Detection of *Aggregatibacter actinomycetemcomitans* leukotoxin and fimbria-associated protein gene genotypes among periodontitis patients and healthy controls: A case–control study

Krishnan Mahalakshmi1, Padma Krishnan2, S. C. Chandrasekaran3

1Department of Microbiology and Research Lab for Oral-Systemic Health, Sree Balaji Dental College and Hospital, Bharath Institute of Higher Education and Research, 2Department of Microbiology, Dr. ALM PGIBMS, University of Madras, 3Department of Periodontics and Implantology, Sree Balaji Dental College and Hospital, Bharath Institute of Higher Education and Research, Chennai, Tamil Nadu, India

**ABSTRACT**

**Background:** *Aggregatibacter actinomycetemcomitans* has been reported in higher proportions in subgingival microbiota of individuals with aggressive periodontitis (AgP) compared with those with chronic periodontitis (ChP) and healthy controls. The major virulence factors are the ones that help in colonization and evasion of host's defenses. Hence, this study was aimed to assess the prevalence of *A. actinomycetemcomitans* 16S rRNA and its virulent genotypes (leukotoxin [lktA] and fimbria-associated protein [fap]).

**Materials and Methods:** In this case–control study, we performed periodontal examination and measured probing depth and clinical attachment level (CAL). Subgingival plaque samples from 200 (ChP: n = 128 and AgP: n = 72) periodontitis patients and 200 healthy controls were screened for the presence of *A. actinomycetemcomitans* 16S rRNA, lktA, and fap genotypes by polymerase chain reaction. The prevalence of genotypes between periodontitis patients and healthy controls was compared with Pearson's Chi-square test. *P* < 0.05 was considered statistically significant.

**Results:** Mean pocket probing depth and CAL were high as compared to the healthy controls. The prevalence of *A. actinomycetemcomitans* in ChP (n = 128), AgP (n = 72), and healthy individuals (n = 200) was 32.0%, 61.1%, and 2.5%, respectively. *A. actinomycetemcomitans* lktA genotype prevalence was 71.8% among periodontitis patients, while *A. actinomycetemcomitans* fap genotype showed 31.8% prevalence. The prevalence of these genotypes was insignificant in healthy controls.

**Conclusion:** The high odds ratio for *A. actinomycetemcomitans* prevalence suggests its strong link to periodontitis. Detection of *A. actinomycetemcomitans* lktA + genotype may be a useful marker for AgP as its prevalence was found to be high in AgP.

**Key Words:** *Aggregatibacter actinomycetemcomitans*, aggressive periodontitis, chronic periodontitis, polymerase chain reaction

**INTRODUCTION**

*Aggregatibacter actinomycetemcomitans*, formerly *Actinobacillus actinomycetemcomitans*, is a major etiologic agent of aggressive periodontitis (AgP).[1-3] It also exists in chronic periodontitis (ChP) patients.

**Address for correspondence:** Dr. Padma Krishnan, Department of Microbiology Dr. ALM PGIBMS, University of Madras, Chennai - 600 113, Tamil Nadu, India. E-mail: padma.abpkn@gmail.com

**How to cite this article:** Mahalakshmi K, Krishnan P, Chandrasekaran SC. Detection of *aggregatibacter actinomycetemcomitans* leukotoxin and fimbria-associated protein gene genotypes among periodontitis patients and healthy controls: A case–control study. Dent Res J 2018;15:185-90.
and periodontally healthy individuals. The prevalence and serotypes of *A. actinomycetemcomitans* strains differ in different periodontal conditions. *A. actinomycetemcomitans* has been shown to possess numerous virulence factors that facilitate its survival in the oral cavity and enable it to evade the host’s protective mechanisms. The prime virulence factors are the ones that help in colonization and persistence (adhesins, invasins, bacteriocins, and antibiotic resistance) that interfere with the host’s defenses (leukotxin [*lktA*], lipopolysaccharides, chemotactic inhibitors, cytolethal distending toxin, immunosuppressive proteins, and Fe-binding proteins) and factors that destroy host tissues (cytotoxins, heat shock proteins, collagenase, and bone resorption agents). Among the various virulence factors reported, the fimbriae of *A. actinomycetemcomitans* play a major role in colonization of various types of host cells. The fimbria-associated protein (*fap*) gene is strongly expressed in fimbriated *A. actinomycetemcomitans* strains but not in nonfimbriated ones. Strains possessing fimbriae adhere more efficiently than nonfimbriated variants of *A. actinomycetemcomitans*. Neutrophils are successful in eradicating the pathogenic bacteria, but *A. actinomycetemcomitans* can produce a unique *lktA* encoded by the *lktA* gene that leads to the destruction of human neutrophils and monocytes.

This bacterial species has been reported in higher proportions in the subgingival microbiota of patients with localized AgP compared with those with ChP or in healthy controls. The main aim of the present study was to determine the prevalence of 16s rRNA of *A. actinomycetemcomitans* and its virulent genotypes (*A. actinomycetemcomitans* *lktA* gene and *fap* gene) in AgP, ChP, and healthy individuals.

**MATERIALS AND METHODS**

**Study population**

In this case-control study Two hundred periodontitis patients (ChP: *n* = 128 and AgP: *n* = 72) were recruited from the Department of Periodontics and Implantology, Tamil Nadu, Government Dental College and Hospital, Chennai, and Sree Balaji Dental College and Hospital for the study. The age of the study population ranged between 20 and 60 years. The inclusion criteria were more than three teeth with a pocket probing depth (PPD) of ≥5 mm and bleeding on probing. Patients who were on periodontal therapy and dental hygiene procedures in the past 1 year, those who were on antibiotic therapy during the past 6 months, pregnant women, and those with a history of diabetes, other systemic conditions, and smoking were excluded. Two hundred healthy controls with a PPD of ≤3 mm and ≤3.6% of sites which exhibited gingival bleeding were included as control group. Informed consent was obtained from patients and healthy controls. The present study was reviewed and approved by the human ethics committee of Dr. A.L.M Postgraduate Institute of Basic Medical Sciences, University of Madras, Chennai.

**Sample collection and DNA isolation**

The PPD and the clinical attachment level (CAL) were recorded. The PPD was measured with a graduated Williams’ periodontal probe, and subgingival plaque was collected from three different sites using a sterile Gracey curette after careful removal of supragingival plaque with sterile cotton roll from periodontitis patients and healthy controls. The samples from each patient were pooled into 500 μl of phosphate buffered saline (PBS, pH 8.0), transported in ice, and stored at −20°C until assay. Subgingival plaque samples in PBS were microcentrifuged at 10,000 rpm for 5 min, supernatant was discarded, and the pellet was resuspended in 150 μl of lysis broth (10 mmol/L Tris-HCl, 1.0 mmol/L EDTA, 1.0% Triton X-100, pH 8.0). The lysis broth was further vortexed and kept in water bath at 100°C for 10 min, cooled, and centrifuged at 10,000 rpm for 2 min. The supernatant was stored at −20°C and was used as template for polymerase chain reaction (PCR) assay.

**Polymerase chain reaction assays**

All the PCR analyses were performed in duplicate. Positive and negative controls were incorporated in all batches of the samples which were examined. The positive controls consisted of DNA extracted from clinical samples (subgingival plaque), which was previously tested and was found to be positive as was confirmed by PCR and gene sequencing (16S rRNA gene of *A. actinomycetemcomitans* GenBank accession no: HQ188689 and *A. actinomycetemcomitans* *lktA* gene GenBank accession no: HQ269830). Sterile millipore water was included as a negative control. The PCR reactions were run in a thermal cycler (Eppendorf Mastercycler Gradient; Eppendorf AG, Hamburg, Germany). The PCR mixture (50 μl) for detection of 16S rRNA gene of *A. actinomycetemcomitans* contained 5 μl of 10X PCR buffer.
(20 mM/L Tris-HCl, 50 mM/L KCl, pH 8.4), 1.25 U Taq DNA polymerase (Bangalore Genei Pvt., Ltd., India), 0.25 mmol/L of each dNTP (Medox Biotech India Pvt., Ltd.), 1.5 mM MgCl$_2$ (Sigma-Aldrich Pvt., Ltd., India), 0.5 µM of each primer (Sigma-Aldrich Pvt., Ltd., India) [Table 1] and 5 µl of the template. PCR thermocycling conditions included an initial denaturation at 95°C for 2 min, followed by 36 cycles at 94°C for 30 s, at 55°C for 1 min, and at 72°C for 2 min, and a final extension step at 72°C for 10 min.

**Polymerase chain reaction protocol for the detection of fimbria-associated protein and leukotoxin genes of *Aggregatibacter actinomycetemcomitans***

To detect *fap* and *lktA* genes of *A. actinomycetemcomitans*, PCR amplification was performed in a volume of 50 µl containing 5 µl of template, 5 µl PCR buffer (20 mM/L Tris-HCl, 50 mM/L KCl, pH 8.4), and 1 U Taq polymerase (Bangalore Genei Pvt., Ltd., India), 0.25 mmol/L of each dNTP, 2.5 mM/L MgCl$_2$, 50 pmol primers [Table 1] for *A. actinomycetemcomitans fap* gene, and 25 pmol primers for *A. actinomycetemcomitans lktA* gene. Thermal cycling conditions included an initial denaturation at 94°C for 5 min, followed by 36 cycles at 94°C for 1 min, 50°C for 1 min, and 72°C for 1.5 min, and a final extension step at 72°C for 7 min.

**Gel electrophoresis**

The PCR products were fractionated in a 1.5% agarose gel electrophoresis in Tris-borate EDTA buffer. The gel was stained with 0.5 µg/ml ethidium bromide and photographed under a Bio-Rad UV gel documentation system. 100 bp ladder (Medox Biotech India Pvt., Ltd.) was served as a molecular weight marker [Figures 1-3].

**Statistical analysis**

The mean clinical measurements such as PPD and CAL were computed for each patient, and they

---

**Table 1: Primers used for the study**

| Gene   | Primers                                      | Amplicon size (bp) |
|--------|----------------------------------------------|--------------------|
| 16S rDNA | Forward-5'-AAACCCATCTCTGAGGTTCTTCTTC-3'   | 443                |
|         | Reverse-5'-ATGCCAACTTGACGTTAAAT-3'          |                    |
| (Slots et al., 1995) |                                         |                    |
| lktA   | 5'TCGCGAATCAGCTCGCCG-3'                      | 285                |
|         | 5'GCTTTGCAAGTCTCCAC-3'                       |                    |
| (Watanabe and Frommel, 1996) |                                    |                    |
| fap    | 5'-ATTAATCTTAAACTACTAAAGC-3'                | 210                |
|         | 5'-GCACGTATGAGTCTGACG-3'                     |                    |
| (Ishihara et al., 1997) |                                      |                    |
were then averaged across the patients within the groups. Any difference of $P < 0.05$ was considered as statistically significant. The prevalence of the genotypes between periodontitis patients and healthy controls was compared with Pearson’s Chi-square test. A $P < 0.05$ was considered as statistically significant. Odds ratio was calculated using Fisher’s exact test.

RESULTS

A significant difference was observed for mean PPD and CAL ($P = 0.0001$) between the study population and control group [Table 2]. The prevalence in ChP ($n = 128$), AgP ($n = 72$), and healthy individuals ($n = 200$) was 32.0%, 61.1%, and 2.5% for \textit{A. actinomycetemcomitans} 16S rRNA, respectively. The prevalence of \textit{A. actinomycetemcomitans} lktA gene and \textit{fap} gene among periodontitis (ChP and AgP) patients was 71.8% and 31.8%, respectively. Two out of five \textit{A. actinomycetemcomitans}-positive healthy controls showed the presence of lktA gene. Table 3 shows \textit{A. actinomycetemcomitans} lktA gene and \textit{fap} gene prevalence in different groups. The odds of detecting \textit{A. actinomycetemcomitans} 16S rRNA was 25.82 times high in individuals with periodontitis as compared to those in healthy controls. A significant prevalence was observed for lktA genotype among ChP and AgP patients compared to \textit{fap} genotype. The presence of both lktA and \textit{fap} genes was observed in 17 (23.6%) AgP and 6 (4.7%) ChP patients, respectively ($P > 0.05$). \textit{A. actinomycetemcomitans} lktA + \textit{fap} + genotype were present in periodontitis patients with pocket depth $\geq$7 mm.

DISCUSSION

In agreement with the previous studies,[2,14,17-21] the results of the present study support the notion that \textit{A. actinomycetemcomitans} is a predominant pathogen in the etiology of AgP. The occurrence of \textit{A. actinomycetemcomitans} in AgP and ChP is associated with severity of the disease in regard to PPD and CAL. \textit{A. actinomycetemcomitans} was most frequently detected in sites with pocket depth $\geq$5 mm and clinical attachment loss $\geq$7 mm. The prevalence of \textit{A. actinomycetemcomitans} (61.1%) among AgP in the present study is statistically significant ($P = 0.0001$).

In contrast to the results of the present study by PCR (61.1% in AgP, 32.0% in ChP, and 2.5% in healthy controls), Yang et al.[5] have reported a higher prevalence of 84.3%, 60.4%, and 64.0% in AgP, ChP, and healthy periodontal individuals, respectively, by indirect immunofluorescence assay using serotype-specific polyclonal antisera to \textit{A. actinomycetemcomitans}. The prevalence of \textit{A. actinomycetemcomitans} among ChP is consistent with few earlier studies.[22-24] The present study shows a very low prevalence of \textit{A. actinomycetemcomitans} in healthy controls compared to Kumar et al., 2003,[25] who have reported 21% and 30% in ChP and healthy individuals, respectively. On the contrary, Junior et al., 2006[26] have reported a very high prevalence (76.7%) in healthy controls. The present study reports a high prevalence of \textit{A. actinomycetemcomitans} among periodontitis patients compared to few other studies.[27-32] On the contrary, a number of studies have reported a higher prevalence than the present study in AgP.[6,20,26,33]

One of the most intriguing properties of \textit{A. actinomycetemcomitans} lktA is its ability to selectively kill human neutrophils and monocytes. Here, we report a very high prevalence (81.8%) of \textit{A. actinomycetemcomitans} lktA + genotype among AgP patients exhibiting a very good statistical significance in comparison with healthy controls ($P < 0.033$). The prevalence of \textit{A. actinomycetemcomitans} lktA + genotype (61.0%) among ChP patients was low compared to the finding of Wu et al., who have reported 75.4% in the Chinese population.[16] Junior et al. have observed leukotoxic genotype only in patients with generalized aggressive disease, while we have shown a significant presence in ChP as well.[26]
A. actinomycetemcomitans fap + genotype showed a prevalence of 22.0% in ChP patients which is relatively low when compared to the findings of Wu et al., 2007, who have reported 50% in ChP patients. Conversely, A. actinomycetemcomitans fap + genotype were detected among 40.9% of AgP patients. Only one (20.0%) healthy controls showed the presence of A. actinomycetemcomitans fap + genotype. Statistical significance was not observed for fap genotype (P = 0.581).

As predicted, none of the A. actinomycetemcomitans 16S rRNA-negative samples was positive for either lktA or fap. AgP is a disease of adolescents that can have profound cosmetic, functional, and psychological effects with the highest prevalence of A. actinomycetemcomitans. Hence, microbiological analyses to identify A. actinomycetemcomitans in subgingival plaque samples are important for screening, treatment planning, treatment evaluation, and monitoring of periodontal diseases.

CONCLUSION

The high odds ratio for A. actinomycetemcomitans suggests a strong association between them and periodontitis. Detection of A. actinomycetemcomitans lkt + genotype may be a useful marker for AgP as its prevalence was found to be very high in AgP group in the present study.

Acknowledgments

We thank Dr. K. H. Panishankar, Professor, Department of Periodontics and Implantology, Tamil Nadu, Government Dental College and Hospital, Chennai, for help rendered in collection of clinical samples.

Financial support and sponsorship

This work was supported by the funds which were generated through the university–industry collaborative research program of the University of Madras.

Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

REFERENCES

1. Cortelli JR, Cortelli SC, Jordan S, Haraszthy VI, Zambon JJ. Prevalence of periodontal pathogens in Brazilians with aggressive or chronic periodontitis. J Clin Periodontol 2005;32:860-6.
2. Leung WK, Ngai VK, Yau JY, Cheung BP, Tsang PW, Corbet EF, et al. Characterization of Actinobacillus actinomycetemcomitans isolated from young Chinese aggressive periodontitis patients. J Periodontal Res 2005;40:258-68.
3. Nonnenmacher C, Mutters R, de Jacoby LF. Microbiological characteristics of subgingival microbiota in adult periodontitis, localized juvenile periodontitis and rapidly progressive periodontitis subjects. Clin Microbiol Infect 2001;7:213-7.
4. Gafan GP, Lucas VS, Roberts GJ, Petrie A, Wilson M, Spratt DA, et al. Prevalence of periodontal pathogens in dental plaque of children. J Clin Microbiol 2004;42:4141-6.
5. Yang HW, Huang YF, Chan Y, Chou MY. Relationship of Actinobacillus actinomycetemcomitans serotypes to periodontal condition: Prevalence and proportions in subgingival plaque. Eur J Oral Sci 2005;113:28-33.
6. Lakio L, Kuula H, Dogan B, Asikainen S. Actinobacillus actinomycetemcomitans proportion of subgingival bacterial flora in relation to its clonal type. Eur J Oral Sci 2002;110:212-7.
7. Malik R, Changela R, Krishan P, Gugnani S, Bali D. Virulence factors of Aggregatibacter actinomycetemcomitans – A status update. J Int Clin Dent Res Organ 2015;7:137-45.
8. Ishihara K, Honma K, Miura T, Kato T, Okuda K. Cloning and sequence analysis of the fimbiae associated protein (fap) gene from Actinobacillus actinomycetemcomitans. Microb Pathog 1997;23:63-9.
9. Inoue T, Tanimoto O, Ohta H, Kato K, Murayama Y, Fukui K, et al. Molecular characterization of low-molecular-weight component protein, Flp, in Actinobacillus actinomycetemcomitans fimbiae. Microbiol Immunol 1998;42:253-8.
10. Guthmiller JM, Lally ET, Korostoff J. Beyond the specific plaque hypothesis: Are highly leukotoxic strains of Actinobacillus actinomycetemcomitans a paradigm for periodontal pathogenesis? Crit Rev Oral Biol Med 2001;12:116-24.
11. Poulsen K, Ennibi OK, Haubek D. Improved PCR for detection of the highly leukotoxic JP2 clone of Actinobacillus actinomycetemcomitans in subgingival plaque samples. J Clin Microbiol 2003;41:4829-32.
12. Slots J, Reynolds HS, Genco RJ. Actinobacillus actinomycetemcomitans in human periodontal disease: A cross-sectional microbiological investigation. Infect Immun 1980;29:1013-20.
13. Mandell RL, Socransky SS. A selective medium for Actinobacillus actinomycetemcomitans and the incidence of the organism in juvenile periodontitis. J Periodontol 1981;52:593-8.
14. Zambon JJ, DeLuca C, Slots J, Genco RJ. Studies of leukotoxin from Actinobacillus actinomycetemcomitans using the promyelocytic HL-60 cell line. Infect Immun 1983;40:205-12.
15. Bueno LC, Mayer MF, DiRienzo JM. Relationship between conversion of localized juvenile periodontitis-susceptible children from health to disease and Actinobacillus actinomycetemcomitans leukotoxin promoter structure. J Periodontol 1998;69:998-1007.
16. Wu YM, Yan J, Chen LL, Gu ZY. Association between infection of different strains of Porphyromonas gingivalis and Actinobacillus actinomycetemcomitans in subgingival plaque and clinical parameters in chronic periodontitis. J Zhejiang Univ Sci B 2007;8:121-31.
17. Haraszthy VI, Harirahan G, Tinoco EM, Cortelli JR, Lally ET,
Davis E, et al. Evidence for the role of highly leukotoxic Actinobacillus actinomycetemcomitans in the pathogenesis of localized juvenile and other forms of early-onset periodontitis. J Periodontol 2000;71:912-22.

18. Haubek D, Ennibi OK, Abdellaoui L, Benzarti N, Poulsen S. Attachment loss in Moroccan early onset periodontitis patients and infection with the JP2-type of Actinobacillus actinomycetemcomitans. J Clin Periodontol 2002;29:657-60.

19. Yang HW, Asikainen S, Doğan B, Suda R, Lai CH. Relationship of Actinobacillus actinomycetemcomitans serotype b to aggressive periodontitis: Frequency in pure cultured isolates. J Periodontol 2004;75:592-9.

20. Lee JW, Choi BK, Yoo YJ, Choi SH, Cho KS, Chai JK, et al. Distribution of periodontal pathogens in Korean aggressive periodontitis. J Periodontol 2003;74:1329-35.

21. Schacher B, Baron F, Rossberg M, Wohlfeil M, Arndt R, Eickholz P, et al. Aggregatibacter actinomycetemcomitans as indicator for aggressive periodontitis by two analysing strategies. J Clin Periodontol 2007;34:566-73.

22. Meng S, Zhao L, Yang H, Wu Y, Ouyang Y. Prevalence of Actinobacillus actinomycetemcomitans in Chinese chronic periodontitis patients and periodontally healthy adults. Quintessence Int 2009;40:53-60.

23. Ashimoto A, Chen C, Bakker I, Slots J. Polymerase chain reaction detection of 8 putative periodontal pathogens in subgingival plaque of gingivitis and advanced periodontitis lesions. Oral Microbiol Immunol 1996;11:266-73.

24. Vieira EM, Raslan SA, Wahasugui TC, Avila-Campos MJ, Marvulle V, Gaetti-Jardim Júnior E, et al. Occurrence of Aggregatibacter actinomycetemcomitans in Brazilian Indians from Umutina reservation, Mato Grosso, Brazil. J Appl Oral Sci 2009;17:440-5.

25. Kumar PS, Griffen AL, Barton BJ, Paster BJ, Moeschberger ML, Leys EJ, et al. New bacterial species associated with chronic periodontitis. J Dent Res 2003;82:338-44.

26. Junior WR, Souza RC, Andrade AF, Colombo AP. Analysis of leukotoxin gene types of A. actinomycetemcomitans in Brazilians with aggressive periodontitis. Brazil J Microbiol 2006;37:127-34.

27. Mullally BH, Dace B, Shelburne CE, Wolff LF, Coulter WA. Prevalence of periodontal pathogens in localized and generalized forms of early-onset periodontitis. J Periodontal Res 2000;35:232-41.

28. Takeuchi Y, Umeda M, Ishizuka M, Huang Y, Ishikawa I. Prevalence of periodontopathic bacteria in aggressive periodontitis patients in a Japanese population. J Periodontol 2003;74:1460-9.

29. Cortelli JR, Roman-Torres CV, Aquino DR, Franco GC, Costa FO, Cortelli SC, et al. Occurrence of Aggregatibacter actinomycetemcomitans in Brazilians with chronic periodontitis. Braz Oral Res 2010;24:217-23.

30. Lafaurie GI, Contreras A, Barón A, Botero J, Mayorga-Fayad I, Jaramillo A, et al. Demographic, clinical, and microbial aspects of chronic and aggressive periodontitis in Colombia: A multicenter study. J Periodontol 2007;78:629-39.

31. Herrera D, Contreras A, Gamonal J, Oteo A, Jaramillo A, Silva N, et al. Subgingival microbial profiles in chronic periodontitis patients from Chile, Colombia and Spain. J Clin Periodontol 2008;35:106-13.

32. Yoshida Y, Suzuki N, Nakano Y, Shibuya K, Ogawa Y, Koga T, et al. Distribution of Actinobacillus actinomycetemcomitans serotypes and Porphyromonas gingivalis in Japanese adults. Oral Microbiol Immunol 2003;18:135-9.

33. Chen LL, Wu YM, Yan J, Sun WL, Sun YZ, Ojcius D, et al. Association between coinfection of Porphyromonas gingivalis, Actinobacillus actinomycetemcomitans and Treponema denticola and periodontal tissue destruction in chronic periodontitis. Chin Med J (Engl) 2005;118:915-21.