

Present and Future Non-Surgical Therapeutic Strategies for the Management of Periodontal Diseases

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1. Introduction

Periodontal disease is a chronic bacterial infection of the periodontium affecting the tissues surrounding and supporting the teeth. Periodontal disease progression is associated with subgingival bacterial colonization and biofilm formation principal to chronic inflammation of soft tissues, degradation of collagen fibers supporting the tooth to the gingiva and alveolar bone, as well as resorption of the alveolar bone itself. Since the fundamental role of microorganisms in its etiology was systematically demonstrated some forty years ago, research efforts have long focused on identifying the pathogenic microorganisms and their virulence factors (Socransky and Haffajee, 1994). The search for these putative microorganisms was driven, in part, by knowledge indicating that colonization of the oral cavity and presence of dental biofilm is normally associated with health, similarly to the colonization of the colon. To treat periodontal diseases as an infectious disease, numerous therapeutic strategies aimed at eradication of periodontal pathogens have been studied over the years, including local and systemic delivery of antimicrobial and antibiotic agents. This review will cover an update on chemotherapeutic agents used adjunctively to treat and manage periodontal diseases.

In the current paradigm of periodontal disease, specific periodontal pathogens are necessary for disease initiation; however, the extent and severity of tissue destruction are largely dependent on the nature of the host-microbial interactions. These interactions are dynamic, since both the microbial composition of the dental biofilm and the competency of host immune responses can vary, in the same individual, over time. This concept was developed in parallel to the advances on the understanding of the immune response, and research on periodontal disease has been emphasizing mechanisms of host-microbial interactions to understand the disease process, as well as for the development of novel therapeutic strategies. For the past two decades, the host response to the bacterial challenge originating from the dental biofilm has been considered to play a major role on both initiation of the disease and on the tissue destruction associated with its progress (Kirkwood, et al., 2007). The importance of host-microbial interactions is reinforced by epidemiological data indicating different susceptibilities to periodontal disease among individuals, in spite of the

long-term presence of oral biofilm (Baelum and Fejerskov, 1986, Baelum, et al., 1988, Loe, et al., 1986). Other studies demonstrating increased susceptibility and greater severity of periodontal disease in individuals with impaired immune response due to systemic conditions also indicate the significance of the host response to the bacterial challenge (Feller and Lemmer, 2008, Mealey, 1998). Both past and future directions of host-modulatory agents will be addressed here to provide the dental practitioner with a broader prospective of chemotherapeutic agents used to manage periodontal diseases.

2. Antibiotics

Contemporary periodontal therapies aim at mechanical removal of bacterial deposits to maintain a healthy sulcus or produce an environment suitable for new attachment. The inability of mechanical treatment to produce a desirable root surface in all cases coupled with the nature and complexity of the subgingival biofilm has fueled the search for adjunctive treatment regimens that increase the likelihood to successfully manage periodontal diseases.

While more than 700 bacterial species may be present in the gingival sulcus, it is clear that only a subset of bacterial species are consistently found to be associated with diseased sites. These findings make the prospect of targeted antibiotic therapy an attractive goal. The literature on antimicrobial periodontal therapy has been thoroughly reviewed (Ellen and McCulloch, 1996, Goodson, 1994, van Winkelhoff, et al., 1996).

2.1 Systemic antibiotics

Adjunctive systemic antibiotic therapies have indicated beneficial effects for patients with periodontal diseases. The optimal timing of antimicrobial drug administration is still a subject of discussion, as the literature is controversial whether it should be administered during the initial non-surgical phase (Loesche, et al., 1992), or during a subsequent surgical phase (Herrera, et al., 2008). Although not directly confirmed yet by a clinical trial, it seems preferable, from a general health point of view, to let patients benefit early from the positive systemic effects of successful periodontal therapy. Table 1 provides an overview of some orally active systemic antibiotics commonly used in clinical periodontics.

Caution should be noted that none of these antibiotics is to be used as a monotherapy to treat periodontal diseases. Systemic antibiotics reach the periodontal tissues by transudation from the serum then cross the crevicular and junctional epithelia to enter the gingival sulcus. The concentration of the antibiotic in this site may be inadequate for the desired antimicrobial effect without mechanical disruption of the plaque biofilm. In addition to any effect produced in the sulcus, a systemically administered antibiotic will produce antimicrobial effects in other areas of the oral cavity. This additional effect will reduce bacterial counts on the tongue and other mucosal surfaces, thus potentially aiding to delay re-colonization of subgingival sites. Research however, indicates that antibiotics are detectable in the sulcus and the range of their concentrations in the gingival crevicular fluid is known to be in therapeutic range treatment efficacy. Table 2 provides information to facilitate the clinician's decision to the most reasonable choice of antibiotic, dose and duration of administration.

Many studies have been completed and published describing the effect of systemic antibiotic therapy on periodontal disease. Several different treatment regimens have been employed successfully to manage periodontal diseases (Slots and Ting, 2002). Considering a number of studies, it can be stated generally that systemic antibiotic therapy has little effect

on supragingival plaque accumulation with a possible exception in one study where doxycycline significantly decreased plaque accumulation at a twelve-week evaluation compared to placebo (Ng and Bissada, 1998).

Antibiotic Class	Agent	Effect	Target Organisms	Limitation
Penicillin	Amoxicillin	Bacteriocidal	Gram + and Gram -	Penicillinase sensitive Patient hypersensitivity
	Augmentin	Bacteriocidal	Narrower spectrum than Amoxicillin	More expensive than Amoxicillin
Tetracycline	Tetracycline	Bacteriostatic	Gram + > Gram -	Bacterial resistance
	Minocycline	Bacteriostatic	Gram + > Gram -	
	Doxycycline	Bacteriostatic	Gram + > Gram -	
Quinolone	Ciprofloxacin	Bacteriocidal	Gram - rods	Nausea, GI discomfort
Macrolide	Azithromycin	Bacteriostatic OR Bacteriocidal depending on concentration		
Lincomycin	Clindamycin	Bacteriocidal	Anaerobic bacteria	
Nitroimidazole	Metronidazole	Bacteriocidal to Gram -	Gram -; esp. <i>P. gingivalis</i> and <i>P. intermedia</i>	Not good choice for <i>A. Actinomycetemcomitans</i> infections

Table 1. Systemic antibiotic choices.

Single Agent	Regimen	Dosage/Duration
Amoxicillin	500 mg	Three times per day X 8 days
Azithromycin	500 mg	Once daily X 4-7 days
Ciprofloxacin	500 mg	Twice daily X 8 days
Clindamycin	300 mg	Three times daily X 10 days
Doxycycline or Minocycline	100-200 mg	Once daily X 21 days
Metronidazole	500 mg	Three times daily X 8 days
Combination Therapy		
Metronidazole + Amoxicillin	250 mg of each	Three times daily X 8 days
Metronidazole + Ciprofloxacin	500 mg of each	Twice daily X 8 days

Table 2. Systemic antibiotic dosing regimens.

Except for the combination of metronidazole with amoxicillin, systemic antibiotic treatment produces no clinically significant effects on periodontal pocket depth reduction compared with controls (Winkel, et al., 2001) ((Cionca, et al., 2009). A seven-day regimen of systemic metronidazole significantly reduced the percentage of sites with bleeding compared to controls (Watts, et al., 1986). Others have reported a 12-month reduction in bleeding after treatment with a metronidazole-amoxicillin combination compared to a placebo treatment (Lopez, et al., 2000). With respect to clinical attachment levels, systemic metronidazole and combinations of metronidazole with other antibiotics has shown improvement in several studies. Several investigators found significant improvement of attachment levels at sites initially 4-6 mm in depth with a seven-day treatment with metronidazole (Elter, et al., 1997, Loesche, et al., 1992, Loesche, et al., 1984). Winkel et al. showed that the combination of metronidazole and amoxicillin for 7 to 14 days produced a significant increase in the percentage of sites showing improved attachment levels compared to control sites (Winkel, et al., 2001). A combination of metronidazole and clindamycin for three weeks also produced improved attachment levels. (Gomi, et al., 2007, Sigusch, et al., 2001).

Some data to date supports a clinical benefit from the use of azithromycin as a systemic approach in combination with mechanical routines. In one limited study, seventeen subjects receiving azithromycin (500 mg), three days before full-mouth scaling and root planing produced greater clinical improvement than in seventeen subjects treated with full-mouth scaling and root planing alone (Gomi, et al., 2007). Dastoor et al. studied thirty patients who reported smoking more than one pack per day and presented with periodontitis. A comparison was made between the response to treatment with periodontal surgery and 500 mg Azithromycin per day for three days and treatment with periodontal surgery only. The addition of Azithromycin did not enhance improvements seen in both groups for attachment gain, depth reduction and reduction of bleeding on probing. However, the adjunctive use of Azithromycin was associated with a lower gingival index at two weeks and what the authors saw as more rapid wound healing. The addition of Azithromycin also produced reductions of red-complex bacteria that were maintained to three months (Dastoor, et al., 2007).

It is important to remember that the systemic antibiotic therapy is not intended as a monotherapy but is always best as an adjunctive therapy combined with traditional mechanical therapy and patient plaque control.

2.2 Local antibiotic therapy

After considering the risk to benefit ratio of systemic antibiotic administration as an adjunct treatment of periodontal diseases, interest in antibiotic therapy applied locally was developed. Historically, the first such local antibiotic therapy for periodontal disease was the Actisite™ (no longer commercially available) fiber system. Actisite™ was supplied as hollow, nonabsorbable fibers filled with tetracycline (12.7 mg/9 inch fiber). The fiber was inserted into the pocket, wrapped repeatedly circumferentially around the tooth keeping the fiber in the pocket. Often a periodontal dressing was placed to aid maintaining the fiber in the pocket. The fiber was retained for ten days until operator removal. During this ten-day period drug concentrations of more than 1300 µg/ml of tetracycline were achieved and maintained. When the fiber was removed the soft tissue was often distended allowing temporary improved access and visibility of the root surfaces for any additional root planing or calculus removal. Following removal of the fiber the soft tissues generally showed

shrinkage and pocket reduction and reduction of the inflammatory response were commonly seen. The Actisite™ system, while very effective, was tedious to use and required the second visit for removal of the fiber. These issues fueled the development of an absorbable system (Table 3).

Antimicrobial Agent	Delivery Form	Drawback	GCF Concentration	Time to Absorption	Brand Name
Tetracycline 12.7 mg per 9 inches of fiber	Hollow fibers	2 nd procedure for fiber removal	>1300 ug/ml for 10 days	Not absorbable	Actisite No longer commercially available
10% Doxycycline	Fluid; multi-site depending on volume of site; in syringe	Often pulls out when removing syringe	250 ug/ml still noted at 7 days	21 days	Atridox
25% Metronidazole Gel	Fluid; multi-site depending on volume of site; in syringe	May require multiple applications for desirable results	More than 120 mg/ml of sulcus fluid in the first few hours	Concentration decreases rapidly after the first few hours (Knoll-Kohler, 1999)	Elyzol
2% Minocycline Spheres	Solid; in unit doses applied with syringe	Unit doses may not be sufficient for every site volume	Therapeutic drug levels for 14 days	14 days	Arestin

Table 3. Local antibiotic delivery systems.

The first resorbable local antibiotic system was Atridox™ (Atrix Laboratories). In this system, longer half-lived doxycycline replaced tetracycline supplied at a concentration of 42.5 mg per unit of material. Atridox™ improved the local antibiotic routines by allowing placement of the material to the depth of most pockets and in a manner that allowed it to conform to the shape of the pocket unlike the solid fibers of Actisite™. Depending on the size of the pocket, more than one site could be treated with a single unit of Atridox™.

Further development of absorbable local antibiotic systems led to Arestin™ (OraPharma) that uses minocycline in a microsphere configuration, each sphere measuring 20-60 microns in diameter. The antibiotic maintains therapeutic drug levels and remains in the pocket for 14 days. This configuration of the material allows placement to the depths of most pockets and while the material cannot conform to the shape of the pocket as well as the Atridox™ gel it is still better than the solid Actisite™ fibers.

Another material, not available in the United States, is Elyzol™ (Colgate), a metronidazole gel system. This material is supplied as 25% metronidazole in a glyceryl mono-oleate and sesame oil base. The concentration of Metronidazole in this system is 250 mg/g of material that is applied as a gel using a syringe method.

Overall efficacy of local antibiotic therapies has been evaluated using meta-analysis of fifty articles, each reporting studies of at least six months follow-up (Bonito, et al., 2005). The meta-analysis considered studies of the addition of local adjuncts and found such additions provide generally favorable but minimal differences. The clinical effects of these various systems have been reported in several publications. Table 4 summarizes several studies of various local adjunctive materials. The overall treatment effect is somewhat variable and while found to be statistically significant has led many to be suspect of the general clinical benefit.

Agent	Subjects	Depth Change with S/RP Only	Depth Change with S/RP + Agent	Sites With At Least 2 mm Attachment Gain with S/RP + Agent
Tetracycline Fibers (Goodson, et al., 1991)	107	0.67	1.02 (fiber only)	Not reported
Doxycycline gel (Garrett, et al., 1999)	411	1.08	1.30 (drug only)	38% (drug only)
Doxycycline gel (Wennstrom, et al., 2001)	105	1.3	1.5	52%
Doxycycline gel (Machion, et al., 2006)	48	1.5 - 2.19	1.63-2.29	34.4% vs. 18.1% S/RP only
Minocycline spheres (Williams, et al., 2001)	728	1.08	1.32	42%
Minocycline spheres (Goodson, et al., 2007)	127	1.01	1.38	Not reported; reports attachment gain of 1.16 with agent, 0.8 S/RP only
Metronidazole gel (Ainamo, et al., 1992)	206	1.3	1.5 (drug only)	Not reported
Azithromycin gel (Pradeep, et al., 2008)	80	2.13	2.53	Not reported; reports greater gain at all time points with agent

Table 4. Local Antibiotic System Studies.

3. Antiseptics

The use of chemical agents with anti-plaque or anti-gingivitis action as adjuncts to oral hygiene seems to be of limited value, since mouthrinses do not appreciably penetrate into the gingival crevice, but they are of specific benefit when used as adjuncts to control gingival inflammation, especially in acute situations and during periods of interrupted hygiene (Ciancio, 1989). The challenge with chemical plaque control is to develop an active anti-plaque agent that does not disturb the natural flora of the oral cavity. The American Dental Association (ADA) Seal of Acceptance is seen as a standard for oral health care products. The ADA Seal Program ensures that professional and consumer dental products meet rigorous ADA criteria for safety and effectiveness. Guidelines have been established for the control of gingivitis and supragingival plaque

(<http://www.ada.org/ada/seal/index.asp>). These guidelines describe the clinical, biological, and laboratory studies necessary to evaluate safety and effectiveness and are subject to revision at any time. Importantly, they do not describe criteria for evaluating the management of periodontitis or other periodontal diseases. All claims of efficacy, including all health benefit claims, (e.g. gingivitis reduction), and all claims which imply a health benefit (e.g. plaque reduction) must be documented. There will be two Seal statements to be used with an Accepted product, depending on whether or not the product's mechanism of action is related to plaque reduction.

Oral antiseptics have evolved from short-lived effects (soon after rinsing) as with the first generation antimicrobials (Table 5) to the second generation, which have the antimicrobial effect that lasts for a time period after the mouthrinse has been expectorated (Table 6).

Anti-microbial	Commercial Name	ADA Seal of Acceptance	Active ingredients	Alcohol content	Mechanism of Action	Efficacy published by the manufacturer
Phenolic Compounds	Listerine (Johnson & Johnson)	Yes	Essential oils: Thymol (0.06%) Eucalyptol (0.09%) Methyl salicylate (0.06%) Menthol (0.04%)	26.9%	Appears to be related to alteration of the bacterial cell wall	52% plaque reduction 36% gingivitis reduction (www.listerine.com)
Sanguinarine	Viadent (Colgate)	No	0.03% Sanguinarine extract	5.5%	Alteration of bacterial cell surfaces so that aggregation and attachment is reduced	28% plaque reduction 24% gingivitis reduction (www.colgateprofessional.com/products/Viadent-Advanced-Care-Oral-Rinse/details)
Quaternary Ammonium Compounds	Cepacol and Scope (Procter & Gamble)	No	Cepacol: 0.05% CPC Scope: 0.045% CPC + 0.005% domiphen bromide	Cepacol 14% Scope 18.9%	Related to increased bacterial cell wall permeability, which favors lysis, decreased cell metabolism and a decreased ability for bacteria to attach to tooth surfaces.	15.8% plaque reduction 15.4% gingivitis reduction (www.cepacol.com/products/mouthwash.asp) and (www.pg.com/product_card/prod_card_main_scope.html)

Table 5. First generation antimicrobials.

On the downside, it is also recognized that oral hygiene products may have the potential for producing harm in the mouth, some of which are more serious and long lasting than others. These types of harm range from production of a cosmetic nuisance, such as staining occurring as a result of the use of cationic antiseptics like chlorhexidine and cetylpyridinium chloride, to more permanent damage to the dental hard tissues through possible erosive and abrasive effects of low-pH mouthrinses and toothpastes respectively. Of serious concern is controversially the ability to produce carcinogenic changes to the oral mucosa through the use of alcoholic mouthrinses. Recently, the potential harm of oral hygiene products to oral and systemic health was fully reviewed with reference to present-day evidence (Addy, 2008).

Antimicrobial	Cetylpyridinium chloride	Chlorhexidine
Commercial Name	Crest Pro-Health (Procter & Gamble)	Peridex (3M Espe) Periogard (Colgate)
ADA Seal of Acceptance	No	Yes
Active ingredients	0.07% CPC	0.12% Chlorhexidine gluconate (solutions.3m.com/wps/portal/3M/en_US/preventive-care/home/products/home-care-therapies/peridex/) and (www.colgateprofessional.com/products/Colgate-Periogard-Rinse-Rx-only/details)
Mechanism of Action	Bactericidal agent interacts with the bacterial membrane. The cellular pressure disrupts the cell membrane and effectively kills the bacteria.	Positively charged chlorhexidine molecule binds to negatively charged microbial cell wall, altering osmotic equilibrium, causing potassium and phosphorous leakage, precipitation of cytoplasmic contents and consequent cell death.
Efficacy published by the manufacturer	Similar to Listerine (www.dentalcare.com/soap/products/index.htm)	Certain aerobic and anaerobic bacteria reduction from 54 - 97% through six months use (solutions.3m.com/wps/portal/3M/en_US/preventive-care/home/products/home-care-therapies/peridex/) - 29% gingivitis reduction - 54% plaque reduction (www.colgateprofessional.com/products/Colgate-Periogard-Rinse-Rx-only/details)

Table 6. Second generation antimicrobials.

3.1 Phenolic compounds

Among the first generation antimicrobials, the phenolic compounds, such as Listerine® and its clones, are the only ones that have the ADA Seal of Acceptance to prevent and reduce supragingival plaque accumulation and gingivitis. Short-term studies have shown plaque and gingivitis reduction averaging 35% (Fornell, et al., 1975) and long-term studies have shown plaque reduction between 13.8 and 56.3% and gingivitis reduction between 14 and

35.9% (DePaola, et al., 1989, Gordon, et al., 1985). Possible adverse effects reported in the literature include a burning sensation, bitter taste and possible staining of teeth.

3.2 Chlorhexidine

Chlorhexidine gluconate (0.12%), such as Peridex® and Periogard®, is sold in the United States by prescription only. It was the first antimicrobial shown to inhibit plaque formation and the development of chronic gingivitis (Loe and Schiott, 1970). Chlorhexidine is effective against gram-positive and negative bacteria and yeast. It has very low toxicity, since it is poorly absorbed from the GI tract and 90% is excreted in the feces. Chlorhexidine 0.12% is indicated for short-term (less than 2 months), intermittent short-term (alternating on and off every 1 to 2 months) and long-term (greater than 3 months to indefinitely) use (Table 7). Of all the products included here, chlorhexidine appears to be the most effective agent for reduction of both plaque and gingivitis with short-term reductions averaging 60% (Flotra, et al., 1972). Long-term reductions in plaque averaged between 45-61% and in gingivitis, 27-67% (Ciancio, 1989). Adverse effects reported may include staining of teeth, reversible desquamation, poor taste and alteration of taste and an increase in supragingival calculus (Flotra, et al., 1972, Overholser, et al., 1990).

Short-term indication (less than 2 months)	Intermittent short-term indications (alternating on and off every 1 to 2 months)	Long-term indications (greater than 3 months to indefinitely)
Gingivitis	Gingivitis	Patients with reduced resistance to bacterial plaque: AIDS, leukemia, kidney disease, bone marrow transplants, agranulocytosis, thrombocytopenia
Following periodontal and oral surgery	Periodontal maintenance	Physically handicapped patients: rheumatoid arthritis, scleroderma, disturbance of muscles and/or motor capacity and coordination
During initial periodontal therapy	Physically and /or mentally handicapped	Patients treated with: cytotoxic drugs, immunosuppressive drugs, and radiation therapy.
Treatment of candidiasis	Extensive prosthetic reconstruction	

Table 7. Chlorhexidine 0.12% Indications.

3.3 Other antimicrobial mouthrinses

Several other agents have been evaluated for their effect on bacterial plaque and gingivitis, but results are inferior to those of chlorhexidine and phenolic compounds (see Table 8). Pires et al. (Pires, et al., 2007) have concluded that a mouthwash containing a combination of Triclosan/Gatrez and sodium bicarbonate has an *in-vitro* antimicrobial activity superior to that of a placebo, but still inferior to that of chlorhexidine.

Anti-microbial	Commercial Name	ADA Seal of Acceptance	Active ingredients	Mechanism of Action	Efficacy
Oxygenating agents	Peroxyl (Colgate)	No	Hydrogen Peroxide	Anti-inflammatory properties reduce bleeding on probing, a major sign of inflammation; bacterial load is not necessarily reduced; bubbling action cleans and alleviates discomfort to promote healing.	Long-term studies do not support effectiveness. Short-term studies offer contradictory findings.
Chlorine Dioxide	RetarDEX (Periproducts) Oxyfresh	No	1% chlorine dioxide	Stable, free radical and an oxidant with algicidal, bactericidal, cysticidal, fungicidal, sporicidal, and viricidal properties.	Minimal plaque reduction, but has shown decreases in volatile sulfur compounds and halitosis.
Zinc Chloride	Breath Rx	No	-Zinc chloride -Phenolic oils (Thymol and Eucalyptus oil)	Zinc has an affinity to sulfur and odorizes sulphhydryl groups with zinc ions forming stable mercaptides with the substrate, the precursors, and/or the volatile sulfur compounds directly.	BreathRx is a scientific bad breath treatment specially designed to help treat both the causes of bad breath and the symptoms.
Triclosan	Not available in the US	N/A	Triclosan	A low toxicity, non-ionic phenolic derivative with a wide spectrum of antimicrobial and anti-inflammatory activities (Kim, et al., 2005).	<i>In vitro</i> studies show antimicrobial activity superior to that of a placebo, but inferior to that of chlorhexidine (Pires, et al., 2007)

Table 8. Other antimicrobial mouthrinses.

Antiseptics compared	Methodology	Results	References
Listerine Viadent Peridex Placebo	31 volunteers with healthy gingiva ceased all oral hygiene procedures but rinsing with the designated mouthrinse for 21 days	Peridex was superior in its ability to maintain optimal gingival health during the entire time of mouthrinse use.	Siegrist et al. (Siegrist, et al., 1986)
Listerine Peridex Placebo	Double blind, controlled clinical trial. After a baseline complete dental prophylaxis, 124 healthy adults used the mouthrinse as a supplement to regular oral hygiene for 6 months.	Both Listerine and Peridex significantly inhibited development of plaque by 36.1% and 50.3%, respectively, and the development of gingivitis by 35.9% and 3.05% respectively, compared to placebo.	Overholser et al. (Overholser, et al., 1990)
Chlorhexidine 0.12% Hydrogen Peroxide 1% Placebo	32 subjects ceased oral hygiene procedures, but rinsed, twice a day, with the designated mouthrinse for 21 days.	The chlorhexidine group showed 95% reduction in gingivitis incidence, 100% reduction in BOP, and 80% reduction in plaque scores compared to placebo.	Gusberty et al. (Gusberty, et al., 1988)

Table 9. Comparison studies.

4. Anti-inflammatory strategies

It is well established that periodontal disease is an infectious disease and that the host immune and inflammatory response to the microbial challenge mediates tissue destruction (Offenbacher, 1996). Considering that the primary etiology of the disease are bacteria in the plaque and their products, mechanical and chemical approaches to reduce the presence of periodontopathogens in the plaque have been largely used in the treatment of periodontal patients over the years (Greenwell, 2001). Most recently, the better understanding of the participation of host immune-inflammatory mediators in the disease progression has increased the investigation of the use of modulating agents as an adjunctive therapy to the periodontal treatment. Inhibition or blockade of proteolytic enzymes, pro-inflammatory mediators and of osteoclast activity has been the focus of these agents which has led to encouraging results in pre-clinical and clinical studies (Reddy, et al., 2003). More specifically, three types of host-modulatory agents have been investigated for the management of periodontitis including anti-proteinases (MMP inhibitors), anti-inflammatory agents, and anti-resorptive agents.

4.1 MMP Inhibitors

One important group of proteolytic enzymes present in the periodontal tissues is formed by the matrix metalloproteinases (MMPs), which include collagenases, gelatinases and metalloelastases. MMPs are produced by many periodontal tissues and are responsible for remodeling the extracellular matrix (Birkedal-Hansen, 1993). In 1985, tetracyclines were found to have anti-collagenolytic activity and proposed as a host modulating agent for periodontal treatment (Golub, et al., 1985). Initial studies demonstrated that doxycycline was the most potent tetracycline in inhibition of collagenolytic activities (Burns, et al., 1989). This property of doxycycline provided the pharmacological rationale for the use of a low or subantimicrobial dose of doxycycline (SDD) that was shown to be efficient in inhibiting mammalian collagenase activity without developing antibiotic resistance (Golub, et al., 1990).

Several clinical studies have been conducted assessing the benefits of the SDD as an adjunctive therapy to scaling and root planing (SRP) in the treatment of the periodontal disease. Reddy et al. recently presented a meta-analysis (Reddy, et al., 2003) of 6 selected clinical studies comparing long-term systemic SDD (20mg bid doxycycline) to placebo control in periodontal patients. A statistically significant adjunctive benefit on clinical attachment levels (CAL) and probing depth was found when SDD was used in combination with SRP, in both 4 to 6mm and ≥ 7 mm pocket depth categories. Bleeding on probing (BOP) was not assessed in the meta-analysis but, in general, SDD did not improve this parameter when compared to placebo. No significant adverse effects were reported in any of the studies.

4.2 Non-steroid anti-inflammatory drugs

The non-steroidal anti-inflammatory drugs (NSAIDs) represent the next major pharmacological class of agents that has been well studied as inhibitors of the host response in periodontal disease. These agents are well known for the ability to prevent prostanoid formation. In this process, arachidonic acid liberated from membrane phospholipids of cells after tissue damage or stimulus is metabolically transformed via cyclooxygenase or

lipoygenase pathways in compounds with potent biological activities (Offenbacher, 1996). The cyclooxygenase enzymes are recognized to have two isoforms: cyclooxygenase 1 (COX1) which is a constitutive enzyme present in most of cells and cyclooxygenase 2 (COX2) which is inducible and is present in cells involved in inflammatory processes (DeWitt, et al., 1993). The cyclooxygenase pathway produces prostaglandins, prostacyclin and thromboxane, called prostanoids. Some prostanoids have proinflammatory properties and have been associated with destructive process in inflammatory diseases. In periodontal diseases, Prostaglandin E₂ (PGE₂) has been extensively correlated to inflammation and bone resorption (Offenbacher, 1996). Its levels in gingival tissues and in the gingival crevicular fluid (GCF) have been shown to be significantly elevated in periodontally diseased patients compared to healthy patients (Dewhirst, et al., 1983, Offenbacher, et al., 1981).

Selective NSAIDs are capable of inhibiting COX-2 without affecting constitutive isoform COX-1. Some studies have indicated that COX-2 inhibitors retain bone sparing effects (Bezerra, et al., 2000, Holzhausen, et al., 2002, Holzhausen, et al., 2005, Shimizu, et al., 1998) without inducing adverse effects associated with COX-1 suppression, such as gastroduodenal problems and renal toxicity (Hawkey, 1993, Lindsley and Warady, 1990). Several adjunctive periodontal clinical trials have been conducted with NSAIDs. In a systematic review (Reddy, et al., 2003), ten clinical studies in which therapeutic outcomes of NSAIDs were expressed in clinical attachment level (CAL) or alveolar crestal height as measured by subtraction radiography were selected. In these studies a variety of different NSAIDs were systemically or locally administered, including flurbiprofen, meclofenamate, ibuprofen, ketorolac, naproxen and aspirin. Although the heterogeneity of data did not permit a meta-analysis, limited quantitative analysis tended to show a significant benefit related to alveolar bone maintenance when NSAIDs were combined with conventional therapy. Notably, none of these studies found significantly less attachment loss after NSAIDs adjunctive therapy when compared to SRP alone.

4.3 Anti-bone resorptive therapeutics

Alveolar bone destruction is the hallmark feature of periodontal disease. The use of bone-sparing drugs that inhibit alveolar bone resorption is another field in host-modulation therapy. Bisphosphonates are a class of agents that binds to hydroxyapatite in bone matrix to prevent matrix dissolution by interfering with osteoclast function through a variety of direct and indirect mechanisms (Rogers, et al., 2000). The principal therapeutic purpose of bisphosphonates is in the prevention and treatment of osteoporosis and also in treatment of Paget's disease and metastatic bone disease (Fleisch, 1997). In periodontics, their use was proposed initially for diagnostic and therapeutic use. As therapeutic agents, bisphosphonates were shown to reduce alveolar bone loss and increase mineral density but not to improve clinical conditions in animal periodontitis models (Brunsvold, et al., 1992, Reddy, et al., 1995). Five studies that assessed the effect of bisphosphonates as an adjunctive agent to SRP in human periodontal treatment were found to date (El-Shinnawi and El-Tantawy, 2003, Jeffcoat, et al., 2007, Lane, et al., 2005, Rocha, et al., 2004, Rocha, et al., 2001). Alendronate was the bisphosphonate used in four studies during a period of 6 months. One study used risedronate during 12 months (El-Shinnawi and El-Tantawy, 2003). All the studies presented significant clinical improvement when compared to placebo, including: probing depth reduction, clinical attachment gain, bleeding on probing reduction, alveolar bone gain and increase in bone mineral density. These results encourage the use of

bisphosphonates as an adjunctive agent to periodontal therapy. Additional studies need to be implemented to confirm the benefits of these drugs.

However, there can be significant dental related adverse effects associated with the use of bisphosphonates therapeutics. High-dose, long-term use of bisphosphonates has been reported to be associated with osteonecrosis of the jaw (ONJ) (Marx, 2003, Ruggiero, et al., 2004). Data from multiple sources indicates that patients with prior dental problems may have a higher risk of ONJ. However, as more data is being reported, it still remains controversial that bisphosphonates indeed are causative for ONJ. Since bisphosphonates are potent osteoclast inhibitors, their long-term use may suppress bone turnover and compromise healing of even physiologic micro-injuries within bone (Odvina, et al., 2005). Despite the encouraging therapeutic results, further long-term studies are warranted to determine the relative risk-benefit ratio of bisphosphonate therapy.

5. Future host modulatory approaches

A variety of treatment strategies have been developed to target the host response to LPS-mediated tissue destruction. MMP inhibitors such as low dose formulations of doxycycline have been used in combination with scaling and root planing (Caton, et al., 2001) or surgical therapy (Gapski, et al., 2004). In addition, high-risk patient populations such as diabetics or patients with recurrent periodontal disease have benefited from systemic MMP administration (Chang, et al., 1996, Golub, et al., 2001, Novak, et al., 2002). Encouraging results have been shown using soluble antagonists of TNF and IL-1 delivered locally to periodontal tissues in nonhuman primates (Assuma, et al., 1998, Graves, et al., 1998).

5.1 Novel host modulators

Host response modulation is key therapeutic target used to control periodontal inflammation leading to tissue and bone destruction. Bone loss as a consequence of bacterial-induced inflammation due to subgingival plaque in the periodontal pocket is controlled by the expression of cytokines that direct the biological process of osteoclast differentiation. Several inflammatory cytokines, including interleukin (IL)-1, IL-6 and other cytokines enhance the expression of receptor activator of nuclear factor kappa-B ligand (RANKL) which induced osteoclast formation and leads to bone resorption. RANK is the receptor located on osteoclast precursor cells that respond to RANKL to initiate formation of mature osteoclasts. To balance the effects of RANKL, osteoprotegerin (OPG) acts as a decoy receptor to bind RANKL and inhibits osteoclast development. In periodontal disease, the roles of RANKL, RANK, and OPG in the alveolar bone resorption have been extensively investigated. Based on pre-clinical animal studies and on preliminary human clinical studies, the OPG/RANKL/RANK axis is a new target for the treatment of destructive periodontal disease and other bone resorption related diseases (Cochran, 2008). However, further studies are necessary to determine the most efficacious therapeutic approach based upon molecular interactions in the periodontal environment.

All immune cells within periodontal tissues generate innate immune cytokines require intracellular signaling to transduce extracellular cues into biochemical information required for inflammatory cytokine gene expression. Cytokines and bacterial components activate many signal transduction pathways. With this concept in mind, new strategies for preventing cell activation via targeting signal transduction pathways could abolish both cell

activation by cytokines or other stimuli and production of proinflammatory cytokines. Signal transduction pathways closely involved in inflammation include the mitogen-activated protein kinase (MAPK) pathway, phosphatidylinositol-3 protein (PI3-kinase) pathway, janus kinase-signal transducer and activator of transcription (Jak-STAT), and nuclear factor kappa B (NF-kB). Thus, small molecule inhibitor compounds have emerged as the new therapeutic strategies that are being explored are aimed at inhibiting signal transduction pathways involved in inflammation. Pharmacological inhibitors of NF-kB and p38 mitogen activating protein (MAP) kinase pathways are actively being developed to manage inflammatory bone diseases (Adams, et al., 2001, Kumar, et al., 2001). p38 inhibitors have already shown promise in preclinical models of periodontal diseases (Kirkwood, et al., 2007, Rogers, et al., 2007). Using this novel strategy, inflammatory mediators including proinflammatory cytokines (IL-1, TNF, IL-6), MMPs and others would be inhibited at the level of cell signaling pathways required for transcription factor activation necessary for inflammatory gene expression or mRNA stability. These therapies may provide the next wave of adjuvant chemotherapeutics that may be used to manage chronic periodontitis.

6. Future directions

Most therapeutics has relied on systemic delivery. Thus, it may be difficult to potentially use systemic therapeutics for periodontal disease due to the long-term chronic nature of the periodontal inflammation and destruction. The future may be the adjunctive use of locally delivered therapeutics, and the need for new targets of therapeutics for periodontal disease. Also, the need for new in situ delivery systems with the ability to locally deliver therapeutics to the periodontal lesion bypassing systemic issues of toxicity.

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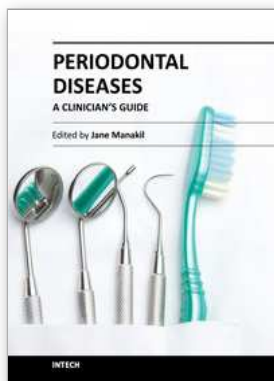
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"Periodontal diseases" is a web-based resource intended to reach the contemporary practitioners as well as educators and students in the field of periodontology. It is fully searchable and designed to enhance the learning experience. Within the book a description is presented of the current concepts presenting the complex interactions of microbial fingerprint, multiple genotypes, and host modulations. In addition, an overview is given of the clinical outcome of the disease's progression, as influenced by the epigenetic factors. Emerging concepts on periodontitis as a risk factor for various systemic diseases and as a bilateral modulating factor have been elucidated in detail as well.

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