Microbiological study of periodontal disease in populations with HIV: a systematic review and meta-analysis

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Abstract

**Background:** No systematic review/meta-analysis has been conducted on the microbiological profile associated with the occurrence of periodontitis in patients with HIV. The aim of this study was to evaluate the prevalence of identified bacteria in HIV-infected patients with periodontal disease.

**Methods:** Three English electronic databases (MEDLINE (via PubMed), SCOPUS, and Web of Science) were searched systematically from the beginning to 13 February 2021. The frequency of each identified bacteria in HIV-infected patients with periodontal disease was extracted. All meta-analysis methods were performed using STATA software.

**Results:** Twenty-two articles met inclusion criteria and enrolled into the systematic review. This review analyzed a total of 965 HIV-infected patients with periodontitis. The prevalence of periodontitis was higher in HIV-infected male patients (63% (CI95%: 76-88%)) compared to females (28% (CI95%: 17-39%)). In our study, the pooled prevalence of necrotizing ulcerative periodontitis and necrotizing ulcerative gingivitis in patients with HIV infection was 67% (CI95%: 52-82%) and 60% (CI95%: 45-74%), while a lower prevalence of linear gingivitis erythema was reported (11% (CI95%: 5-18%)). More than 140 bacterial species were identified from HIV-infected patients with periodontal disease. High prevalence of *Tannerella forsythia* (51% (CI95%: 5-96%), *Fusobacterium nucleatum* (50% (CI95%: 21-78%)), *Prevotella intermedia* (50% (CI95%: 32-68%)), *Peptostreptococcus micros* (44% (CI95%: 25-65%)), *Campylobacter rectus* (35% (CI95%: 25-45%)), and Fusobacterium spp. (35% (CI95%: 3-78%)) in HIV-infected patients with periodontal disease was found.

**Conclusion:** Our study demonstrated that the prevalence of red and orange complex of bacteria in HIV patients with periodontal disease is relatively high.

Background

Globally, the number of individuals infected with the human immunodeficiency virus (HIV) continues to rise. At the end of 2019, nearly 38.0 million people worldwide were diagnosed with HIV, with 1.7 million being newly infected [1].

HIV periodontal manifestations were first identified in 1987 [2]. At least 24 distinct oral lesions have been identified in the HIV literature, but only ten of these are observed consistently. In decreasing order of prevalence, they are oral candidiasis, oral hairy leucoplakia, herpes simplex virus infection, Kaposi's sarcoma, nonspecific ulceration, aphthous ulcers, periodontal disease, and salivary gland disease, oral melanotic hyperpigmentation, and oral warts [3].

Periodontal disease is closely linked to HIV infection and refers to a group of inflammatory-based diseases that include gingivitis and periodontitis [4]; however, it is unclear if the combination of HIV infection and periodontitis raises the risk of aggravation of their periodontitis [5, 6].

Severe periodontitis, which can lead to tooth loss, threatens 5–20 percent of the world's adult population [7]. The prevalence of HIV periodontitis and gingivitis was reported to be 14%, 9.3%, 8%, and 4.4%, respectively, in Asia, Europe, Africa, and America [3].

Numbers of scientific research has been dedicated to the study of periodontal-disease-associated microflora, ranging from traditional cultural techniques to new genetic, whole-genome, and proteomic approaches [8].

Bacteria that cause periodontal disease can be categorized based on how they interact with each other when colonizing the gingival sulcus [9]. There is a balance between microbial challenge and host immune response; any change to that with the presence of other modifying factors is responsible for periodontal infection clinical manifestation. [10].

For several years, scientists have recognized that studying oral health and disease requires recognizing and comprehending the pathogenic potential of all bacteria that colonize the oral cavity [11]. More than 700 bacterial species have been identified in the subgingival plaque, and some of these microorganisms have been linked to the initiation /progression of periodontal diseases. *Porphyromonas gingivalis, Tannerella forsythia* (previously known as *Bacteroides forsythia*), and *Actinobacillus actinomycetemcomitans* were classified as key pathogens. In 1998, Socransky et al. proposed that understanding oral diseases could be enhanced by concentrating on consortia of species rather than individual pathogens. They discovered five groups of bacteria, or complexes, that were present together in periodontitis on several occasions. They hypothesized that the most pathogenic complex included *P. gingivalis, T. forsythia, and Treponema denticola* (the red complex) and was dependent on earlier colonization of the pocket by the orange complex, a group of less pathogenic species [11, 12].

There are several unanswered questions in dental science [13], especially in the microbiology, immunology, inflammatory host response, and epidemiological developments of periodontal disease in HIV-infected populations. No systematic review/meta-analysis has been conducted on the microbiological profile associated with the occurrence of periodontitis in patients with HIV. The aim of this study was to evaluate the prevalence of identified bacteria in HIV-infected patients with periodontal disease.

Methods

**Search method and selection criteria**

Three English electronic databases (MEDLINE (via PubMed), SCOPUS, and Web of Science) were searched systematically from the beginning to 13 February 2021. Publication searches were performed by various combinations of the following terms: "Immunodeficiency" or "Human immunodeficiency virus" AND "Periodontitis" AND "Bacteria" or "Oral microbiota" or "Oral microbial" or "Aggregatibacter actinomycetemcomitans" or "Porphyromonas gingivalis" or "Tannerella forsythia" or "Prevotella intermedia" or "Treponema denticola" or "Fusobacterium nucleatum" or "Campylobacter rectus" or "Eikenella corrodens" or "Eikenella corrodens" or "Peptostreptococcus micros". The reference lists of selected articles were also screened manually and applicable articles were
included. Abstracts of papers presented at conferences were not reviewed because they lacked sufficient details data. Dissertations and thesis were not included. The study was conducted according to the guidelines of PRISMA (the preferred reporting items for systematic reviews and meta-analyses).

Inclusion criteria

Titles and abstracts of all articles were screened by one reviewer, and eligibility of the screened articles was assessed by two independent investigators using the following criteria: titles, abstracts, and full texts. When necessary, authors were contacted for additional information. Studies were excluded if they had insufficient data.

Periodontal diseases

A periodontal diseases related to HIV was categorized as necrotizing ulcerative periodontitis, necrotizing ulcerative gingivitis, and linear gingivitis erythema [14].

Bacterial complex definition

Six closely related classes of bacterial species were included for meta-analysis. Colors ranging from red to yellow have distinct connotations. The most pathogenic color is red, while yellow represents commensales. A red complex composed of \textit{P. gingivalis}, \textit{T. denticola}, and \textit{T. forsythia} that is highly correlated with the clinical progression of chronic periodontitis [15], an orange complex included anaerobic gram-negative species such as \textit{Prevotella intermedia}, \textit{Prevotella nigrescens}, \textit{Prevotella micros}, and \textit{Fusobacterium nucleatum}, a yellow complex consisting of members of the genus \textit{Streptococcus}, a green complex included \textit{Capnocytophaga} species, \textit{A. actinomycetemcomitans} serotype A, \textit{Eikenella corrodens} and \textit{Campylobacter} and a purple complex containing \textit{Veillonella parvula} and \textit{Actinomyces odontolyticus} [16].

Exclusion criteria

Investigations with not-relevant topics, review and case report articles, books, non-english articles or the ones worked on non-human subjects were excluded. The articles, in which bacterial information was given in a graph/phylogenetic tree or as mean value or relative distribution, were deleted. The articles, in which bacterial frequency data was reported among the sites or isolates studied, were also omitted.

Data extraction

Data from eligible studies was extracted independently by 2 reviewers and checked by a third reviewer. Disagreements among the reviewers were resolved through discussion. The following data were extracted from included studies: first author and publication year, country region, sample size, sex and age of patients, number of HIV-positive patients diagnosed with periodontal diseases, type of sampling, type of the periodontal diseases, diagnostic methods used, and the frequency of each type of microorganisms. If the data was reported as a percentage, the number was calculated through the use of proportions. The frequency of each identified bacteria in HIV-infected patients with periodontal disease was extracted.

Data analysis

All meta-analysis methods were performed using STATA (Release 12. statistical software. College Station, Texas: STATA Corp LP). Results of the meta-analysis were illustrated by a forest plot diagram, which demonstrated the pooled prevalence of each microorganism and their relevant 95% confidence interval (CI).

The Cochrane Q-test and the inverse variance index ($I^2$) were used to evaluate the heterogeneity in this study. The $I^2$ values of 25%, 50%, and 75% were representatives of low, moderate and high heterogeneity, respectively [17].

Publication bias was estimated by a funnel plot diagram based on Egger's regression test [18].

Quality assessment

The quality of the studies included in this study was independently evaluated by two reviewers using the Joanna Briggs Institute's updated Critical Appraisal Checklist for Prevalence Studies, which includes nine questions that the reviewers answered for each of the qualifying studies. Any dispute was resolved through discussion [19].

Results

Of the 2075 records identified in the mentioned electronic databases, 559 and 252 articles remained after duplicates removal and title-based screening. By screening of full-texts, 230 records were excluded for various reasons including reported bacterial data in graph/phylogenetic tree or as mean value or relative distribution. Twenty-two articles met inclusion criteria and enrolled into the systematic review (Fig. 1).

This review analyzed a total of 965 HIV-infected patients with periodontitis. Demographic and clinical information is presented in Table 1.
| First author              | Date     | Country     | Age range | Male | Female | Sample size | HIV periodontal | Gingivitis | Periodontitis | Microbial samples | Identifying microorganism |
|--------------------------|----------|-------------|-----------|------|--------|-------------|-----------------|------------|--------------|---------------------|--------------------------|
| Zambón J. J. [36]        | 1990     | USA         | 27–51     | 45   | 5      | 50          | -               | 18         | 32           | -                   | Subgingival plaque       |
| Rams T. E. [21]          | 1991     | USA         | 25–50     | 13   | 1      | 14          | -               | -          | 14           | -                   | Subgingival plaque       |
| Lucht E. [20]            | 1991     | Sweden      | -         | 28   | 2      | 30          | -               | -          | -            | Subgingival plaque    | Culture                  |
| Rosenstein D. I. [37]     | 1993     | USA         | 21–55     | -    | -      | 11          | 11              | -          | -            | Subgingival plaque    | Culture                  |
| Moore L. V. H. [23]      | 1993     | USA         | 28–51     | 37   | 2      | 39          | 39              | 22         | 17           | Subgingival plaque    | Culture/detection        |
| Brady L. J. [22]         | 1996     | USA         | 33–46     | 25   | 25     | -           | 21              | 13         | -            | plaque samples        | Analysis microscop Mycosel |
| Brady L. J. [22]         | 1996     | USA         | 33–46     | 25   | 25     | -           | 21              | 13         | -            | Subgingival plaque    | Analysis microscop Mycosel |
| Hofer D. [24]            | 1996     | Switzerland | 27–43     | 6    | 1      | 7           | -               | 7          | -            | Biofilm              | Culture                  |
| Mellanen L. [40]         | 1996     | Finland     | 23–68     | 46   | 10     | 56          | -               | -          | -            | Subgingival plaque    | -                        |
| Nakou M. [25]            | 1997     | Greece      | 34.3–41.1 | 32   | 28     | 60          | 60              | -          | -            | Periodontal pocket    | Culture                  |
| Lucht E. [39]            | 1998     | Sweden      | -         | 33   | 12     | 45          | 13              | -          | -            | Periodontal pocket    | Microscop                 |
| Chattin B. R. [26]       | 1999     | Japan       | 15–65     | 61   | 6      | 67          | 67              | -          | -            | Gingival papilla and contiguous plaque | Culture/f |
| Teanpaisan R. [27]       | 2001     | Thailand    | -         | 40   | 10     | 50          | -               | -          | -            | Subgingival plaque    | Culture/TEM/SE            |
| Tsang C. S. [29]         | 2001     | China       | 20–50     | 21   | -      | 21          | -               | -          | -            | Subgingival plaque    | staining/TEM/SE            |
| Cobb C. M. [38]          | 2003     | USA         | 18–35     | 10   | 6      | 16          | 16              | -          | -            | Saliva               | TEM/SE                   |
| Botero J. E. [28]        | 2007     | Colombia    | -         | 26   | 5      | 31          | 31              | -          | 31           | Plaque               | Culture                  |
| Brito A. [34]            | 2008     | Venezuela   | -         | 27   | 5      | 32          | 32              | -          | -            | Plaque               | PCR                      |
| Júnior E. G. [30]        | 2008     | Brazil      | 20–43     | 59   | 21     | 80          | 80              | 40         | 40           | Saliva/Subgingival plaque | Culture                  |
| Grande S. R. [35]        | 2009–2010| Brazil      | -         | 36   | 14     | 50          | 50              | 23         | 27           | Subgingival plaque    | PCR                      |
| Gušić, I. [31]          | 2010–2011| Serbia      | -         | 51   | 9      | 60          | 60              | -          | -            | Subgingival plaque    | Culture                  |
| Cembranelli S. B. S. [32]| 2013     | Brazil      | -         | 51   | 31     | 82          | 82              | -          | -            | Gingival pockets      | PCR/fret examina          |
| Jordan R. A. [41]        | 2016     | Germany     | -         | 11   | 11     | 11          | 11              | -          | -            | Saliva/plaque/feces   | DNA chip                 |
| Dai L. [33]              | 2020     | USA         | 21–67     | 32   | 21     | 53          | -               | -          | -            | Periodontal pocket    | PCR/ELISA                |

PCR: Polymerase chain reaction
ELISA: enzyme-linked immunosorbent assay
TEM: transmission electron microscope
SEM: Scanning Electron Microscopy
Sample sizes of the HIV-infected group with periodontitis ranged from 7 to 82. With regard to the applied method for organism identification, the majority of the studies used the culture method \[20–31\], while five studies used the polymerase chain reaction (PCR) method \[26, 32–35\]. No study considered children exclusively. The age groups of the investigated patients were > 15 years in 13 papers, respectively. However, the age group of the study population was not mentioned in the remaining 9 studies. Regarding sampling, in the majority of the studies (n = 11), subgingival plaque was used as the specimen for analysis. However, the periodontal pocket (n = 3), saliva (n = 3), gingival papilla and contiguous supragingival plaque (n = 1), gingival pockets (n = 1), biofilm samples (n = 1), and plaque (n = 2), and feces (n = 1) were also applied in other studies.

The prevalence of periodontitis was higher in HIV-infected male patients (83% (CI95%: 76–88%)) compared to females (28% (CI95%: 17–39%)). Seven studies were from the USA \[21–23, 33, 36–38\], three from Brazil \[30, 32, 35\], two from Sweden \[20, 39\], one from Switzerland \[24\], one from Finland \[40\], one from Greece \[25\], one from Japan \[26\], one from Thailand \[27\], one from China \[29\], one from Colombia \[28\], one from Venezuela \[34\], one from Serbia \[31\], and one from Germany \[41\].

In our study, the pooled prevalence of necrotizing ulcerative periodontitis and necrotizing ulcerative gingivitis in patients with HIV infection was 67% (CI95%: 52–82%) and 60% (CI95%: 45–74%), while a lower prevalence of linear gingivitis erythema was reported (11% (CI95%: 5–18%)) (Table 2).

| The pooled estimate of HIV related oral lesions and bacteria identified from clinical samples of HIV-infected cases with periodontal disease |
|---|
| **HIV related oral lesions** |
| Necrotizing ulcerative gingivitis | 60 | 45–74 | 84.36 | 44.68 | < 0.001 |
| Necrotizing ulcerative periodontitis | 67 | 52–82 | 88.87 | 71.88 | < 0.001 |
| Linear gingivitis erythema | 11 | 5–18 | | | < 0.001 |
| **Bacteria** |
| T. forsythia | 51 | 5–96 | 96.9 | 96.7 | < 0.001 |
| F. nucleatum | 50 | 21–78 | 73.29 | 73.29 | < 0.001 |
| P. intermedia | 50 | 32–68 | 92.19 | 92.19 | < 0.001 |
| P. micros | 44 | 25–65 | 89.49 | 89.49 | < 0.001 |
| C. rectus | 35 | 25–45 | 49 | 49 | < 0.001 |
| Fusobacterium spp. | 35 | 3–78 | 95.13 | 95.13 | < 0.001 |
| S. sanginosus | 27 | 7–53 | 91.87 | 91.87 | < 0.001 |
| S. intermedius | 25 | 3–57 | 92.6 | 92.6 | < 0.001 |
| P. gingivalis | 23 | 11–39 | 90.34 | 90.34 | < 0.001 |
| B. gracilis | 22 | 6–44 | 88.91 | 88.91 | < 0.001 |
| A. naeslundii | 22 | 11–35 | 70.78 | 70.78 | < 0.001 |
| A. viscosus | 19 | 13–25 | 9.23 | 9.23 | 0.57 |
| A. israelii | 16 | 2–40 | 88.45 | 88.45 | < 0.001 |
| E. corrodens | 16 | 7–27 | 67.88 | 67.88 | < 0.001 |
| A. actinomycetemcomitans | 15 | 8–24 | 79.13 | 79.13 | < 0.001 |

In this systematic review, more than 140 bacterial species were identified (supplementary file).

To calculate the pooled prevalence of associated groups of bacterial species of each complex (if the number of studies were more than 3), the cumulative meta-analysis was performed and the forest plots indicated separately.

In the red complex group, the pooled prevalence of Tannarella forsythia and Porphyromonas gingivalis was 51% (CI95%: 5–96%) and 23% (CI95%: 11–39%), respectively (Fig. 2).

In the green complex group, the pooled prevalence of A. actinomycetemcomitans and E. corrodens was 15% (CI95%: 8–24%) and 16% (CI95%: 7–27%), and the heterogeneity was very high, with $I^2$ equal to 93.29% (p-value < 0.001), and 67.88% (p-value = 0.01), respectively (Fig. 3).

In the orange complex group, the pooled prevalence of F. nucleatum and P. intermedia was 50% (CI95%: 21–78%) and 50% (CI95%: 32–68%), and the heterogeneity was very high, with $I^2$ equal to 92.29% and 92.19%, (p-value < 0.001), respectively. P. micros and C. gracilis showed a pooled prevalence of 44%
Therefore, designing and implementing of low-cost and easily available diagnostic and therapeutic methods for periodontal diseases is highly recommended.

Poor oral hygiene is a typical clinical finding in HIV patients. Despite the obvious need for oral health services, these patients are not provided with proper treatments have demonstrated promising results, and could be investigated further in prospective clinical trials.

Increased oral health knowledge and the discovery of different disease-causing pathogens contribute in the reduction of risk factors for oral diseases. Certain bacteria can function in a variety of ways, including passively occupying niches, restricting a periodontal pathogen's ability to bind to suitable tissue surfaces, improving a pathogen's vitality and growth, and enhancing a pathogen's ability to produce virulence factors. We found a high prevalence of red complex bacteria, particularly T. forsythia in HIV-infected patients with periodontal disease, which is basically in agreement with some previous studies.

Periodontal infections have been linked to an increased risk of HIV-1 reactivation in infected people, as well as the progression of acquired immunodeficiency syndrome (AIDS). Furthermore, it would suggest that preventing and treating periodontitis induced by red complex infection could effectively inhibit further clinical progression of AIDS.

The periodontal clinical parameters are closely linked to the occurrence of the red complex [44]. T. forsythia, P. gingivalis, and A. actinomycetemcomitans are strongly related to the onset of periodontal infection, disease development, and failed periodontal therapy [42, 45]. However, in this study, the pooled prevalence of T. forsythia was higher than P. gingivalis (23% (CI95%: 11–35%), 19% (CI95%: 13–25%), and 16% (CI95%: 2–40%), respectively (Fig. 6).

Based on the results of Egger's regression test, the publication bias among included studies could not be ignored (p-value < 0.0001).

**Discussion**

To our knowledge, this is the first systematic review and meta-analysis to determine the periodontal conditions and the distribution of associated groups of bacterial species in HIV-infected patients with periodontal disease.

In this study, high prevalence of T. forsythia (51% (CI95%: 5–96%)), F. nucleatum (50% (CI95%: 21–78%)), P. intermedia (50% (CI95%: 32–68%)), P. micros (44% (CI95%: 25–65%)), C. rectus (35% (CI95%: 25–45%)), and Fusobacterium spp. (35% (CI95%: 3–78%)) in HIV-infected patients with periodontal disease was found. Therefore, periodontal disease may be regarded as a polymicrobial infection.

We found a high prevalence of red complex bacteria, particularly T. forsythia in HIV-infected patients with periodontal disease, which is basically in agreement with some previous studies [41, 42].

Periodontal infections have been linked to an increased risk of HIV-1 reactivation in infected people, as well as the progression of acquired immunodeficiency syndrome (AIDS). Furthermore, it would suggest that preventing and treating periodontitis induced by red complex infection could effectively inhibit further clinical progression of AIDS [43].

The periodontal clinical parameters are closely linked to the occurrence of the red complex [44]. T. forsythia, P. gingivalis, and A. actinomycetemcomitans are strongly related to the onset of periodontal infection, disease development, and failed periodontal therapy [42, 45]. However, in this study, the pooled prevalence of T. forsythia was higher than P. gingivalis (23% (CI95%: 11–35%), and A. actinomycetemcomitans (15% (CI95%: 8–24%), respectively. Despite the fact that P. gingivalis is one of the most common microbial diseases in humans [43], it was found to have a lower prevalence in HIV-infected patients with periodontal disease (23% (CI95%: 11–39%)). Moreover, P. gingivalis can be present even though there is no disease, ruling out its position as an exogenous pathogen [46].

F. nucleatum has been shown to be a major marker for destructive periodontal disease in adult subjects. It is also likely to play a role in biofilm colonization and lead to the reducing conditions required for the emergence of oxygen-intolerant anaerobes [46]. It has also been mentioned that F. nucleatum promotes P. gingivalis invasion of host cells [47].

Moderately strong evidence has been accumulated for other bacteria isolated from subgingival microbiota, including P. intermedia, C. rectus, P. micros, F. nucleatum, and Eubacterium nodatum [14].

Bacterial organisms should be able to colonize the subgingival region and develop virulence factors that either directly (enzymes and toxins) or indirectly (antigens and activators) cause an individual's destructive inflammatory response and periodontal tissue injury. Proteases, alkali and acid phosphatases produced by microorganisms, fatty and organic acids, IgG- and IgA-proteases, chondroitinsulfatase, and toxic products including endotoxins, leukotxin, mucoproteptides of the bacterial wall, and end-products of metabolism are types of agents that directly damage periodontal tissues [42].

On the other hand, certain variations in cellular immunity can also promote the proliferation of virulent commensals or combinations of bacterial species, and possible symbiotic relationship between the species [48]. The role of all recognized periodontal bacteria in various periodontal diseases is unknown, but it is known that these bacteria can function in a variety of ways, including passively occupying niches, restricting a periodontal pathogen's ability to bind to suitable tissue surfaces, improving a pathogen's vitality and growth, and enhancing a pathogen's ability to produce virulence factors [42].

The pooled prevalence of S. sanguis was 27% (CI95%: 7–53%) and S. intermedius was 25% (CI95%: 3–57), which was higher than the pooled estimate of A. actinomycetemcomitans (15% (CI95%: 8–24)). It has been reported that S. sanguis develops hydrogen peroxide, which can destroy A. actinomycetemcomitans either directly or by host-enzyme amplification; therefore, some of the beneficial microorganisms which can produce anti-periodontal pathogen factors should not be ignored [45].

Increased oral health knowledge and the discovery of different disease-causing pathogens contribute in the reduction of risk factors for oral diseases. Certain treatments have demonstrated promising results, and could be investigated further in prospective clinical trials [16].

Poor oral hygiene is a typical clinical finding in HIV patients. Despite the obvious need for oral health services, these patients are not provided with proper dental care due to the HIV-related stigma that exists in many settings, putting them at a greater risk for developing oral and systemic diseases [49, 50]. Therefore, designing and implementing of low-cost and easily available diagnostic and therapeutic methods for periodontal diseases is highly recommended [51].
This study has several limitations. The stage of HIV infection and its progression was not mentioned in the studies and this can affect the final evaluation. There are evident gaps in knowledge in relation to periodontal diseases in patients with HIV in some countries in Africa, Asia and Europe. Data heterogeneity within these studies can be explained by differences in detection strategies, genetic history, behavioral and/or environmental factors.

**Conclusion**

In conclusion, our study demonstrated that the prevalence of red and orange complex of bacteria in HIV patients with periodontal disease is relatively high. This information will eventually lead to the implementation of innovative and/or more effective preventive and therapeutic methods, as well as diagnostic applications in periodontics. Early diagnosis, efficient periodontal management, proper oral hygiene maintenance is the key for the treatment of periodontal manifestation of HIV.

**Abbreviations**

HIV: human immunodeficiency virus

PCR: polymerase chain reaction

AIDS: acquired immunodeficiency syndrome

**Declarations**

**Ethics approval and consent to participate**

Not applicable.

**Consent for publication**

Not applicable.

**Availability of data and materials**

All data obtained

**Competing interests**

The authors declare that they have no competing interests.

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**Authors’ contributions**

SM: involved in designing, interpretations and writing of the manuscript. NKV: involved in gathering and grouping the articles. BH and MTA revised the manuscript. All authors read and approved the final manuscript.

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**Figures**
Figure 1
Summary of the literature search and study selection

![Diagram showing the literature search process](image)

Figure 2
Forest plot analysis of the prevalence of bacterial species of red complex group in HIV-infected cases with periodontal disease (A= P. gingivalis, B= T. forsythia)
Figure 3

Forest plot analysis of the prevalence of bacterial species of green complex group in HIV-infected cases with periodontal disease (A= Actinobacillus actinomyctetemcomitans, B= Eikenella corrodens)

Figure 4
Forest plot analysis of the prevalence of bacterial species of orange complex group in HIV-infected cases with periodontal disease (A= Campylobacter rectus, B= Fusobacterium nucleatum, C= Peptostreptococcus micros, D= Prevotella intermedia, E= Campylobacter gracilis, F= Fusobacterium spp.)

Figure 5

Forest plot analysis of the prevalence of bacterial species of yellow complex group in HIV-infected cases with periodontal disease (A= Streptococcus intermedius, B= Streptococcus sanguinis)

Figure 6

Forest plot analysis of the prevalence of bacterial species of blue complex group in HIV-infected cases with periodontal disease (A= Actinomyces israelii, B= Actinomyces naeslundii, C= Actinomyces viscosus)

Supplementary Files

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