

Micro RNA-146a effect on Periodontitis is Independent on OPG/RANKL Axis

Mandana Sattari

Shahid Beheshti University of Medical Sciences

Somayeh Ghotloo

Kashan University of Medical Sciences

Ramezan-Ali Taheri

Baqiyatallah University of Medical Sciences

Reza ArefNezhad

Shiraz University of Medical Sciences

Hossein Motedayyen (✉ hmotedayyen@gmail.com)

Kashan University of Medical Sciences

Research Article

Keywords: MiR-146a, OPG, Periodontitis, RANKL.

Posted Date: June 23rd, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-598474/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Background

MicroRNA-146a (miR-146a) is a regulator of inflammatory response. Periodontitis is a disease with immune pathophysiology of the periodontium in which the inflammation results in the destruction of the soft tissues and alveolar bone. Therefore, this study was investigated whether miR-146a may contribute to periodontitis through affecting the levels of OPG and RANKL.

Methods

The levels of miR-146a, RANKL, and OPG in gingival tissues from patients with generalized periodontitis stages II and III and grades A and B (n = 15, group A), patients with generalized periodontitis stages III and IV and grade C (n = 15, group B), and healthy individuals (n = 10) were determined by real-time PCR. The associations of miR-146a expression with OPG and RANKL levels were evaluated.

Results

The levels of miR-146a in two subgroups within periodontitis patients were significantly higher than healthy subjects ($P < 0.0001$). MiR-146a showed the increased level in group A of patients compared with group B ($P < 0.05$). Clinical parameters such as probing depth (PD) and clinical attachment loss (CAL) were significantly higher in patients than control group ($P < 0.05$). The levels of OPG and RANKL were increased in patients compared with healthy subjects, although the elevated levels were not statistically significant. MiR-146a was not associated with the levels of OPG and RANKL.

Conclusion

The results of this study failed to show the effect of miR-146a on the pathophysiology of disease through OPG/RANKL axis.

Clinical Relevancy:

MiR-146a may participate in the pathophysiology of disease through independent mechanism(s) of OPG/RANKL axis.

Background

MicroRNAs (miRNAs) are small ribonucleic acids (RNAs) which participate in the gene regulation at post-transcriptional level affecting more than 30% of human genes (1, 2). They bind to the complementary

regions in messenger RNAs (mRNAs) resulting in their degradation and/or translation inhibition (1). MicroRNA-146a (miR-146a) as a member of miRNAs controls innate immunity and inflammation through down-regulation of inflammatory mediators (3, 4).

Periodontitis is a disease with immune pathophysiology of the periodontium which the inflammation damages the soft tissues and destroys the alveolar bone (5). The consequences are detachment of gingival tissues from the teeth, destruction of alveolar bone, and loss of teeth (5).

Alveolar bone destruction is stimulated by osteoclasts. The differentiation and function of osteoclast are induced by receptor activator of nuclear factor- κ B ligand (RANKL) upon binding to its receptor, RANK (6). Osteoprotegerin (OPG) is a decoy receptor which binds to RANKL and inhibits its binding to RANK, and thereby preventing osteoclastogenesis (6). The inflammation affects bone homeostasis through enhancing the expression of RANKL and reducing the production of OPG (6).

Extensive data from the literature have indicated that patients with periodontitis had the increased level of miR-146a in comparison with healthy subjects (7–9). Previous studies revealed that the level of miR-146a was directly correlated to the clinical features of disease severity including probing depth (PD) and clinical attachment loss (CAL). It is suggested that miR-146a may contribute to the pathogenesis of the disease (10, 11). Furthermore, animal studies have provided some evidence to show that miR-146a exerts anti-inflammatory impacts in periodontitis through inhibiting the expressions of the pro-inflammatory cytokines such as tumor necrosis factor- α (TNF- α), interleukin-1 β (IL-1 β), and interleukin-6 (IL-6) in periodontal tissue (7, 12, 13). On the other hand, several reports have demonstrated that pro-inflammatory cytokines stimulate the expression of RANKL and suppress the production of OPG (14–16). This study was therefore focused on investigating whether miR-146a exerts anti-inflammatory impacts on pathobiology of disease through RANKL/OPG axis.

Methods

Sample collection and clinical examination

Gingival tissue samples were obtained from 30 periodontitis patients and 15 healthy subjects. Patients were divided into two groups according to the new classification of periodontitis (17) including: 1) patients with generalized periodontitis stages II and III and grades A and B (n = 15, group A); 2) patients with generalized periodontitis stages III and IV and grade C (n = 15, group B). The diagnosis of periodontitis and its stage, extent, and grade was performed by a periodontist based on the new classification of periodontitis (17). Supra- and sub-gingival scaling, polishing, and oral hygiene instructions were performed at least 1 month before surgery as the preliminary phase of periodontal therapy. The average sizes of gingival tissue samples obtained from periodontitis and healthy subjects were about 25 and 8.5 mm, respectively.

Gingival tissues used as control group were obtained from healthy individuals during crown-lengthening surgery with the inclusion criteria including PD < 3 mm, CAL < 3 mm and no evidence of the alveolar bone

destruction based on the radiographic images.

The informed consent was collected from the participants. This study was approved by the Ethics Committee of Kashan University of Medical Sciences and performed according to the principles of Helsinki Declaration. Clinical parameters (PD and CAL) were measured by a calibrated periodontal probe (Hu Friedy, Chicago, Illinois, USA).

Measurements of the expression levels of miR-146a, OPG, and RANKL

To determine the relative expression level of miR-146a, gingival tissue samples were homogenized using 1.0-mm silicon carbide beads (BioSpec products, Bartlesville, OK, USA). The researchers were blinded to sample information. Total RNA was isolated using a mirVana miRNA isolation kit (Ambion, Thermo Fisher Scientific, Waltham, MA, USA) according to the manufacturer's protocol. The yield and purity of RNAs were quantified by nano drop (BioTek, Epoch, USA). Afterwards, RNA was reverse transcribed to complementary DNA (cDNA) using a TaqMan microRNA Reverse Transcription Kit (Applied Biosystems, Thermo Fisher Scientific, USA) based on the manufacturer's instructions. The level of mature miR-146a was quantified by real-time polymerase chain reaction (Real-time PCR). This method was performed using a Rotor Gene 6000 (Qiagen, Hilden, Germany), TaqMan® Universal Master Mix II, no UNG, and hsa-miRNA146a kits (Applied Biosystems, USA). The machine was programmed as follows: 30 seconds incubation at 95°C followed by 40 cycles consisted of a 95°C denaturing temperature for 5 seconds and an annealing-extension temperature at 60°C for 30 seconds. A non-template control containing 0.5 µL of Dnase/Rnase free water was used as the negative control. All analyses were performed in duplicate.

To measure the levels of OPG and RANKL, cDNAs were synthesized from total RNAs using a RevertAid First Strand cDNA Synthesis Kit (Thermo Fisher Scientific, Wilmington, Delaware, USA). Afterwards, Real-time PCR was performed in a reaction mixture consisted of Master Mix (7.5 µL) (SYBR® Premix Ex Taq™ II; TaKaRa, Kyoto, Japan), 10 pM forward and reverse primers (0.5 µL), cDNA template (0.5 µL), and DNase-RNase free water (6 µL). The cycling parameters for OPG and RANKL were the same as those used to miR-146a. The melting curve was generated in 55°C to 99°C temperature range. Sequences of the primers are shown in Table. 1.

Glyceraldehyde 3 phosphate dehydrogenase (GAPDH) gene expression served as endogenous control to normalize the expression of genes (Table 1). With the exception of the annealing temperature (55°C for 30 seconds), the mixture reaction and cycling parameters were similar to those for RANKL and OPG. Relative expressions of OPG and RANKL were calculated using $2^{-\Delta\Delta ct}$ method (18).

Table 1
Sequences of primers used in the real-time PCR.

Genes	Forward primer (5'-3')	Reverse primer (5'-3')
OPG	GTTTCCGGGGACCACAATGA	ACACGGTCTTCCACTTTGCT
RANKL	AGAGCAGAGAAAGCGATGGT	GATGGGATGTCGGTGGCATT
GAPDH	CTCTGGTAAAGTGGATATTG	GGTGAATCATATTGGAACA

RANKL: receptor activator of nuclear factor-kB ligand; OPG: osteoprotegerin; GAPDH: glyceraldehyde 3 phosphate dehydrogenase.

Table 2
The demographic and clinical characteristics of patient and healthy individuals.

	Group A	Group B	Healthy subjects
Age	42 ± 8	31 ± 7	29 ± 10
CAL (mm)	*4.5 ± 0.35	*7 ± 0.53	2.5 ± 0.28
PD (mm)	*5.78 ± 0.44	*5.35 ± 0.41	2.25 ± 0.25

Data are representative of the mean ± SD. The scores of CAL and PD in periodontitis patients were significantly higher than healthy subjects. * P < 0.05.

Statistical analysis

Data analyses were carried out using the SPSS program (v. 20; SPSS, Chicago, USA). The results are presented as mean ± standard deviation (SD). Kolmogorov-Smirnov test was used to determine normal distribution of data. The comparisons of two groups in normal and non-normal distribution cases were performed by using student's t-test and Mann-Whitney U test, respectively. The correlation analyses were done using Pearson's test (for normal distributions) and Spearman's test (for non-normal distributions). P value < 0.05 was considered statistically significant.

Results

Clinical findings

To determine clinical features of patients and confirm periodontitis, the PD and CAL values of patients and healthy subjects were assessed. As shown in Table. 2, patients in two subgroups within periodontitis had statistically significant higher PD and CAL scores than control group (P < 0.05).

Expression level of miR-146a in gingival tissues of participants

Regarding the fact that miR-146a can be considered as a negative feedback regulator of innate immunity and has possible role in the pathogenesis of some inflammatory diseases, the expression level of miR-146a in periodontitis was investigated. Our results revealed that both groups of patients with generalized periodontitis had an increased level of miR-146a compared with healthy individuals after one-month initial unsuccessful non-surgical treatment ($P < 0.001$, Figure. 1). In addition, miR-146a level was significantly higher in group A of patients (subjects with generalized periodontitis stages II and III and grades A and B) than group B of patients (subjects with generalized periodontitis stages III and IV and grade C) ($P < 0.05$, Figure. 1).

The expression levels of RANKL and OPG in gingival tissues of participants

Having considered that RANKL induces the destruction of alveolar bone, its expression level was analyzed using real-time PCR assay. The expression level of RANKL in gingival tissue of patients in two groups of generalized periodontitis did not statistically differ from that of healthy individuals (Figure. 2A).

In addition, the expression level of OPG, a main inhibitor of the bone destruction, in both groups of patients did not show significant changes compared with healthy subjects (Figure. 2B).

Associations of miR-146a level with RANKL and OPG levels in gingival tissues

To explore possible mechanism(s) suggesting miR-146a impact on the pathogenesis of periodontitis, correlations of miR-146a level with RANKL and OPG were analyzed. No significant association was observed between miR-146a and OPG and RANKL levels.

Discussion

MiRNAs have an important role in several biologic processes, including differentiation, proliferation, and apoptosis of the cells (19, 20). It is reported that changes their levels participate in the development of different diseases such as cancers, cardiovascular diseases, chronic hepatitis, and diabetes (21–24). MiR-146a controls inflammatory responses through down-regulating the expressions of IL-1 receptor-associated kinase-1 (IRAK-1) and tumor necrosis factor receptor-associated factor 6 (TRAF 6) (25, 26). Thus, dysfunction and/ or down-regulation of miR-146a results in the pathogenesis of inflammatory diseases, especially periodontitis (8). In our knowledge, there is no report pointing to anti-inflammatory effect of miR-146a on the pathogenesis of the disease through RANKL/OPG axis. This study was therefore focused on determining the possible contribution of miR-146a in this field.

In previous study, we observed the level of miR-146a in gingival tissues of patients with chronic periodontitis, a form of the disease according to the update of the 1999 American academy of periodontology classification criteria (27, 28), was directly correlated to clinical scores (CAL and PD) of periodontitis. Furthermore, it was observed that level of miR-146a had a direct association with the clinical scores of disease severity in aggressive periodontitis (10, 11), as another form of the disease according to the old classification of periodontitis (27). These findings suggest that miR-146a may be

associated with the pathobiology of disease. In an effort to explore possible downstream targets by which miR-146a may contribute to the pathobiology of disease, the levels of the main pro-inflammatory cytokines such as TNF- α , IL-1 β , and IL-6 were studied in patients with chronic and aggressive periodontitis (29, 30). With the expectation of IL-1 β level in chronic periodontitis, the results showed significant reductions in the levels of pro-inflammatory cytokines in two subgroups within periodontitis patients (10, 11). However, these studies failed to indicate the associations of pro-inflammatory cytokines with the major clinical factors of disease severity. Thus, the key question was how miR-146a may participate in the development and outcome of the disease. In the present study, the levels of two molecular factors involved in the pathogenesis of periodontitis along with miR-146a level were investigated.

Our study showed that miR-146a had an increased level in two subgroups within periodontitis. Interestingly, group A of patients experienced a significant increase in miR-146a level compared with group B of patients. In agreement with these observations, our previous studies revealed that the expressions of IL-1 β , IL-6, and TNF- α were higher in gingival tissue of patients with chronic periodontitis than subjects with aggressive periodontitis (29, 30). These findings suggest that inflammation reactions have higher severity in chronic periodontitis or early disease stages than aggressive form or late disease stages, which the disease progression occur in higher rate (31). Regarding the anti-inflammatory impacts of miR-146a, it is likely that the elevated level of this miRNA is a regulatory response to control destructive and inflammatory responses, leading to the reductions in the destructions of the connective tissue and alveolar bone in group A of patients compared with subjects in group B.

In an attempt to determine other downstream targets influenced by miR-146a, the levels of OPG and RANKL were assessed in two groups of patients. The elevated expressions of OPG and RANKL were observed in periodontitis patients upon preliminary phase of periodontal therapy, although these increases were not statistically significant, due perhaps to low sample size. Furthermore, the expression levels of RANKL and OPG were respectively decreased and increased upon the disease development. These findings were in contract with the results of some studies indicating the elevated level of RANKL accompanied by a significant reduction in OPG level during the disease progression (32–34). However, immunohistochemical studies on periodontal tissues have revealed a negative expression of RANKL and a positive expression of OPG in both oral and periodontal pocket epithelium (35). Moreover, several lines of evidence reveal that RANKL and OPG levels have the tendency to the reduction and elevation upon non-surgical periodontal treatment, respectively (36, 37).

As mentioned previous, miR-146a down-regulates IRAK-1 and TRAF 6, which are the key adaptors in signaling by toll like receptors (TLRs) and cytokine receptors (4). Down-regulation of these adaptor proteins result in the abolished activation of nuclear factor-kappa B, which is a central transcription factor in the transcription of pro-inflammatory genes (38). Other studies have demonstrated that pro-inflammatory cytokines stimulate the expression of RANKL and suppress the production of OPG (14–16). These studies suggest that the reduced level of RANKL and increased expression of OPG during the

disease progression may relate to the elevated levels of miR-146a level in the early disease stage to exert a negative impact on pro-inflammatory cytokine productions and thereby reduce disease progression.

In the next step, to determine the possible impact of miR-146a on the levels of RANKL and OPG, the correlations of miR-146a level with these molecular factors were evaluated. Our results showed that miR-146a level was not correlated to OPG level.

Conclusion

Although it is thought that miR-146a has indirectly effects on RANKL/OPG axis through reducing pro-inflammatory cytokines. The results of this study provide evidence to indicate that anti-inflammatory impacts of miR-146a are independent on RANKL/OPG axis. Nevertheless, additional studies with larger sample sizes are required to confirm our findings and explain the possible mechanism(s) involved in anti-inflammatory effects of miR146a on disease development. It is worthy that future studies will be designed to clarify the impacts of miR-146a on other inflammatory mediators such as prostaglandins, leukotrienes, macrophage colony-stimulating factor, and fibroblast growth factor, which play indispensable roles in bone homeostasis and periodontal disease progression (39).

Abbreviations

TLR: toll like receptor; MiR-146a: microRNA-146a; PD: probing depth; CAL: clinical attachment loss; MiRNA: microRNAs; RNA: small ribonucleic acids; RANKL: receptor activator of nuclear factor-kB ligand; OPG: Osteoprotegrin; TNF- α : tumor necrosis factor-alpha; IL-1 β : interleukin-1 β ; IL-6: interleukin-6; cDNA: complementary DNA; Real-time PCR: real-time polymerase chain reaction; GAPDH: Glyceraldehyde 3 phosphate dehydrogenase; SD: standard deviation; IRAK-1: IL-1 receptor-associated kinase-1; TRAF 6: tumor necrosis factor receptor-associated factor 6.

Declarations

Ethics approval and consent to participate

This work was confirmed by the Ethics Committee of Kashan University of Medical Sciences. Written informed consent to participate in the study was obtained from all subjects before entering the study.

Consent for publication

Not applicable. No personal information was provided in this paper.

Availability of data and materials

All data generated or analyzed during this study are included in this published article. No sequencing data generated in this study to deposit in a suitable public repository such as the National Center for Biotechnology Information (NCBI) database. The raw data are available from the authors to any

researcher who wishes to collaborate with us. Correspondence should be addressed to Hossein Motedayyen at the following email address. Email address: hmotedayyen@gmail.com. Specific primers were

designed using Allele ID 7.5 software (Premier Biosoft) and checked by Primer-BLAST (NCBI) which is an open access database.

Competing interests

The authors declare that there is no conflict of interests.

Funding

This study was financially supported by Kashan University of Medical Sciences (KAUMS, grant no: 92081). KAUMS did not participate in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

Authors' contributions

MS participated in the disease diagnosis. SGh participated in the design of some experiments, and statistical analysis of the data. RAT and RA carried out some of the experiments. HM obtained funding for this work, participated in the study design, and drafted the manuscript. The authors read and approved the final version of manuscript.

Acknowledgement

The authors thank all subjects who participated in this study.

References

1. Ebert MS, Sharp PA. Roles for microRNAs in conferring robustness to biological processes. *Cell*. 2012;149(3):515–24.
2. Lewis BP, Burge CB, Bartel DP. Conserved seed pairing, often flanked by adenosines, indicates that thousands of human genes are microRNA targets. *Cell*. 2005;120(1):15–20.
3. Rusca N, Monticelli S. MiR-146a in Immunity and Disease. *Mol Biol Int*. 2011;2011:437301.
4. Taganov KD, Boldin MP, Chang KJ, Baltimore D. NF-kappaB-dependent induction of microRNA miR-146, an inhibitor targeted to signaling proteins of innate immune responses. *Proc Natl Acad Sci U S A*. 2006;103(33):12481–6.
5. Page RC, Offenbacher S, Schroeder HE, Seymour GJ, Kornman KS. Advances in the pathogenesis of periodontitis: summary of developments, clinical implications and future directions. *Periodontol* 2000. 1997;14:216 – 48.

6. Hienz SA, Paliwal S, Ivanovski S. Mechanisms of Bone Resorption in Periodontitis. *J Immunol Res.* 2015;2015:615486.
7. Gao Y, Hao C. Expression of miR-146a in saliva of chronic periodontitis patients and its influence on gingival crevicular inflammation and MMP-8/TIMP-1 levels. *Shanghai kou qiang yi xue = Shanghai journal of stomatology.* 2018;27(3):309–12.
8. Xie Yf, Shu R, Jiang Sy, Liu DI, Zhang XI. Comparison of microRNA profiles of human periodontal diseased and healthy gingival tissues. *International journal of oral science.* 2011;3(3):125–34.
9. Zhao S, Cheng Y, Kim JG. microRNA-146a downregulates IL-17 and IL-35 and inhibits proliferation of human periodontal ligament stem cells. *Journal of cellular biochemistry.* 2019;120(8):13861–6.
10. Motedayyen H, Ghotloo S, Saffari M, Sattari M, Amid R. Evaluation of MicroRNA-146a and Its Targets in Gingival Tissues of Patients With Chronic Periodontitis. *J Periodontol.* 2015;86(12):1380–5.
11. Ghotloo S, Motedayyen H, Amani D, Saffari M, Sattari M. Assessment of microRNA-146a in generalized aggressive periodontitis and its association with disease severity. *J Periodontal Res.* 2018.
12. Jiang S, Hu Y, Deng S, Deng J, Yu X, Huang G, et al. miR-146a regulates inflammatory cytokine production in *Porphyromonas gingivalis* lipopolysaccharide-stimulated B cells by targeting IRAK1 but not TRAF6. *Biochimica et Biophysica Acta (BBA)-Molecular Basis of Disease.* 2018;1864(3):925–33.
13. Tang L, Li X, Bai Y, Wang P, Zhao Y. MicroRNA-146a negatively regulates the inflammatory response to *Porphyromonas gingivalis* in human periodontal ligament fibroblasts via TRAF6/p38 pathway. *Journal of periodontology.* 2019;90(4):391–9.
14. Chen B, Wu W, Sun W, Zhang Q, Yan F, Xiao Y. RANKL Expression in Periodontal Disease: Where Does RANKL Come from? *BioMed Research International.* 2014;2014:7.
15. Fujihara R, Usui M, Yamamoto G, Nishii K, Tsukamoto Y, Okamatsu Y, et al. Tumor necrosis factor- α enhances RANKL expression in gingival epithelial cells via protein kinase A signaling. *J Periodontal Res.* 2014;49(4):508–17.
16. Kwan Tat S, Padrines M, Theoleyre S, Heymann D, Fortun Y. IL-6, RANKL, TNF- α /IL-1: interrelations in bone resorption pathophysiology. *Cytokine Growth Factor Rev.* 2004;15(1):49–60.
17. Caton JG, Armitage G, Berglundh T, Chapple IL, Jepsen S, Kornman KS, et al. A new classification scheme for periodontal and peri-implant diseases and conditions—Introduction and key changes from the 1999 classification. *Wiley Online Library;* 2018.
18. Livak KJ, Schmittgen TD. Analysis of relative gene expression data using real-time quantitative PCR and the 2^{(-Delta Delta C(T))} Method. *Methods.* 2001;25(4):402–8.
19. Liu CJ, Kao SY, Tu HF, Tsai MM, Chang KW, Lin SC. Increase of microRNA miR-31 level in plasma could be a potential marker of oral cancer. *Oral diseases.* 2010;16(4):360–4.
20. Ebert MS, Sharp PA. Roles for microRNAs in conferring robustness to biological processes. *Cell.* 2012;149(3):515–24.

21. Lovat F, Valeri N, Croce CM, editors. MicroRNAs in the pathogenesis of cancer. *Seminars in oncology*; 2011: Elsevier.
22. Ono K, Kuwabara Y, Han J. MicroRNAs and cardiovascular diseases. *The FEBS journal*. 2011;278(10):1619–33.
23. Shrivastava S, Steele R, Ray R, Ray RB. MicroRNAs: role in hepatitis C virus pathogenesis. *Genes & diseases*. 2015;2(1):35–45.
24. Xu J, Wu W, Zhang L, Dorset-Martin W, Morris MW, Mitchell ME, et al. The role of microRNA-146a in the pathogenesis of the diabetic wound-healing impairment: correction with mesenchymal stem cell treatment. *Diabetes*. 2012;61(11):2906–12.
25. Lovat F, Valeri N, Croce CM. MicroRNAs in the pathogenesis of cancer. *Semin Oncol*. 2011;38(6):724–33.
26. Xu J, Wu W, Zhang L, Dorset-Martin W, Morris MW, Mitchell ME, et al. The role of microRNA-146a in the pathogenesis of the diabetic wound-healing impairment: correction with mesenchymal stem cell treatment. *Diabetes*. 2012;61(11):2906–12.
27. Kaneshiro LCKK, Perez CMR. Classification of periodontal diseases and conditions.
28. Wiebe CB, Putnins EE. The periodontal disease classification system of the American Academy of Periodontology-an update. *Journal-canadian dental association*. 2000;66(11):594–9.
29. Motedayyen H, Ghotloo S, Saffari M, Sattari M, Amid R. Evaluation of microRNA-146a and its targets in gingival tissues of patients with chronic periodontitis. *Journal of periodontology*. 2015;86(12):1380–5.
30. Ghotloo S, Motedayyen H, Amani D, Saffari M, Sattari M. Assessment of micro RNA-146a in generalized aggressive periodontitis and its association with disease severity. *Journal of periodontal research*. 2019;54(1):27–32.
31. Riep B, Edesi-Neuß L, Claessen F, Skarabis H, Ehmke B, Flemmig TF, et al. Are putative periodontal pathogens reliable diagnostic markers? *Journal of clinical microbiology*. 2009;47(6):1705–11.
32. Gabr AM, El-Guindy HM, Saud HI, Morad MA. Evaluation of receptor activator of nuclear factor- κ B ligand and osteoprotegerin levels in saliva and gingival crevicular fluid in patients with chronic periodontitis. *Tanta Dental Journal*.14(2):83.
33. Mogi M, Otogoto J, Ota N, Togari A. Differential expression of RANKL and osteoprotegerin in gingival crevicular fluid of patients with periodontitis. *Journal of dental research*. 2004;83(2):166–9.
34. Teodorescu AC, Martu I, Teslaru S, Kappenberg-Nitescu DC, Goriuc A, Luchian I, et al. Assessment of Salivary Levels of RANKL and OPG in Aggressive versus Chronic Periodontitis. *Journal of immunology research*.2019.
35. Giannopoulou C, Martinelli-Klay CP, Lombardi T. Immunohistochemical expression of RANKL, RANK and OPG in gingival tissue of patients with periodontitis. *Acta Odontologica Scandinavica*. 2012;70(6):629–34.

36. Dereka XE, Markopoulou CE, Fanourakis G, Tseleni-Balafouta S, Vrotsos IA. RANKL and OPG mRNA level after non-surgical periodontal treatment. *Inflammation*.33(3):200–6.
37. Moghadam SA, Sarani S, Alijani E, Moghadam AA. The effect of Phase 1 periodontal treatment on the salivary RANKL/OPG ratio in severe chronic periodontitis. *Clinical, Cosmetic and Investigational Dentistry*.11:251.
38. Lawrence T. The nuclear factor NF-kappaB pathway in inflammation. *Cold Spring Harb Perspect Biol*. 2009;1(6):a001651.
39. Florencio-Silva R, Silva Sasso RG, Sasso-Cerri E, Simões JM, Cerri SP. Biology of bone tissue: structure, function, and factors that influence bone cells. *Biomed Res Int*. 2015;2015.

Figures

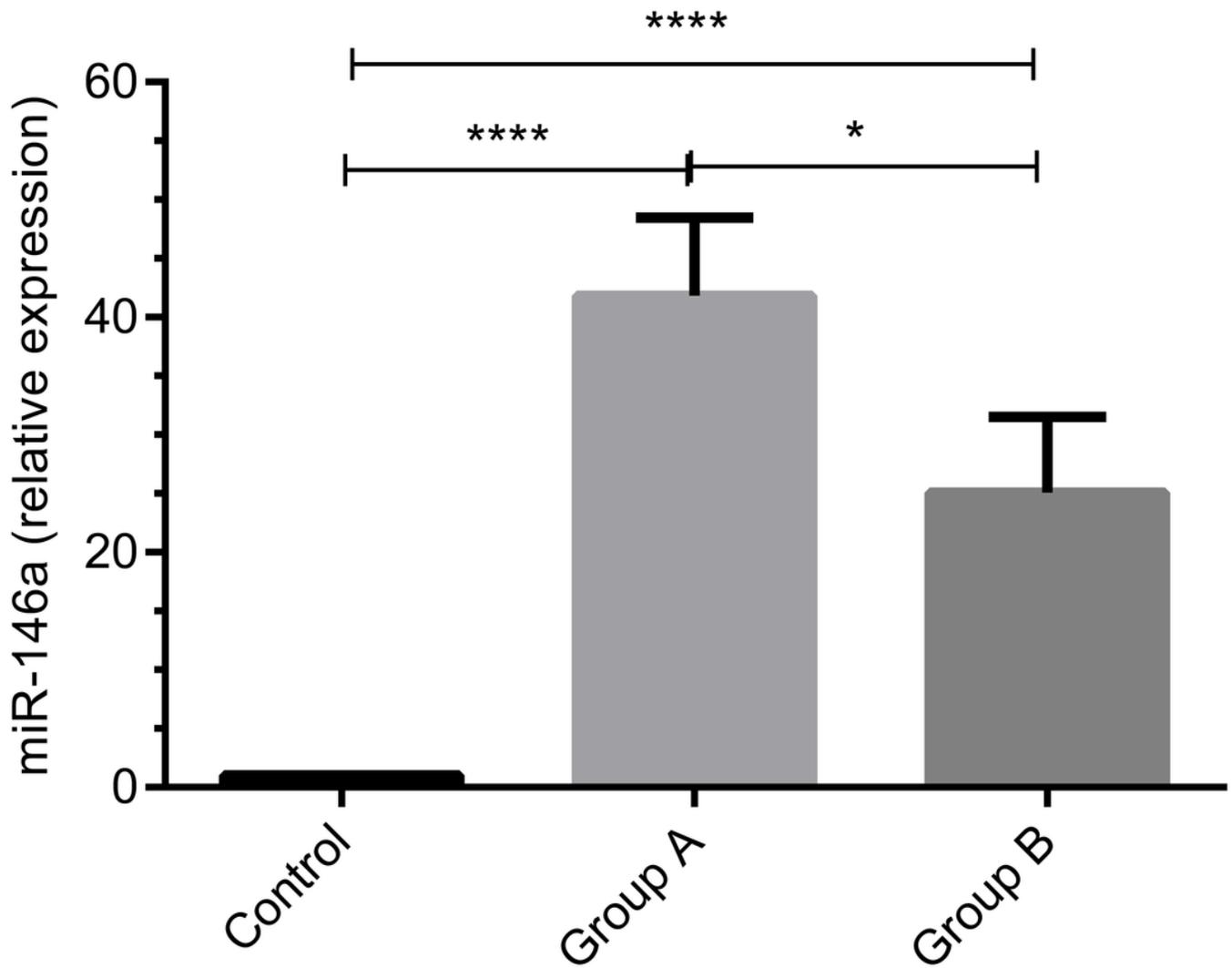


Figure 1

The expression levels of miR-146a in patient and healthy subjects. The levels of miR-146a in gingival tissues from group A (n=15) and B (n=15) of patients and healthy subjects (n = 15) were measured by real-time PCR. Data are shown as mean \pm SD of relative expression of miR-146a. * p<0.05, **** p<0.0001

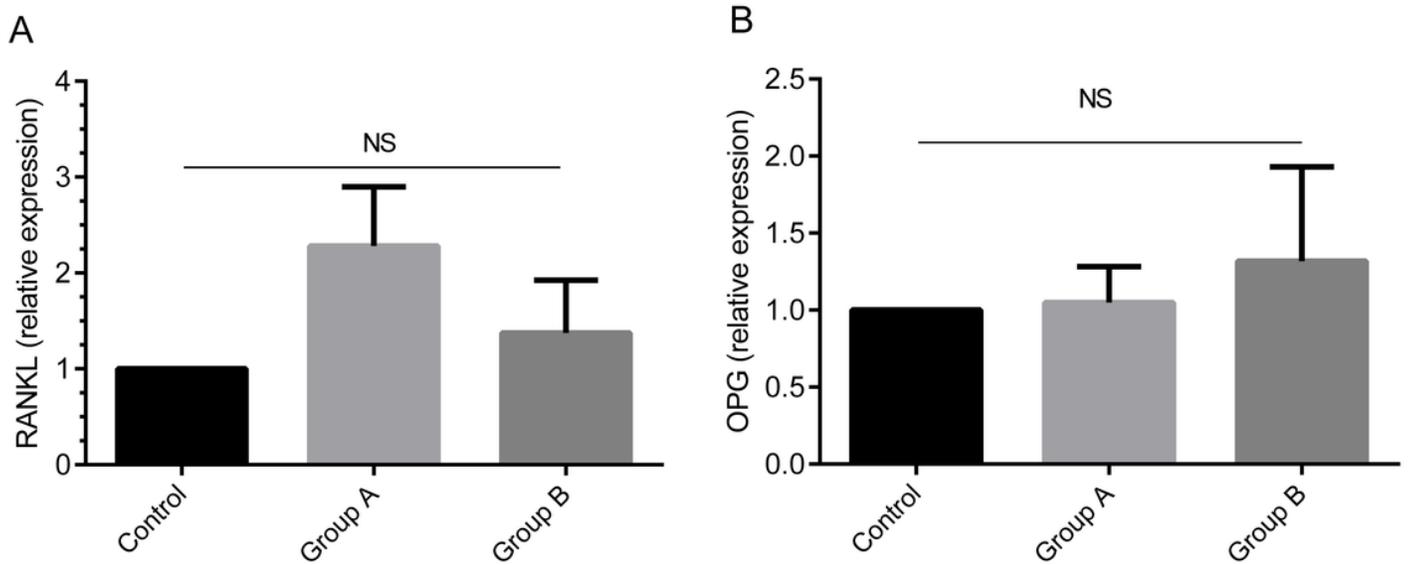


Figure 2

The levels of RANKL and OPG in patient and healthy subjects. The relative expressions of RANKL and OPG in group A (n=15) and B (n=15) of patients and healthy subjects (n = 15) were measured by real-time PCR. The results are shown as mean \pm SD.