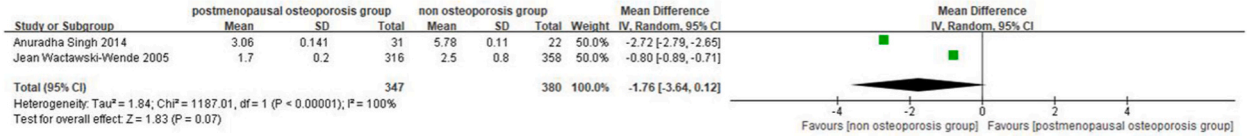

Fig. 9. Forest plot of the comparison of the ACH between the experimental and control group.

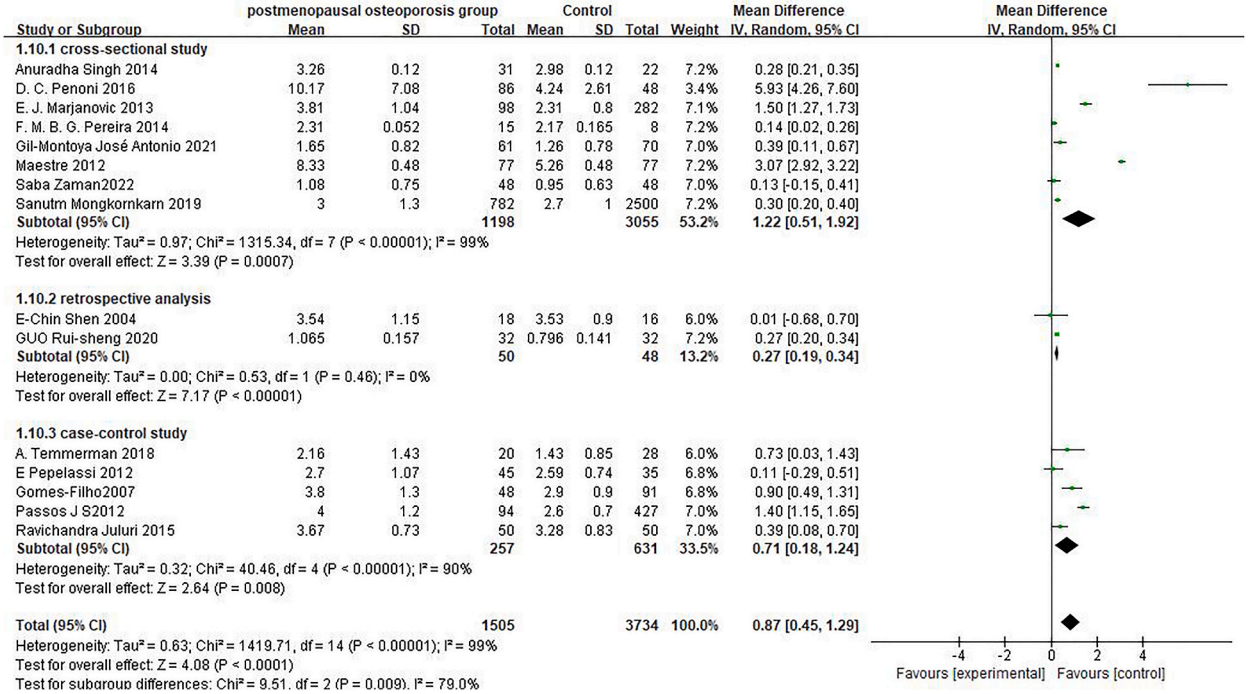

Fig. 10. Forest plot of the comparison of the subgroup analysis between the experimental and control group.

indications to assess the severity of periodontal disease. While BMD is adversely connected with PD and CAL, PD and CAL are favorably correlated with the severity of periodontal disease. The primary molecular link between these two disorders, however, may be pro-inflammatory mediators such as IL-1, IL-6, RANKL, and TNF-, which have been discovered in both diseases and may have a significant impact on osteoclast development and activity [54]. In animal models of both disorders, it had been shown that inhibiting

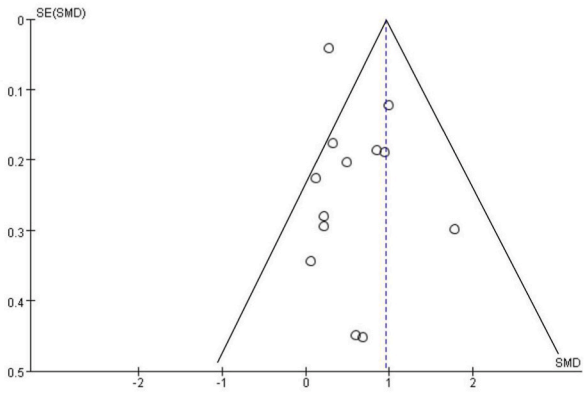

Fig. 11. Funnel plot of percentage of CAL.

the signaling might reduce osteoclastic bone resorption and increase bone formation [55,56]. In addition, through modulating the host response, these mediators may work locally to impede the tissue's ability to respond to periodontitis, worsen the inflammatory response, and hasten systemic bone resorption [57].

According to studies by Peng et al. [58], menopausal women with osteoporosis had a roughly 9-fold higher risk of developing severe periodontitis than the general population. It could be accounted for by the decline in ovarian estrogen production and the rise in testosterone that mark menopause [59]. Increasing osteogenic differentiation of mesenchymal stem cells and inducing osteoclast death by suppressing osteoclast formation are two ways that estrogen influences the balance of bone homeostasis [60]. What's more, the part estrogen plays in inflammation is getting more and more attention. In addition to increasing the production of pro-inflammatory cytokines like IL-1, IL-6, and TNF and decreasing the amount of anti-inflammatory cytokines like OPG and IL-10 [61,62], estrogen deprivation has also been linked to periodontal tissue damage [63]. Menopausal women with periodontitis may thus benefit from hormone replacement treatment (HRT), which has been shown to increase mandibular bone density, lessen gingival bleeding, and stop tooth loss in humans [64,65].

According to the findings of this meta-analysis, osteoporosis and periodontitis risk are strongly associated, and patients with osteoporosis have more severe cases of CAL, OHIS, PD, GR, BOP, and BMD. CAL describes the loss of attachment when the combined epithelium is found in the enamel cementum border at the root and the bottom of the periodontal pocket extends to the root. When this happens, the pathologically deepened gingival sulcus is the real periodontal pocket [43]. Therefore, we think that people with postmenopausal osteoporosis have a higher risk of developing periodontitis or having their current periodontitis deteriorate.

4.2. Limitations and recommendations for future research

The 28 studies that were included in this meta-analysis were all given Grade A rankings (see Table 2), and the highest NOS score (out of 28) was 8. Despite these high rankings, some of the included studies had small sample sizes and/or were cross-sectional studies, which limited their ability to infer etiology. As a result, these studies suffered from selection bias, implementation bias, measurement bias, loss bias, and overall low accuracy and test efficiency, all of which have an effect on the trustworthiness of the results. However, given the databases used in this study were chosen by the authors and the search languages were restricted to English and Chinese, it is possible that there was some form of selection bias. The risk of publication bias cannot be totally eliminated because the included research only covered published studies, despite the fact that the Begg and Egger tests indicated that there was no substantial publication bias throughout the whole study. The strength of the results might have been influenced by these variables in some way.

5. Conclusions

In conclusion, the findings of our investigation showed that both periodontitis and osteoporosis are risk factors for each other. The osteoporosis group had significantly lower levels of bone mineral density than the non-osteoporosis group as well as bleeding on probing, clinical attachment loss, gingival atrophy, and OHIS, which suggests that postmenopausal osteoporosis can increase periodontitis susceptibility or worsen pre-existing periodontitis. In order to intervene and treat chronic periodontal disease as soon as feasible, people with osteoporosis need to obtain curative therapy for oral disorders.

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Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Jing Qi: Conceptualization, Data curation, Software, Writing – original draft. **Jiahui Chen:** Conceptualization, Formal analysis, Software, Supervision, Writing – review & editing. **Yunqing Pang:** Data curation, Methodology, Software, Writing – original draft. **Yufeng Guo:** Data curation, Investigation, Methodology, Software. **Guang Chen:** Conceptualization, Data curation, Investigation, Methodology. **Yuting Liu:** Methodology, Writing – original draft. **Jing Wang:** Supervision, Visualization. **E. Liu:** Conceptualization, Project administration, Supervision, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e20922.

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