

## Elevated Salivary IL-1 $\beta$ , Pge2 And Mmp-3 Levels And Their Significant Reduction Post Therapy In Patients With Chronic Periodontitis Compared To Healthy Individuals

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### Abstract

**Background:** The role of IL-1 $\beta$ , PGE<sub>2</sub> and MMP-3 in the pathogenesis of periodontal disease is well researched. This study aimed to assess and compared the salivary IL-1 $\beta$ , PGE<sub>2</sub> and MMP-3 levels in patients with untreated chronic severe periodontitis and those treated with periodontal phase I therapy and periodontally healthy individuals as controls, in relationship to the presence of salivary anti- $\beta_1$  IgA.

**Methods:** A total of 30 subjects participate in the study: 15 subjects had chronic severe periodontitis and 15 were healthy individuals used as a control. After saliva collection and its purification, we quantify by enzyme-linked immunosorbent assay (ELISA) procedure using as coating antigen a synthetic  $\beta_1$  peptide with an amino acid sequence identical to the second extracellular loop of the human  $\beta_1$  adrenoceptor ( $\beta_1$  AR), the presence of anti  $\beta_1$  AR antibody (IgA) in the saliva of patients and healthy individuals. Also, IL-1 $\beta$ , PGE<sub>2</sub>, nitrites and metalloproteinase 3 (MMP-3) were assessed using ELISA assay.

**Results:** Our data indicated that IL-1 $\beta$ , PGE<sub>2</sub>, nitrites and MMP-3 levels are elevated in the saliva of patients with untreated chronic severe periodontitis and were significantly higher than in healthy subjects. Also, the amounts of anti-  $\beta_1$  IgA in the saliva was significantly higher compared with that of healthy individuals. After periodontal phase I therapy these levels of inflammatory biomarkers are significantly reduced but the titres of the antibody did not change, suggesting a close association between salivary IL-1 $\beta$ , PGE<sub>2</sub>, nitrites and MMP-3 and periodontitis without any changes in the levels of anti  $\beta_1$  IgA.

**Conclusions:** These results suggest that the abnormal amount of these cytokines and enzymes in saliva has potential monitoring applications as a risk marker of the disease progression but the raised levels of anti  $\beta_1$  IgA present in the saliva of chronic severe periodontitis patient, are not directly associated with the course of the disease. Additional studies are needed to validate this assumption.

**Keywords:** Periodontitis, IL-1 $\beta$ , PGE<sub>2</sub>, antibodies anti- $\beta_1$  IgA

### Introduction

Periodontal disease is a chronic microbial and inflammatory process characterized by the presence of sulcular pathogenic bacteria, impaired host immune response, destruction of the connective tissue involved in tooth attachment, and resorption of alveolar bone. Bacterial pathogens are required to initiate the disease process [1-3].

Circulating substances have been detected at elevated levels in gingival crevicular fluid and whole saliva of patients who have periodontal disease, making them putative biomarkers of the disease [4-6]. Periodontal pathogens activate host cells to produce pro-inflammatory mediators [7,8] and cytoplasmic enzymes [9], which, in turn, promote the destruction of periodontal tissues. The release of the inflammatory cytokine, IL-1 $\beta$ , PGE<sub>2</sub> and lysosomal and cytoplasmic enzymes, such as metalloproteinases (MMPs), to periodontal tissues is higher in the areas with inflammation [10,11]. In addition, various enzymes, cytokines and biomarkers of bone turnover have been found to be elevated in the saliva of periodontitis patients in comparison with periodontally healthy controls [12-14].

Recently, we reported that in the sera of periodontitis patients we found autoantibodies against atria cardiac  $\beta_1$ -adrenoreceptor (anti- $\beta_1$ -AR IgG) that were able to mimic the effect of an authentic  $\beta_1$ -AR agonist acting on atria  $\beta_1$ -AR [15,16]. However, the release of host-derived inflammatory mediators, such as cytokines from chronically inflamed periodontal tissues, into the circulation together with the sera anti- $\beta_1$ -AR IgG, may provide a link between periodontal disease and cardiovascular disease [17,18].

Moreover, the effect of anti- $\beta_1$ -AR IgG acting on  $\beta$ -AR in rat atria and its capacity to activate caspase pathway, molecular signals involved in anti- $\beta_1$ -AR IgG- $\beta_1$ -AR-stimulated myocardium apoptosis and increased cAMP production and JNK phosphorylation, and the role of anti- $\beta_1$ -AR IgG in the release of inflammatory mediators (PGE<sub>2</sub>, NO, cGMP) that participate in atria  $\beta_1$ -AR-stimulated cardiomyocytes apoptosis were also determined [19].

Based on these observations, we considered it of special relevance to investigate whether salivary secretory IgA (anti- $\beta_1$  IgA) from patients with chronic severe periodontitis could be a new marker of the pathophysiological event that occurs in this disease in relationship with host-derived enzymes (MMPs), cytokines (IL-1 $\beta$ ) and PGE<sub>2</sub> present in the saliva of the untreated periodontitis patients and those treated with periodontal phase I therapy in its.

### Materials and methods

#### Patients

The patients in this study were 40 to 60 year-old, non-smoker males being treated in the Department of Periodontics, School of Dentistry, University of Buenos Aires.

Thirty patients with pre-existing chronic severe periodontitis were included in the test group before and after conventional periodontal I therapy. The assessment of clinical parameters was carried out by a trained periodontist following criteria based on clinical parameters and the severity of periodontal tissue destruction [20].

The characteristic clinical signs of periodontitis included loss of clinical attachment, horizontal and/or angular alveolar bone loss, periodontal pocket formation, and gingival inflammation. To be included in the study, at least six sites with ongoing periodontal disease were required. Clinical measurements in patients with periodontitis included sites with alveolar bone loss >2 mm and a pocket depth >5 mm with bleeding and attachment loss >3 mm. No subject (periodontal patient or healthy individual) had any systemic illness and they were all never-smokers. Patients with periodontitis had not received periodontal treatment or antibiotics within the preceding 5 months or any anti-inflammatory drug within 3 weeks prior to the study. The clinical characteristics of the study population and the healthy subjects (controls) are shown in (Table 1).

Characteristics	Healthy subjects (control) (n=15)	Chronic Periodontitis Patients (n=15)	
		Before Treatment	After Treatment
Age (years, SD)	49.6±5.2	47.9±5.6	47.5±5.4
Male (%)	80	75	75
Smoking (non-smoker/smoker)	0/12	0/15	0/15
CAL ≥ 2 mm (% , SD)	0	80.54±12.31	60.33±11.16*
PD ≥ 4 (% , SD)	0	69.40±15.91	47.96±17.71**
BOP (% , SD)	5.37±1.65	88.44±10.76	75.42±10.26
PI (SD)	1.10±0.51	6.14±0.48	2.28±0.38**
GI (SD)	0.55±0.25	1.46±0.18	1.40±0.21

**Table 1** : Comparison of the Clinical Parameters of the CP patients with or without Conventional Periodontal Treatment.

The control group consisted of thirty healthy non-smoker volunteer males of the same age range, and with a clinically healthy periodontium from the same department. In the healthy subjects (control group), the probing depth was <3 mm and the attachment loss was <2 mm. Moreover, probing pocket depth and clinical attachment level were assessed at six sites per tooth and bleeding on probing at four sites per tooth. This group had <10% of sites with bleeding on probing (BOP), no sites with probing depth (PD) ≥4 mm, no clinical attachment loss (AL), <2 mm, and no radiographic evidence of bone loss.

Exclusion criteria were individuals who had undergone periodontal treatment in the last 6 months; history of medications including antibiotics and anti-inflammatory drugs in the last 6 months; history of any systemic disease; and detection of any obvious oral mucosal lesion.

This study was approved by the Ethical Commission of the School of Dentistry, University of Buenos Aires. Written informed consent was obtained from each participant in this study, which was conducted under the rules of the Helsinki Declaration.

### Saliva collection

Participants were instructed to refrain from eating, drinking and practicing oral hygiene procedures 12 hours before saliva collection. Whole unstimulated saliva was collected early morning after fasting (8 hours) from all patients by expectoration into sterile bulbs. The total amount of saliva collected was 1 ml. Collected samples were placed immediately on ice and transported to the laboratory, where they were centrifuged at 5,000 g for 10 minutes, and the clear supernatants were stored in aliquots at -80°C in presence of protease inhibitors. The samples were thawed and the assays were performed within 2 months of collection.

### Clinical parameters

Clinical data included: CAL: clinical attachment level; PD: probing depth; BOP: bleeding on probing; PI: periodontal index; GI: gingival index (Table 1).

The index measurements were done at six sites per tooth (mesio-buccal, mid-buccal, disto-buccal, disto-lingual, mid-lingual and mesio-lingual) and CAL was obtained by measuring only interproximal sites. These data were recorded and the treatment was performed by a trained periodontist. The data were recorded after saliva sample collection.

### Periodontal therapy

Periodontal phase I therapy (PPIT) consisted of full-mouth scaling, root planning and oral hygiene instructions. Only the patients with periodontitis received PPIT after saliva sample collection and clinical measurements of baseline. The therapy was completed in two visits, each one week apart. No antibiotics were prescribed after the treatment. The patients were re-evaluated for clinical parameters one month afterwards and saliva samples were taken again.

### Purification of saliva IgA

The IgA fractions of 15 patients with chronic periodontitis untreated and treated with PPIT and 15 healthy individuals were independently purified by standard diethylaminoethyl cellulose (DEAE) chromatography. Briefly, saliva samples were dialyzed against 0.01 M phosphate buffer, pH 8.0, for 18 hours and then applied to DEAE cellulose columns equilibrated in the same buffer. The pass-through IgG-rich fractions were discarded and IgA-rich fractions were eluted with 0.05 M NaCl in 0.01 M phosphate buffer, pH 8. The IgA concentration in the enriched fractions was quantified by radial immunodiffusion method after concentration by ultrafiltration with PM-30 filtering membranes (Amicon, Beverly, MA, USA) (cutoff molecular weight, 30,000 Da). The concentration of IgA was 35.8±15.2 mg/dl in the IgA-enriched fractions. IgA was also purified by affinity chromatography of different saliva on Jacalin agarose beads following the recommendations of the supplier (ICN Pharmaceuticals, Irvine, CA, USA) and previously described methods [21].

### ELISA procedure

Fifty microliters of synthetic  $\beta_1$  peptide solution (20  $\mu$ g/ml) in 0.1 M  $\text{Na}_2\text{CO}_3$  buffer, pH 9.6, was used to coat microtiter plates (NUNC, Kastrup, Denmark) at 4°C overnight.

After blocking the wells, diluted sera from patients with chronic severe periodontitis and healthy individuals (control) were added in triplicate and allowed to react with the peptide for 2 hours at 37°C. After the wells were thoroughly washed with 0.05% Tween 20 in phosphate buffered solution (PBS) 100  $\mu$ l of 1:6000 biotinylated goat anti-human IgA antibodies (Sigma Chemical Co., St. Louis, MO, USA) was added and incubated for 1 hour at 37°C. Then, a 1:6000 dilution of extravidin-alkaline phosphatase (Sigma) was allowed to react an extra 30 minutes at 37°C. After extensive washings, p-nitrophenylphosphate (1 mg/ml) was added as the substrate, and the reaction was stopped at 30 minutes. Finally, the plates were read at 405 nm and the results for each sample were expressed as the means and SD of triplicate values.

### Biomarker analysis

Concentration of salivary IL-1 $\beta$  (pg/ml), PGE<sub>2</sub> (ng/ml), nitrites ( $\mu$ M) and MMP-3 (ng/ml) were determined in duplicate using ELISA assay for each patient and the healthy individuals of the human colorimetric immunoreactive kits from Cayman Chemical (Ann Arbor, MI, USA), respectively.

### Drugs

The synthetic  $\beta_1$  peptide corresponded to the sequence of the second extracellular loop of the human  $\beta_1$ -AR (H-W-W-RA-E-S-D-E-A-R-R-C-Y-N-D-P-K-C-C-D-F-V-T-N-R-C) and a 27-mer non-related peptide S-G-S-G-S-G-S-G-S-G-S-G-S-G-S-G-S-G-S-G-S-G-S-G-S-G-S-G-S, as a negative control, were synthesized by Peptide Genetic Research Company (Livermore, CA, USA) as described previously [22].

### Statistical analysis

Student's t-test for unpaired values was used to determine the levels of significance. Analysis of variance (ANOVA) and a *post hoc* test (Dunnett's method and Student-Newman-Keuls test) were employed when pair-wise multiple comparison procedures were necessary. Differences between means were considered significant at  $P < 0.05$ .

## Results

It can be seen in (Table 2) the total salivary IgA (Total IgA ( $\mu\text{g/ml}$ ) in periodontitis patients:  $164\pm 19$ ; healthy subjects:  $180\pm 22$ ;  $n=15$  in each group) and its subtypes: IgA<sub>1</sub> ( $\mu\text{g/ml}$ ): periodontitis patients:  $66\pm 5^*$ ; healthy subjects:  $72\pm 6$ ;  $*P<0.0001$  comparing with healthy subjects;  $n=15$  in each group and IgA<sub>2</sub> ( $\mu\text{g/ml}$ ): periodontitis patients:  $98\pm 8^*$ ; healthy subjects:  $108\pm 9$ ;  $*P<0.0001$  comparing with healthy subjects;  $n=15$  in each group. Also, the values of the salivary flow (Basal salivary flow (ml/10 min) in periodontitis patients:  $1.2\pm 0.6^*$ ; healthy subjects:  $9.7\pm 3.5$ ;  $*P<0.0001$  comparing with healthy subjects;  $n=15$  in each group) were performed with commercial plates for radial immunodiffusion containing anti-IgA.

The distribution of anti- $\beta_1$ -AR IgA was studied in clarified human whole saliva (CHWS) from untreated chronic periodontitis patients, treated with PPIT chronic severe periodontitis patients and in healthy individuals (control). The scattergram of (Figure 1) shows that the optical density values (at 405 nm) of salivary anti- $\beta_1$ -AR IgA from CHWS of the untreated chronic severe periodontitis patients (periodontal CHWS) and those from chronic severe periodontitis patients treated with PPIT. Also, the optical density values in healthy individuals (control CHWS) was shown. It can be seen that the data from periodontal CHWS and periodontal CHWS+PPIT were significantly higher ( $P<0.0001$ ) than those of control CHWS. It is important to note that there is no significant difference between patients with chronic periodontitis before and after PPIT in the amount of this autoantibody. On the other hand, the immunoreactivity of saliva from untreated and treated patients were asserting the immunological recognition of the anti- $\beta_1$  AR IgA salivary only when the coating antigen is the synthetic  $\beta_1$  peptide.

## Discussion

The fair amount is known about the immunological mechanisms responsible for the pathology observed in the disease. The morphology of chronic periodontitis lesions, and the clinical signs and symptoms of the disease suggest that cytokines (IL-1 $\beta$ , PGE<sub>2</sub>) [23,24], nitric oxide levels [25] and cytoplasmic enzymes (MMP-3) [26] are important in the pathogenesis of the disorders. But, we considerer important to determine if the anti  $\beta_1$  adrenoceptor IgA present in the saliva of chronic severe patients, participates in the pathophysiology of the disease.

In this study we demonstrated high concentrations of IL-1 $\beta$ , PGE<sub>2</sub>, nitrites and MMP-3 in saliva from untreated chronic severe periodontitis patients. Moreover, the highest levels of IL-1 $\beta$  and PGE<sub>2</sub> were found in the saliva of these patients compared with those detected in healthy individuals (control). Previously was demonstrated that in human gingival fibroblasts are able to produce large amounts of PGE<sub>2</sub> in response to inflammatory cytokines, and the increased PGE<sub>2</sub> would be a potent stimulator of bone resorption [27]. Macrophages, mononuclear cells and fibroblasts from gingival tissues and endothelial cells are responsible for the increase in IL-1 $\beta$  production [28]; thus, there is a close association between IL-1 $\beta$  levels and periodontal disease status. After periodontal based therapy in patients with chronic periodontitis, IL-1 $\beta$  levels are reduced in all patients tested, which is correlated with clinical improvement. PGE<sub>2</sub> is thought to be involved in the pathogenesis of the oral lesions observed in untreated chronic periodontitis, because of its role as a potent stimulator of bone resorption and association with attachment loss was published [29]. Therefore, there is a reciprocal interaction between PGE<sub>2</sub> and IL-1 $\beta$ ; IL-1 $\beta$  is a potent stimulator of PGE<sub>2</sub> production in human gingival fibroblasts. However, PGE<sub>2</sub> differential regulates IL-1 $\beta$ -induced matrix metalloproteinase (MMP-3) production. In human gingival fibroblasts from healthy gingiva, PGE<sub>2</sub> down-regulates IL-1 $\beta$ -induced MMP-3 production, whereas in human gingival fibroblasts from periodontitis patients, PGE<sub>2</sub> enhances it [29]. These data may reflect the heterogeneity of immuno-inflammatory responses in healthy and disease conditions, in which the concentrations of IL-1 $\beta$ , PGE<sub>2</sub> MMP [30-31] may play a critical role as a marker of chronic severe periodontitis disease progression and oral manifestations.

The correlation between the amount of PGE<sub>2</sub> and MMP-3 in the saliva of each patient studied in this study has demonstrated an important relationship with the amount of anti- $\beta_1$  IgA. Analysis of this result, PGE<sub>2</sub> and MMP-3 performer on follow up studies underlines the correlation on the levels of the cytokine and the enzyme in the saliva of untreated patients with chronic periodontitis and the presence of salivary anti- $\beta_1$  IgA. It is important to note that, as previously reported, the pathogenesis of periodontal disease involves essential immunologic factors associated with infections caused by bacteria in sub-gingival plaques. The level of nitrite in saliva and its increment in patients with untreated chronic periodontitis was observed, and also an increased expression of iNOS in periodontal disease biopsy samples as well as in gingival fibroblast cell culture was described [22,32]. NO levels are associated with the severity of periodontitis, allowing differentiation between moderate and advanced generalized chronic periodontitis and NO levels were correlated with probing depth [25].

The biological plausibility of the differences observed in this study indicated that nitric oxide levels may be important in the pathogenesis of the disorders, and may be only in partly explained, by periodontal bacterial components triggering the host-immune response and causing inflammation and activation of pro-inflammatory mediators (IL-1 $\beta$ , PGE<sub>2</sub> and MMP-3). All of these molecules travelling in blood, together with those produced locally by the inflammatory process in the soft and hard oral tissues, might influence the pathophysiology of chronic periodontitis, but the real importance of the presence in the saliva of an anti  $\beta_1$  adrenoceptor IgA remain to be determined.

## Conclusions

The findings of the markedly elevated salivary IL-1 $\beta$ , PGE<sub>2</sub> and MMP-3 levels and their significant reduction post therapy in patients with chronic periodontitis compared to healthy individuals (control), suggest a close association between salivary cytokines and enzymes and the periodontal status. But, the real participation of an anti  $\beta_1$ adrenoceptor IgA present in the saliva of patients with severe chronic periodontitis, incorporated another pathophysiological factor in this multifactorial disease was not clarified yet in this present work. Future longitudinal studies with larger sample sizes are needed to validate in saliva not only if IL-1 $\beta$ , PGE<sub>2</sub> and MMP-3 are "real biomarkers" for periodontal disease but to know what role would play the autoantibody ( $\beta_1$  adrenoceptor IgA) present in the saliva of these patients in the course of the periodontal disease or in its pathophysiology.

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