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HIV-infection and periodontal diseases: an overview of the post-HAART era

Running head:HIV-infection and periodontal diseases

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ABSTRACT
HIV infection remains a global health problem of unprecedented dimensions, although the development of highly active antiretroviral therapy (HAART) has significantly modified the course of HIV disease into a manageable chronic disease with longer survival and improved quality of life in HIV-infected subjects. Among the HIV-associated infections, oral lesions have been recognized as prominent features since the beginning of the epidemic and continue to be important. Periodontal diseases strongly associated with HIV infection are classified as Linear Gingival Erythema (LGE), Necrotizing Ulcerative Gingivitis (NUG), and Necrotizing Ulcerative Periodontitis (NUP), and are included among the cardinal oral lesions. Although oral candidiasis appears to be the infection more significantly decreased after the introduction of HAART, the current literature suggests that the prevalence and course of periodontal lesions have also been modified. Higher prevalence of opportunistic microorganisms has been frequently detected in the subgingival flora of HIV-infected individuals, probably due to the immune status of those patients, as colonization and overgrowth of atypical pathogenic species is facilitated by immunosuppression. Additional research is required regarding biological issues such as the role of oral immune factors and periodontal disease in the persistency of HIV infection, the possibility of oral transmission and the re-emerging of HIV infection.
INTRODUCTION

HIV infection remains a global health problem of unprecedented dimensions. Unknown 27 years ago, HIV has already caused an estimated 25 million deaths worldwide and has generated profound demographic changes in the most heavily affected countries. While the percentage of people living with HIV has stabilized since 2000, the overall number of people living with HIV has steadily increased, as new infections occur each year, HIV treatments extend life, and in addition, new infections still outnumber AIDS deaths.

The development of highly active antiretroviral therapy (HAART) especially after 1995, has significantly modified the course of HIV disease, at least in the industrialized world, into a manageable chronic disease with longer survival and improved quality of life in HIV-infected subjects.

HAART generally consists of a dual nucleoside analogue reverse transcriptase inhibitor (NRTI) “backbone” and a third or “cornerstone” drug, such as a nonnucleoside inhibitor (NNRTI) or a protease inhibitor (PI), usually a “boosted” one. The use of a NNRTI as a third drug is less potent and therefore, in most settings not a preferred option, and it is recommended that baseline resistance testing should guide the specific regimen design.

HAART increases CD4+ cell count, decreases levels of HIV RNA, and extends AIDS-free survival, at least in the shorter term. Moreover, HIV suppression with antiretroviral therapy may decrease inflammation and immune activation thought to contribute to higher rates of cardiovascular and other co-morbidities reported in HIV-infected cohorts.

Eradication of HIV infection cannot be achieved with available antiretroviral regimens. This is mainly attributed to the fact that the pool of latently infected CD4+ T-cells is established during the earliest stages of acute HIV infection and persists with a long half-life, even with prolonged suppression of plasma viremia.

It is known that HAART is associated with significant problems, including toxic side effects, development of virological resistance and great financial expense. Up to half of patients on antiretroviral therapy may experience adverse effects of the medications (Fellay et al, 2001). Common side-
effects vary depending on the drug regimen, but can include hypersensitivity, lactic acidosis, increases in blood lipids, bleeding events, anaemia, neuropathy, lipodystrophy, and pancreatitis (UNAIDS, 2008). While most side-effects diminish over time, some can be life-threatening, underscoring the importance of careful patient monitoring (UNAIDS, 2008).

Due to the intensity of combined antiretroviral treatment and widespread use of HAART, the incidence of many AIDS-related opportunistic infections in patients with advanced HIV infection has significantly decreased but despite dramatic declines in the incidence of opportunistic infections in many resource-rich nations, opportunistic infections remain a leading cause of hospitalization and death for persons with HIV infection.

Among the HIV-associated infections, oral lesions have been recognized as prominent features of HIV infection since the beginning of the epidemic and continue to be important.

Purpose of the present review is to overview the features, prevalence, bacteriology and host response characteristics of periodontal infections in HIV patients, especially as modified during the HAART era.

FEATURES OF PERIODONTAL LESIONS IN HIV INFECTED PATIENTS

HIV infection in adults is linked with the expression of various types of periodontal lesions, which include specific forms of gingivitis and necrotizing periodontal diseases, as well as with possible exacerbation of preexisting periodontal disease (Winkler et al, 1992; Robinson et al, 2002; EC-Clearinghouse, 1993). Periodontal diseases strongly associated with HIV infection are classified as Linear Gingivitis Erythema (LGE), Necrotizing Ulcerative Gingivitis (NUG), and Necrotizing Ulcerative Periodontitis (NUP) and are included among the seven cardinal oral lesions, which have been identified and recognized internationally, as follows: oral candidiasis, oral hairy leukoplakia, Kaposi sarcoma, LGE, NUG, NUP and non-Hodgkin lymphoma (Armitage, 1999;EC-Clearinghouse, 1993; Coogan et al, 2005).

The criteria for diagnosis of HIV-related oral lesions are not well defined in children. Orofacial manifestations have been categorised into three
groups: those less commonly, commonly, and strongly but rarely associated with pediatric HIV infection. LGE has been reported between those commonly associated (Ramos-Gomez et al, 1999; Coogan et al, 2005).

Together with other oral infections, HIV-associated periodontal diseases are regarded as serious complications of HIV infection and have an important diagnostic and prognostic value (EC-Clearinghouse, 1993; Glick et al, 1994a; Shangase et al, 2004; Coogan et al, 2005). They belong among the earliest clinical features of the infection and could predict progression of HIV disease to AIDS. (Robinson et al, 2002; Coogan et al, 2005). It should also be mentioned that for patients on antiretroviral therapy, HIV-related oral lesions in general, may suggest possible treatment failure as will be further discussed in the present review. (Margiotta et al, 1999; Ramirez-Amador et al, 2007; Gaitan-Cepeda et al, 2005; Eyeson et al, 2002; Flint et al, 2006). However, HIV-associated periodontal infections are less common than oral candidiasis and oral hairy leukoplakia and thus not included as criteria in the Centers for Disease Control (CDC) classification (CDC, 1992). HIV-associated periodontal infections have characteristic clinical appearance which has been well described (Winkler et al, 1992; Greenspan & Greenspan, 2008; Reznik, 2006; Murray 1994).

**Linear Gingival Erythema (LGE)** is a form of gingivitis characterized by a distinct fiery red band along the margin of the gingiva (EC-Clearinghouse, 1994). It is usually associated with anterior teeth, commonly extended to the posterior teeth, accompanied in some cases by bleeding and discomfort (Reznik, 2006). In other cases it presents as petechia-like patches on attached or free gingiva. Currently, *Candida* species have been implicated to the aetiopathology of LGE as well as other HIV-associated periodontal pathology.

**Necrotizing Ulcerative Gingivitis (NUG)** is characterized by rapid onset and acute painful inflammation of gingiva with rapid destruction of soft tissues, while **Necrotizing Ulcerative Periodontitis (NUP)** is escorted by bleeding, sharp pain, ulcerated gingival papillae, rapid and extensive soft tissue necrosis and advanced loss of periodontal attachment, frequently
leading to bone exposure (Murray, 1994; Greenspan & Greenspan, 2008; Reznik, 2006).

The rapid establishment and course of necrotizing forms of periodontal disease in patients with HIV/AIDS infection, contrary to the gradually progressing periodontal disease in adults in the general population has been outlined in many studies and had not been reported before AIDS epidemic. (Murray et al, 1989; Murray, 1994; Barr et al, 1992; Yeung et al, 1993a) HAART appears to have profoundly influenced the prevalence, severity and course of periodontal lesions as will be further discussed in the next section of the present review (Parveen et al, 2007).

Risk factors for periodontal disease in HIV-infected individuals besides the general factors of age, smoking, preexisting gingivitis, poor oral hygiene and poor diet, include counts of CD4+ cells (Glick et al, 1994b), viral load and specific species of microbiota.

Oral opportunistic infections, mainly oral candidiasis (OC) and oral hairy leukoplakia, (OHL) have been associated with CD4+ count in both the pre-HAART and the HAART era in several studies. Based on these findings, low CD4+ counts are now considered as the main risk factor associated with the development of oral lesions and especially of oral candidiasis (Margiotta et al, 1999).

Regarding periodontal disease, there is little and unclear data, especially during the HAART era. In 1994, Glick and coworkers have reported an association between NUP and CD4+ count below 200 cells/mm³ in HIV-infected patients and suggested that NUP may be a good marker of immune deterioration. The same authors reported in another 1994 study a positive predictive value (95.1%) for periodontal diseases, which was higher than the values reported for oral hairy leukoplakia (70.1%) and oral candidiasis (69.9%) (Glick et al, 1994a). High positive predictive values have also been reported for necrotizing ulcerative periodontitis (80%) and a moderate (54.5%) one for LGE. (Begg et al, 1996; Patton 2000). In agreement with the previous studies, Margiota et al (1999) reported that NUP and NUG were significantly associated with CD4+ counts lower than 200 cells/mm³ in a cohort of Italian subjects infected with HIV. In contrast to these reports, Schuman et al, in a study conducted in a US population, after the introduction of HAART, reported
that LGE and NUG were not related to HIV serostatus or CD4+ lymphocyte count (Schuman et al, 1998).

Contradictory results have also been reported in a 2000 study by Patton. The author reported that the viral load was significantly related to the presence of strongly HIV-associated oral lesions (Patton, 2000) but that among periodontal lesions, only LGE has a significant predictive value (70%) for immune suppression when measured by CD4 cell counts below 200 cells/mm$^3$. In the same study, the predictive value for necrotizing ulcerative diseases was lower (47.4%) compared to the values reported previously, a finding which could be attributed to the improved antiretroviral management of HIV disease of the population under investigation. A significant correlation between necrotizing ulcerative diseases and CD4+ T cells number below 200/mm$^3$ was also reported in a study from South Africa, with a positive predictive value of 69.6% for HIV infection in otherwise asymptomatic subjects (Shangase et al, 2004).

As HIV infection gradually becomes a chronic disease, the features and course of chronic periodontal disease in HIV infected patients require more extensive investigation. The “conventional” periodontal diseases in the HAART era have been mentioned in very few studies. (Kroidl et al, 2005; Alpagot et al, 2004). Conventional periodontitis progresses gradually, causing no or minimal pain or discomfort, being thus undiagnosed, until considerable tissue loss occurs. (Alpagot et al, 2004). Generally, periodontal inflammation seems to be more severe in cases where CD4+ counts are low (Kroidl et al, 2005) and research nowadays is focused on the accelerated rate with which chronic adult periodontitis presents in seropositive patients. (Lamster et al, 1997)

Overall, findings from the above mentioned studies suggest the value of the identification of periodontal disease, even in patients on HAART therapy, in screening the immune suppression, both in diagnosed and undiagnosed HIV infection in adults.

The relation between oral lesions in general and immune and virologic status is still not well established in children. No association was found between the prevalence of oral lesions and immunological status or viral load in children, while there are no data for periodontal diseases (Gaitan-Cepeda et al, 2002).
PREVALENCE OF PERIODONTAL DISEASES IN HIV-INFECTED INDIVIDUALS

The prevalence of periodontal diseases in HIV-infected individuals remains a controversial issue. Data from relevant studies vary widely due to several factors. Many studies refer to HIV-infected individuals, without mentioning the stage of AIDS or the use and the type of antiretroviral therapy, the use of protease inhibitors or not, as well as the use of adjunctive antimicrobials (antibiotics, antifungals). Factors which influence the prevalence of periodontal disease such as age, immune system competence, smoking habits, oral hygiene level, are not always taken into consideration (Barr et al, 1992; Alpagot et al, 2004). The type of lesion is often not mentioned, while there is some confusion with the terminology. Additionally, it is usually unclear whether diagnosis is made by trained examiners or if universally accepted criteria are used. (EC-Clearinghouse, 1993).

Introduction of antiretroviral therapies and mainly the HAART in 1995 has changed the epidemiology of opportunistic infections in HIV-infected patients (Holtzer et al, 1998; Paul et al, 2002), and has decreased the mortality and morbidity of HIV infection (Pallela et al, 1998). A significant decrease of the overall prevalence of oral lesions from 47-85%, before the introduction of HAART, to 32-46%, post-HAART has been reported (Schmidt-Westhausen et al, 2000; Patton et al, 2000; Gaitan-Cepeda et al, 2008). Oral manifestations significantly decreased in patients on dual and triple therapy in comparison with patients on monotherapy and those on no antiretroviral therapy (Tappuni & Fleming, 2001). Moreover, a lower prevalence (32%) of oral lesions was found in patients on HAART, including efavirenz, compared to patients on HAART including a PI (63%). (Aquino-García et al, 2008). Recently, in a retrospective epidemiological analysis performed in Brazil from 1988 to 2004, HAART was found to be associated with significantly lower prevalence of oral manifestations (Ferreira et al, 2007). Among oral manifestations, oral candidiasis appears to be the lesion most significantly decreased after the introduction of HAART as shown by several studies.
Regarding the prevalence of HIV-associated periodontal diseases in the pre-HAART era, data vary widely both in developed and developing countries. Indicatively, reported rates of prevalence for LGE range between 9 and 50%, for NUG between 11 and 25% and for NUP between 1 and 18% (Laskaris et al, 1992; Masouredis et al, 1992; Tukutuku et al, 1990; Glick et al, 1994b).

After the introduction of HAART, findings from relevant studies also vary and cannot be compared, partly because of the different types of therapy received by participating patients. Data from representative studies in developed and developing countries concerning adult and pediatric populations are shown in Table 1. The effect of HAART on prevalence of HIV-associated periodontal disease is shown in Table 2. It appears that HAART is associated with a lower prevalence of HIV-associated periodontal disease in adults. The difference between pre- and post-HAART in most of the studies was found to be statistically significant.

On the contrary, HAART does not appear to significantly affect the prevalence of periodontal disease in children (Flanagan et al, 2000; Khongkunthian et al, 2001; Parveen et al, 2007).

BACTERIA ASSOCIATED WITH PERIODONTAL DISEASE IN HIV-INFECTED PATIENTS

The development of periodontal disease is generally accepted to depend on the interaction between the host response and the resident oral microbiota, which constitutes a complex dynamic biofilm of multiple microbial communities. Considering that it is a microbial community disease, a distinct microbial profile in these patients, if identified, could assist our understanding of the aetiopathological mechanisms (Kuboniva et al, 2009).

Results from studies on the subgingival microbiota in HIV-infected individuals are quite diverse. Some studies have shown that the microbiota is similar in HIV-positive and HIV-negative patients with periodontitis. (Zambon et al, 1990; Brady et al, 1996; Nakou et al, 1997; Tsang & Samaranayake, 2001; Teanpaisan et al, 2001). Other studies have shown a higher prevalence of putative periodontal pathogens such
as *Aggregatibacter actinomycetemcomitans*, *Fusobacterium nucleatum*, *Porphyromonas gingivalis*, *Prevotella intermedia*, *Tannerella forsythia* and *Treponema denticola*, in HIV-positive patients, in comparison to HIV-negative patients, (Murray *et al.*, 1989; Cross & Smith, 1995; Scully *et al.*, 1999; Alpagot *et al.*, 2004), while there are studies that present the exact opposite, i.e. that putative pathogens are less prevalent in HIV-positive patients. (Tenebaum *et al.*, 1997; Paster *et al.*, 2002; Patel *et al.*, 2003; Gonçalves *et al.*, 2007; Botero *et al.*, 2007)


Data from studies in the HAART era, which apply culture-independent molecular techniques are displayed in Table 3. These techniques as well as other approaches such as proteomics and the study of biofilms will allow an extensive investigation of the microbiota in HIV-infected individuals and the pathogenetic role of “unusual” species.
As shown in Table 3, bacteria that are not usually linked with periodontal disease, such as *Enterococcus faecalis*, *Acinetobacter baumanii*, *Pseudomonas aeruginosa*, *Campylobacter pylori*, were frequently detected in HIV-infected patients, in most of the studies (Gonçalves et al., 2004; Gonçalves et al., 2007; Aas et al., 2007; Gonçalves et al., 2009). Putative periodontopathogenic bacteria, such as *T. forsythia*, *P. gingivalis*, *P. intermedia*, were associated with periodontitis (Alpagot et al., 2004; Goncalves et al., 2004) in HIV-positive patients and were considered as risk factors (Gonçalves et al., 2004), whereas in many studies the prevalence of these classical periodontopathogenic bacteria was found smaller in HIV-positive than in HIV-negative subjects (Paster et al., 2002; Patel et al., 2003; Goncalves et al., 2007; Aas et al., 2007; Gonçalves et al., 2009). Possibly, pathogens such as *P. gingivalis*, that are commonly associated with periodontal disease, do not consist the principle pathogenic factor, while both atypical oral organisms and typical periodontopathogenic bacteria influenced the pathogenesis of periodontitis in HIV-infected patients.

Moreover the recognition of different microbial profiles in the subgingival area of these patients may be significant. More complex microbial profiles were demonstrated in diseased sites than in healthy periodontium in HIV-infected patients (Paster et al., 2002), while certain combinations of microbes were detected exclusively in HIV-infected individuals. These specific “complexes” may be responsible for chronic periodontitis in this group of patients (Patel et al., 2003) since it is known that changes in the humoral and cellular immunity can affect the establishment and growth of pathogens and the resultant combination of microbes in the subgingival pockets of HIV-positive subjects.

**HIV - HOST INTERACTION IN THE PERIODONTAL ENVIRONMENT**

Periodontal disease may result from a loss of regulation of immune responses to oral microbiota (Jotwani et al., 2001).

However, in HIV-infected patients, pathogenetic mechanisms involved in immune responses and in tolerance at the oral mucosa in health and
inflammation remain unclear and studies are required in order to define the interaction between the immuno-compromised host and microbes. In general, it is poorly understood how HIV or HIV-infected cells affect oral mucosal epithelium and influence innate and acquired immunity, and how the altered local or systemic immune response of these patients contributes to the pathogenesis of periodontal disease (Alpagot et al., 2004; Challacombe & Naglik, 2006). Subgingival biofilm microorganisms have the capacity to activate inflammatory cells including polymononuclears (PMN), lymphocytes and macrophages, which produce inflammatory mediators, and subsequently induce MMPs and their inhibitors production. It is known that, in periodontal disease, most of the tissue damage is caused by host response (Lamster & Novak, 1992; Van Dyke & Serhan, 2003). In HIV-infected patients with periodontitis an increase of inflammatory mediators has also been detected. Alpagot et al. (2003) reported that the higher GCF levels of pro-inflammatory cytokine interferon-γ (IFN-γ) is associated with the periodontal disease progression in HIV-positive patients similarly to reports for non-HIV individuals with chronic periodontitis (Dutzan et al., 2009). High levels of significant mediators of inflammation involved in the pathogenesis of periodontal disease such as prostaglandin E₂ (PGE₂), (Leibur et al., 1999), transforming growth factor-beta (TGF-b1), matrix metalloproteinase -1 (MMP-1) were also found in gingival crevicular fluid (GCF) of periodontitis sites in HIV/AIDS patients and could serve as prognostic factors for the progression of tissue destruction in HIV-infected adults.

After the introduction of HAART, HIV-infection is considered as a chronic infection characterized by persistency of the virus in the infected host, and, despite the undetectable plasma levels of the HIV, cessation of therapy results in viral reappearance in circulation. (Chun et al., 1999). Persistency of the virus is possibly due to a very low level of replication and continuous secretion of virus by long-lived infected cells, undetectable by conventional assays, or HIV latency and silencing (reviewed in Mok & Lever, 2008; Williams & Greene, 2007; Dahl, 2009; Colin & Van Lint, 2009). The oral cavity seems to be an important reservoir of HIV-1 as the virus is found in saliva, GCF, and oral epithelial cells. To date, HIV-1
reservoirs have been identified in the reproductive tract, breast, lung, brain, and gastrointestinal tract (Schrager & D’Souza, 1998). Therefore, the role of oral immune factors and periodontal disease in the persistency of HIV infection, the possibility of oral transmission and the re-emerging of HIV infection, should be investigated.

The oral cavity has rarely been reported as a site of HIV transmission. (Klein et al, 1988; Cohen et al, 2000; Jotwani et al, 2004; Cutler & Jotwani, 2006). In saliva, HIV is present at very low levels (Spear et al, 2005) possibly due to low levels of macrophages and lymphocytes and to inhibitory factors in the saliva of HIV-infected patients. A number of host defense factors are present in the saliva including, the hypotonic nature of saliva (Baron et al, 1999), endogenous inhibitors of HIV, particularly secretory leukocyte protease inhibitor (SLPI) that blocks HIV infection in several cell-culture systems (Shugars et al, 1999), salivary mucins MUC5B and MUC7 which trap and aggregate the virus and can inhibit it by 100% (Habte et al, 2006), sIgA antibodies which neutralize HIV, antimicrobial peptides such as a- and b-defensins (Nakashima et al, 1993; Jotwani et al, 2004; Zhang et al, 2002; Mackewicz et al, 2003; Quinones-Mateu et al, 2003), histatins (Groot et al, 2006) and lactoferrin. It seems that the inhibitory factors may act synergistically (Bolscher et al, 2002).

Recently, HIV-specific antibody dependent cell-mediated cytotoxicity (ADCC) activity, an important part of cell mediated immunity, was demonstrated in saliva. (Kim et al, 2006). More over, studying the possible effect of microbial components on HIV, inhibition of virus entry by a binding domain (HGP44) of P. gingivalis was demonstrated (Xie et al, 2006).

HAART appears not to adversely affect inherent salivary oral host defense in HIV- patients with mild to moderate immune dysfunction. (Lin et al, 2006).

In many studies RNA (Spear et al, 2005; Shugars et al, 2001) and DNA of HIV have been detected in saliva (Goto et al, 1991; Yeung et al, 1993 b; Levy & Greenspan, 1988). Possible sources of infectious virions and proviral HIV-1 DNA in saliva include serum and HIV-containing macrophages and lymphocytes from GCF, which is increased during periodontal infection. In most studies, HIV is present in patients’ saliva at
very low levels, lower than blood. However, Shugars et al (2001) reported that 5 out of 67 HIV-positive subjects expressed higher levels in saliva than blood and also had more advanced HIV-associated periodontal disease, suggesting that HIV can be produced locally in the oral cavity and may be influenced by oral tissue inflammation.

Although, relatively little and contradictory information on HIV excretion patterns in GCF is available in the literature, however the presence of periodontitis may be a contributing factor. Proviral HIV-1 DNA, viral RNA and p24 antigen has been detected in up to 50% of GCF samples from HIV-infected subjects with periodontitis (Sanz et al, 1996; Chebbi et al, 1997; Maticic et al, 2000) while in some reports the virus or the p24 antigen have not been detected in GCF samples (O'Shea et al, 1990; Chebbi et al, 1997). These results suggest that infected mononuclear cells present in GCF could be a potential source of HIV-1.

More over it has been demonstrated that HIV-1 infects and replicates in vitro in keratinocytes isolated from normal oral mucosa (Moore et al., 2003) as well as in vivo in oral mucosal epithelial cells (Rodríguez-Iñigo et al, 2005), which could represent a reservoir for the virus, although this is not a universal finding (Quinones-Mateu et al, 2003).

Regarding gingival tissues, studies have shown that dendritic cells (DCs) and macrophages in gingiva express C-type lectin receptors DC-SIGN (Dendritic-cell-specific ICAM-3-grabbing non-integrins, CD209), MR mannose receptors, CD206), and Langerin (CD 207), which are targets for HIV and other microbes (van Kooyk et al, 2004). Using these receptors HIV could advance by down-regulating intracellular signalling and effective immune response and cause chronic infections that persist for life. However, recent studies showed that, during health, in lamina propria cells usually express the DC-SIGN receptors and mannose receptors, but very few of the cells present the CCR5 on their surface and none present the CXCR4 HIV co-receptors. (Jotwani et al, 2004). In the epithelium, cells do not express CD4 but instead glycosphingolipid-galactosylceramide (GalCer) and Langerin receptors (Jotvani et al, 2004; Challacombe & Naglik, 2006). HIV co-receptors CCR5 and/or CXCR4 were found closer to
the basal layer far from the surface-associated layers (Jotwani et al., 2004). So, in health, low expression of CCR5, and restricted expression of CXCR4 in oral mucosa suggest an unfavourable environment for the virus and this may play a significant role in the resistance of gingiva to infection with HIV-1. (Jotwani et al., 2004; Jameson et al., 2002).

In the presence of inflammation, there is evidence of up-regulation of various receptors, including HIV receptors, on the surface of oral epithelium, and the epithelium may become more permeable. (Challacombe & Naglik, 2006). Moreover, in patients with chronic periodontitis there is a significant increase in the number of dermal dendritic cells (DDCs) expressing DC-SIGN receptors and a trend for increased mannose receptors identified in the inflamed gingival lamina propria (Jotwani et al., 2004). It is suggested that HIV uses both the above C-type lectin receptors to attach to different dendritic cells subsets (Turville et al., 2001). It has been shown that dendritic cells, DDCs and LCs, form immune conjugates with CD4+ T cells in the lamina propria (Jotwani & Cutler, 2003) and under these conditions it is possible for dendritic cells to transfer HIV in the T-lymphocytes in the inflamed gingival lamina propria.

It has also been reported that in the presence of oral lesions and periodontal disease there is a continuous shedding of HIV-infected blood into the oral cavity from mucosal and gingival lesions in HIV-infected patients, resulting in the detectable presence of the HIV at a high frequency in the oral cavity, with an increased possibility for HIV transmission. (Bolscher et al., 2002).

According to the above mentioned findings, inflammation is considered as a risk factor for HIV infection although defensive mechanisms. However, during chronic periodontitis there is a ten fold increase in α-defensin-1 (Jotwani et al., 2004), known to have potent anti-HIV activity, while HBD2 and HBD3 are also up-regulated during inflammation. (Dale et al., 2002; Quiñones-Mateu et al., 2003).

Notably, co-infection with the endogenous pathogen *P. gingivalis* in vitro, revealed an upregulation of CCR5 receptors of oral keratinocytes, which are not usually expressed in health, through LPS stimulating the Toll-like
receptors and gingipains. The R5-type HIV-1 co-receptors CCR5, is the target of R5-type HIV-1 associated with most primary systemic infections. Thus infection with *P. gingivalis* could increase transmission of HIV infection through the oral cavity. (Giacaman *et al*, 2007).

In addition, periodontal diseases and other oral opportunistic infections in HIV-infected patients could influence HIV reactivation. They represent chronic infections and associated inflammation, with a possibility of latently infected host cell stimulation. Transcription of the HIV-provirus is dependent on the interaction between cellular and viral transcription factors (reviewed in Mok & Lever, 2008; Williams & Greene, 2007). The mechanisms involved in the reactivation of latency remain to be elucidated, however a number of factors such as different cellular environments and LTR (Long Terminal Repeat) variations in different HIV-1 isolates have been proposed that may play a role (Rohr *et al*, 2003).

In vitro exposure of latently infected resting CD4+ cells to a number of cytokines, bacterial antigens, mitogens or monoclonal antibodies directed to T-cell receptors CD3 can induce viral replication, but these findings have not been reproduced in vivo. It is also suggested that in the progress of an opportunistic infection microorganisms or their components, such as LPS, stimulate and activate Toll-like receptors (TLRs), and subsequently NFκB and other transcription factors. In addition, transcription factors can be activated indirectly by the large amounts of pro-inflammatory cytokines and chemokines which are produced during infection (reviewed in González *et al*, 2009). Regarding periodontal pathogens, it has recently been shown that *P. gingivalis* produces high concentrations of butyric acids causing histone acetylation which is involved in repressing HIV transcription and results in virus persistency (Imai *et al*, 2009). The results of the study and the above mentioned possible mechanism of reactivation of HIV, suggest that periodontal disease could act as a risk factor for HIV reactivation in infected individuals and might contribute to the systemic dissemination of the virus.

This hypothesis could be the biological basis linking a chronic infection such as periodontitis to the “immune reconstitution inflammatory syndrome” (IRIS) (Gaitan-Cepeda *et al*, 2008) a situation in which, pre-existing asymptomatic or mildly symptomatic infections or inflammatory
conditions paradoxically worsen with a substantial increase in inflammation during the initial months of host immune reconstitution, as a result of HAART (Feller et al, 2007; Murdoch et al, 2007).

Opportunistic oral infections have not yet been characterized as IRIS, but Nicolatou-Galitis et al (2004) and Greenspan et al (2004) have reported a lack of reduction of oral lesions despite a higher mean CD4+ count and a lower mean viral load, with HAART treatment. Recently, Gaitan-Cepeda et al (2008) found that HIV+/AIDS patients under HAART who present CD4+ lymphocyte counts of >500 cells /ml and undetectable viral loads can suffer opportunistic oral HIV-associated infections. IRIS may lead to increased frequency of periodontal disease as the presence of latent infection(s) has been considered as a risk factor for the syndrome (Crum-Cianflone 2006; Murdoch et al, 2007). However, it is not known if the appearance of these lesions is the consequence of a qualitative failure of immune cell response, or examples of de novo infections.

CONCLUSIONS
The introduction of highly active antiretroviral therapy (HAART) has significantly modified the course of HIV disease, at least in the industrialized world, into a manageable chronic disease with longer survival and improved quality of life in HIV-infected subjects. Oral lesions are among the clinical manifestations whose prevalence, severity and course have been affected by this treatment. Although oral candidiasis appears to be the infection more significantly decreased after the introduction of HAART, the current literature suggests that the prevalence and course of periodontal lesions have also been modified. Additional research is required regarding biological issues such as the role of oral immune factors and periodontal disease in the persistency of HIV infection, the possibility of oral transmission and the re-emerging of HIV infection.
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defensin 1, 2, and 3 to the anti-HIV-1 activity of CD8 antiviral factor. 

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### Table 1 Prevalence of HIV-associated and conventional periodontal disease in the HAART era

<table>
<thead>
<tr>
<th>Authors</th>
<th>Country</th>
<th>Subject sample</th>
<th>HIV associated periodontal disease</th>
<th>Conventional disease</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>LGE</td>
<td>NUG</td>
</tr>
<tr>
<td><strong>ADULTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schuman et al (1998)</td>
<td>USA</td>
<td>867 HIV+</td>
<td>13.6%</td>
<td>11.6%</td>
</tr>
<tr>
<td>Patton et al (2000)</td>
<td>USA</td>
<td>606 HIV+</td>
<td>3.3%</td>
<td></td>
</tr>
<tr>
<td>Ceballos et al (2000)</td>
<td>Spain</td>
<td>154 HIV+</td>
<td>0.6%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Eyeson et al (2002)</td>
<td>UK</td>
<td>203 HIV+</td>
<td>6%</td>
<td>8%</td>
</tr>
<tr>
<td>Reichart et al (2003)</td>
<td>Thailand</td>
<td>87 HIV+</td>
<td>Thai 8%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cambodia</td>
<td>63 HIV+</td>
<td>Cambodian 0%</td>
<td></td>
</tr>
<tr>
<td>Pinheiro et al (2004)</td>
<td>Brazil</td>
<td>161 HIV+</td>
<td>9%</td>
<td>NUG/NUP=3.6%</td>
</tr>
<tr>
<td>Kroidl et al (2005)</td>
<td>Germany</td>
<td>139 HIV/AIDS</td>
<td>12%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>100% on HAART</td>
<td></td>
<td>Periodontal disease 4.4%</td>
</tr>
<tr>
<td>Bravo et al (2006)</td>
<td>Venezuela</td>
<td>75 HIV+</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>63% on ART</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>52% on HAART</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ranganathan et al, (2004)</td>
<td>India</td>
<td>774 HIV+</td>
<td>72%</td>
<td>33%</td>
</tr>
<tr>
<td>Gaitan et al (2008)</td>
<td>Spain</td>
<td>86 HIV/AIDS</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Brady et al (1996)</td>
<td>USA</td>
<td>25 HIV/AIDS</td>
<td>84%</td>
<td>52%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100% on HAART</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceballos et al (1996)</td>
<td>Spain</td>
<td>396 HIV+</td>
<td>Periodontal disease 78.3%</td>
<td></td>
</tr>
<tr>
<td>Alpagot et al (2004)</td>
<td>USA</td>
<td>152 HIV+ patients</td>
<td>19%</td>
<td>73%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>63% on HAART</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CHILDREN</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Santos et al (2001)</td>
<td>Brazil</td>
<td>80 HIV+</td>
<td>17.5%</td>
<td></td>
</tr>
<tr>
<td>Khongkunthian et al, (2001)</td>
<td>Thailand</td>
<td>45 HIV+</td>
<td>2.2%</td>
<td></td>
</tr>
<tr>
<td>Reichart et al (2003)</td>
<td>Thailand</td>
<td>45 HIV+</td>
<td>2.2%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>33% on ART</td>
<td></td>
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</tr>
</tbody>
</table>

ART=Any type of antiretroviral therapy, HAART=Highly active antiretroviral therapy, HAART/ PI=Highly active antiretroviral therapy with protease inhibitor as the third drug, GING=Gingivitis, PERIO=Periodontitis, LGE= linear gingival erythema, NUG=necrotizing ulcerative gingivitis, NUP= necrotizing ulcerative periodontitis
<table>
<thead>
<tr>
<th>Authors</th>
<th>Country</th>
<th>Subject sample</th>
<th>HIV-associated periodontal disease</th>
<th>Effect of therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aguirre et al.</td>
<td>Spain</td>
<td>72 HIV+ patients CD4+ &lt; 499 on HAART</td>
<td>LGE 48.6% NUG 31.9%</td>
<td>LGE are down, NUG has remained steady in comparison to two earlier studies from the Spain</td>
</tr>
<tr>
<td>Schmidt et al.</td>
<td>Germany</td>
<td>103 HIV+ patients one month on HAART</td>
<td>LGE 1.9% NUG 2.9%</td>
<td>After 6 months of therapy, from 61 re-examined patients only one had NUP. Significant decrease of NUP (p=0.03)</td>
</tr>
<tr>
<td>Patton et al.</td>
<td>USA</td>
<td>Pre-HAART, 271 HIV+ 8% on HAART</td>
<td>LGE 4.8% NUG 1.7%</td>
<td>Significant decrease of NUP (p=0.03)</td>
</tr>
<tr>
<td>Ceballos et al.</td>
<td>Spain</td>
<td>154 HIV/AIDS on HAART/PI for at least 6 months</td>
<td>LGE 0.6% NUG 0.6%</td>
<td>More than 30% decrease of HIV associated periodontal disease in comparison with historical controls</td>
</tr>
<tr>
<td>Tappuni and Fleming</td>
<td>UK</td>
<td>195 HIV+ not on ART 89 HIV+ on ART</td>
<td>LGE 6% NUG 2%</td>
<td>Decrease of NUG</td>
</tr>
<tr>
<td>Ferreira et al.</td>
<td>Brazil</td>
<td>1230 HIV+ on HAART (1988-2004)</td>
<td>LGE 2.5% NUG 1.6% NUP 1.3%</td>
<td>HAART associated with a significant lower prevalence of LGE (p&lt;0.001)</td>
</tr>
<tr>
<td>Nicolatou et al</td>
<td>Greece</td>
<td>HIV+ not on ART HIV+ on double ART and HAART/PI</td>
<td>LGE 8.1% NUG 0%</td>
<td>Decrease of NUG</td>
</tr>
</tbody>
</table>

HAART=Highly active antiretroviral therapy, HAART/PI=Highly active antiretroviral therapy with protease inhibitor as the third drug, ART=Any type of antiretroviral therapy, HIV-associated periodontal disease: LGE=linear gingival erythema, NUG=necrotizing ulcerative gingivitis, NUP=necrotizing ulcerative periodontitis.
<table>
<thead>
<tr>
<th>Authors</th>
<th>Subject sample</th>
<th>methodology</th>
<th>Principal findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paster et al</td>
<td>8 HIV+/NUP</td>
<td>Checkerboard DNA hybridization assay</td>
<td>Over 200 probes</td>
</tr>
<tr>
<td>2002</td>
<td>HAART: data not available</td>
<td>108 species identified (65 uncultivable)</td>
<td>Most frequent: <em>Bulleidia extructa</em>, <em>Dialister</em>, <em>Fusobacterium</em>, <em>Selenomonas</em>, <em>Phylum TM7 Peptostreptococcus</em>, <em>Veillonella</em>, Classical periodontal pathogens not detected</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Different and more complex microbial profiles</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>in periodontitis than in healthy periodontium</td>
</tr>
<tr>
<td></td>
<td>20 HIV+/CP</td>
<td>PCR for <em>P. nigrescens</em>, <em>C. rectus</em>,</td>
<td>Three microbial profiles exclusively in HIV+</td>
</tr>
<tr>
<td>Patel et al</td>
<td>20 HIV+/CP</td>
<td></td>
<td><em>P. intermedia</em>, <em>P. gingivalis</em>, <em>T. denticola</em>, <em>E. corroden</em>,</td>
</tr>
<tr>
<td>2003</td>
<td>HAART: data not available</td>
<td></td>
<td><em>A. actinomycetemcomitans</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>T. denticola</em> and <em>P. gingivalis</em> less prevalent in HIV+ subjects</td>
</tr>
<tr>
<td>Alpagot et al</td>
<td>152 HIV+/CP</td>
<td>Fluorescent assay for selective Gram-negative species</td>
<td><em>F. nucleatum</em>, <em>P. intermedia</em>, <em>A. actinomycetemcomitans</em>, <em>P. gingivalis</em>: risk factors for periodontitis in HIV+</td>
</tr>
<tr>
<td>2004</td>
<td>63% HAART</td>
<td></td>
<td>Several classical pathogens more prevalent in HIV+/CP than in HIV+/healthy periodontium:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>E. faecalis</em>, <em>F. nucleatum</em> more prevalent in patients with lower T CD4+ cells</td>
</tr>
<tr>
<td>Goncalves et al</td>
<td>64 HIV+/CP</td>
<td>Checkerboard DNA hybridization assay</td>
<td>Probes for 22 species</td>
</tr>
<tr>
<td>2004</td>
<td>100% HAART</td>
<td></td>
<td>Bacterial species and classical periodontal pathogens less frequent in HIV+/CP, than in HIV-/CP (T. forsythia, S. gordonii, P. gingivalis, S. intermedius,)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Unusual for CP species more commonly in HIV+ (A. baumannii, E. faecalis)</td>
</tr>
<tr>
<td>Goncalves et al</td>
<td>37 HIV+/CP</td>
<td>Checkerboard DNA hybridization assay</td>
<td>Probes for 33 species</td>
</tr>
<tr>
<td>2007</td>
<td>35 HIV+/HP</td>
<td></td>
<td>Unusual for CP microbes more frequent in CP than in healthy periodontium (<em>E. faecalis, E. pylori, P. aeruginosa</em>)</td>
</tr>
<tr>
<td></td>
<td>100% HAART</td>
<td></td>
<td><em>E. pylori</em> most prevalent in CP in HIV+</td>
</tr>
<tr>
<td>Aas et al</td>
<td>14 HIV+/CP, gingivitis, LGE</td>
<td>16S and 18S rRNA- cloning and sequencing</td>
<td>109 species (42% uncultivable) were identified: <em>Gemella</em>, <em>Dialister</em>, <em>Streptococcus</em>, <em>Veillonella</em> were predominant</td>
</tr>
<tr>
<td>2007</td>
<td>HAART: data not available</td>
<td>Classical periodontal pathogens not detected: (T. denticola, P. gingivalis, T. forsythia)</td>
<td>Unusual for CP microbes (Pseudomonas, Neisseria) more commonly in HIV+ and severe immunosuppression</td>
</tr>
<tr>
<td>Goncalves et al</td>
<td>13 HIV+/CP</td>
<td>PCR for <em>H. pylori</em>, <em>E. faecalis</em>,</td>
<td>Unusual for CP microbes more frequent in CP than in healthy periodontium (<em>E. faecalis, E. pylori, P. aeruginosa</em>)</td>
</tr>
<tr>
<td>2009</td>
<td>10 HIV+/HP</td>
<td><em>P. aeruginosa</em></td>
<td><em>E. pylori</em>* most prevalent in CP in HIV+</td>
</tr>
<tr>
<td></td>
<td>100% HAART</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 3.** Studies of subgingival plaque microbiota in HIV infected patients in HAART era using culture-independent methods

CP= chronic periodontitis  
NUP= necrotizing ulcerative periodontitis  
HP= healthy periodontium  
HAART= Highly active antiretroviral therapy  
LGE= linear gingival erythema