Association Between Alleles of Cytokine Genes with Rheumatoid Arthritis in Russian Population

Nataliya E Soroka¹, Svetlana A Morozova¹, Valery V Ilinsky², Dmitry Y Trofimov¹ and Denis V Rebrikov¹,²,⁴

¹DNA-Technology JSC, Kashirskoe shosse, 23-5-14, Moscow, 115478, Russia
²Institute of General Genetics of Russian Academy of Sciences, Gubkina str., 3, Moscow, 119991, Russia

Abstract

Background: Rheumatoid arthritis (RA) is a multi-factor disease with a key role of genetic component in its genesis. Development of osteoporosis and articular destruction is attributed with overexpression of pro-inflammatory cytokines and reduced production of anti-inflammatory ones. In this work probable associations of IFN-γ, IL-1α, IL-1β, IL-4, IL-6, IL-10, IL-18 and TNFα alleles with rheumatoid arthritis were studied among Russian ethnic group.

Methods: A total of 69 Russian ethnic group patients with RA (cases) and 133 healthy control individuals (controls) were genotyped for variants in 8 cytokines genes (IFN-γ, IL-1α, IL-1β, IL-4, IL-6, IL-10, IL-18 and TNFα). Individual genotype and haplotype frequencies were compared between cases and controls. Odds ratios were calculated with asymptotic 95% confidence intervals and P values less than 0.05 were considered statistically significant.

Results: The distribution of studied alleles of cytokine genes in Russian population is similar to other European populations. Genotype, allele and haplotype frequencies were equally distributed between RA cases and controls for IFN-γ (rs2430561), IL-1α (rs1800587), (rs17561), IL-1β (rs1143627), (rs16944), (rs1143634), IL-10 (rs1800871), IL-18 (rs1946518) and TNFα (rs361525). Meanwhile, significant associations (p<0.05) were found between RA cases and controls for IL-4 (rs2243250) T/T, IL-6 (rs1800785) G/G, IL-10 (rs1800872) A/A, IL-10 (rs1800896) G/A, IL-18 (rs187238) G/C and TNFα (rs1800629) G/A.

Conclusions: These results indicate that common variants of the IL-4, IL-6, IL-10, IL-18 and TNFα may significantly contribute to RA susceptibility.

Abbreviations: CI: Confidence Interval; CJC: Circulatory Immune Complexes; DNA: Desoxyribonucleic Acid; HLA: Human Leukocyte Antigen; IFN: Interferon; Ig: Immunoglobulin; IL: Interleukin; OR: Odds Ratio; PCR: Polymerase Chain Reaction; RA: Rheumatoid Arthritis; RR: Relative Risk; SNP: Single Nucleotide Polymorphism; TNF: Tumor Necrosis Factor

Background

Rheumatoid arthritis (RA) is a progressive systemic chronic inflammatory autoimmune disease: which is characterised by destruction of joints and sometimes articular onsets with prevalence of 1% worldwide. Etiology of A is still unknown: but it is considered to have both a genetic and an environmental basis [1]. Genetic component of A susceptibility was established by data from previous published research [2]. And recent twin analysis confirms that RA heritability is about 60% [3].

The number of molecular markers of RA increases rapidly [4,5]. Pro-inflammatory cytokines such as TNF-α and L-1 are involved in an inflammatory process: which is partly counterbalanced by anti-inflammatory mediators: such as IL-10 [6]. Polymorphisms in cytokine genes could cause high expression of pro-inflammatory or low expression of anti-inflammatory ones. SNPs of regulator sites or enhancer structures. Such positive and negative regulation of cytokine expression plays an important role in development of local inflammations, and is one of RA etiological factors. Main effects of studied cytokines are indicated in Table 1. According to previously published data, distribution and role of FN-γ, IL-1α, IL-1β, IL-4, IL-6, IL-10, IL-18 and TNFα in RA development differ from one ethnic or population group to the other [15-19], but no studies have been done in Russian ethnic group. So, the purpose of the research was be studies of frequencies of alleles of above-mentioned cytokines in patients with RA in comparison with healthy individuals of Russian ethnic group and the search for possible associations between these alleles and RA.

Methods

Clinical samples

A total of 69 venous blood samples (obtained from 11 white Caucasian men (Russians) and 58 women at the age of 17-70: average duration of illness is 9 years) with RA and 133 samples from healthy unrelated individuals were used in this study. From all participants an informed consent was obtained. RA was diagnosed according to diagnostic criteria’s of the Institute of Rheumatology of Russian Academy of Medical Sciences (RAMS). For genetic analysis 1 ml of venous blood was used.

SNP selection and genotyping

Functional SNPs in IFN-γ, IL-1α, IL-1β, IL-4, IL-6, IL-10, IL-18 and TNFα genes were selected using genotyping data available from the International Hapmap project. Blood samples were collected in EDTA-anticoagulated tubes. DNA was extracted using standard methods.

*Corresponding author: Denis V Rebrikov, Institute of General Genetics of Russian Academy of Sciences, Gubkina str., 3, Moscow, 119991, Russia, E-mail: denis@dna-technology.ru

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### Table 1: Key effects of studied cytokines.

| Cytokine name | Effects | References |
|---------------|---------|------------|
| IL-1          | Activation of osteoclasts, Activation of T-cells, Activation of matrix metalloproteinases, destroying cartilage | [7, 8] |
| TNF-α         | Activation of osteoclasts, activation of matrix metalloproteinases, increase expression of HLA II molecules by antigen presenting cells, increase expression of intercellular adhesion molecules | [9-11] |
| IL-6          | Activation of osteoclasts, Support of B-cells differentiation and antibody production | [12] |
| IL-4          | Decrease of pro-inflammatory cytokines, production of Support of B cells differentiation and antibody production | [13] |
| IL-10         | Increase expression of HLA II molecules by antigen presenting cells, increase expression of intercellular adhesion molecules, Enhancement of T-cell proliferation and Th1 cytokine production | [14] |
| IL-18         | Increase of IFN-γ T-cells production | [9-11] |

### Table 2: Distribution of genotypes among patients with RA and healthy control group.

| Gene (SNP) | Genotype | RA cases, no (%) | Controls, no (%) |
|------------|----------|------------------|------------------|
| IFN-γ (+874, rs2430561) | A/A | 20 (29%) | 40 (30%) |
| | A/T | 37 (54%) | 64 (48%) |
| | T/T | 12 (17%) | 29 (22%) |
| IL-1α (-899, rs1800587) | G/G | 29 (42%) | 66 (50%) |
| | G/T | 32 (46%) | 55 (41%) |
| | T/T | 8 (11%) | 12 (9%) |
| IL-1α (+4845, rs17561) | T/T | 22 (32%) | 48 (36%) |
| | T/C | 43 (62%) | 71 (53%) |
| | C/C | 4 (6%) | 14 (11%) |
| IL-1β (-31, rs1143627) | C/C | 17 (25%) | 49 (37%) |
| | C/T | 44 (63%) | 70 (53%) |
| | T/T | 8 (12%) | 14 (10%) |
| IL-1β (-511, rs16944) | C/C | 38 (55%) | 84 (63%) |
| | C/T | 28 (41%) | 39 (29%) |
| | T/T | 3 (4%) | 10 (8%) |
| IL-4 (-590, rs2243250) | C/C | 20 (29%) | 81 (61%) |
| | C/T | 45 (65%) | 48 (36%) |
| | T/T | 4 (6%) | 3 (3%) |
| IL-6 (-174, rs1800795) | G/G | 31 (45%) | 37 (28%) |
| | G/C | 29 (42%) | 68 (51%) |
| | C/C | 9 (13%) | 28 (21%) |
| IL-10 (-592, rs1800872) | C/C | 28 (41%) | 84 (63%) |
| | C/A | 33 (48%) | 44 (33%) |
| | A/A | 8 (12%) | 5 (4%) |
| IL-10 (-819, rs1800871) | C/C | 37 (54%) | 85 (64%) |
| | C/T | 24 (35%) | 43 (32%) |
| | T/T | 8 (11%) | 5 (4%) |
| IL-10 (-1082, rs1800896) | G/G | 12 (17%) | 28 (21%) |
| | G/A | 49 (71%) | 70 (53%) |
| | A/A | 8 (12%) | 35 (26%) |
| IL-18 (-137, rs187238) | G/G | 26 (38%) | 70 (53%) |
| | G/C | 43 (62%) | 52 (39%) |
| | C/C | 0 | 11 (8%) |
| IL-18 (-607, rs1946518) | C/C | 28 (42%) | 45 (34%) |
| | C/A | 29 (41%) | 64 (48%) |
| | A/A | 12 (17%) | 24 (18%) |
| TNFα (-238, rs361525) | G/G | 83 (91%) | 129 (97%) |
| | G/A | 6 (9%) | 4 (3%) |
| | A/A | 0 | 0 |
| TNFα (-308, rs1800629) | G/G | 37 (34%) | 99 (74%) |
| | G/A | 32 (46%) | 34 (26%) |
| | A/A | 0 | 0 |

All SNPs were genotyped in duplicates using SNiPtest PCR kits (DNA-Technology JSC, Moscow, Russia). Multiple positive and negative controls were included in all genotyping plates to ensure genotyping data. 10% of genotypes were also confirmed by sequencing. Thermal cycling and genotyping were performed in 384-well plates on DT-384 Real-Time PCR Cycler (DNA-Technology JSC, Moscow: Russia).

### Statistical analysis

χ² test, Fisher’s exact test with Bonferroni adjustment: odds ratio with confidence interval of 95% (CI=95%) and relative risk (RR) analysis were used. For all statistical analysis Statistica 8.0 (StatSoft, USA) was used.
Results and Discussions
Frequencies of some SNPs of cytokine genes in Russian ethnic group

We characterised frequencies of the listed above polymorphisms for the group of patients with RA and healthy individuals of Russian ethnic group (Table 2). The distribution of studied alleles of the control group corresponds to ones in European. The control group is in Hardy-Weinberg proportions due to Pearson’s chi-squared test for deviation (χ² values in all alleles are less than 5% significance level).

SNPs not associated with RA

No significant differences were found between healthy individuals and patients with RA on the following SNPs, IFN-γ A/T (rs2430561), IL-1α C/T (rs1800587), IL-1β C/T (rs1143627), IL-1β C/T (rs16944), and IL-6 G/C (rs1800795). These results corresponds to Tulusso et al., who also showed no associations between RA and T-31C, C-511T (IL-1β) in absence of any with T-31C [15]. Finally, similar to our data, Moreno et al. showed association between RA and C-819T (IL-10) for Colombian population [16]. Our data differs from Huang et al., who indicated association between RA and C-607A (IL-6) for Chineese population [17]. This difference may be caused by both interethnic and interpopulational differences and shows necessity of similar studies of different populations.

SNPs associated with RA: IL-4

All SNPs associated with RA are indicated in table 3. Among patients with RA frequency of C-590T (IL-4) C/C homozygotic variant is two times less than homozygotic T/T and heterozygotic C/T. Other SNP such as IL-6 G/C (rs1800795) and IL-10 G/A (rs1800896) have similar p-value but difference between T/T and C/T are not significant.

Table 3: Association between rheumatoid arthritis and investigated SNPs.
Development and its overexpression cause destruction of bones. Moreover, IL-6, equally with IL-1, takes part in osteoporosis. Sediment in synovial membranes of joints and provoke pathological factors and Ig) can form circulating immune complexes (CIC) that lead to hypergammaglobulinemia. These autoantibodies (Rheumatoid factors) can cause overexpression of rheumatoid factors (and subsequent immunoglobulines, sometimes resulting hypergammaglobulinemia. The level of HLA-DR antigenes and intensive production of different inflammatory cytokines. So, A alleles of both C-592A and G-1082A (IL-10) impact IL-10 production. According to published results [26,27], alleles A of both polymorphisms (C-592A and G-1082A) are associated with lower IL-10 expression than alleles C. IL-10 is an anti-inflammatory interleukin that decreases production of inflammatory interleukins, increases production of IL-1 receptor antagonist and decreases adhesion of leucocytes to IL-1-activated endothelial cells. It is supposed that insufficient production of IL-10 may support RA development by low inhibition of production of inflammatory cytokines. So, A alleles of both C-592A and G-1082A (IL-10) may be RA risk factors. On the other hand, according to previous findings of Moreno et al. in Columbian ethnic group [22].

**SNPs associated with RA: IL-6**

For polymorphism G-174C (IL-6) a significant (p=0.0147) association was discovered for G/G genotype. Presence of G allele is associated with higher expression rate of IL-4 in comparison with allele C [21]. IL-4 provides activation of antigen-detection cell properties by increasing the level of HLA-DR antigene and intensive production of different immunoglobulin, sometime resulting hypergammaglobulinemia. Our results on association between RA and allele T corresponds to findings of Moreno et al. in Columbian ethnic group [22].

Earlier researches discovered no association between G-174C (IL-6) and RA for patients from both Spain and Sweden [24,25]. But according to Huang et al. report, this association is significant for Chinese population [17].

**SNPs associated with RA: IL-10**

Differences between frequencies of C-592A and G-1082A (IL-10) among patients with RA and the control group are significant (p=0.0022), so these polymorphisms are associated with RA in the studied ethnic group. It should be noticed, that presence of A/A genotype of C-592A (IL-10) among patients with RA and the control group are significant (p=0.0022), so these polymorphisms are associated with RA in the studied ethnic group. It should be noticed, that presence of A/A genotype of G-1082A (IL-10) is high risk factors of the pathology. It has been shown: that C-592A and G-1082A (IL-10) among patients with RA and healthy individuals, and their significant associate with RA (p<0.001).

### Table 4: Presence of combined genotypes among patients with RA and healthy individuals, and their significant association with RA (p<0.05).

| Gene | Genotype | RA patients, no. (%) | Controls, no. (%) | Alleles associated with susceptibility (P-value) |
|------|----------|---------------------|------------------|----------------------------------------------|
| -590 (IL-4) and -137 (IL-18) | CC GG | 9 (13%) | 46 (35%) | 590T and 137C (0.01955) |
|     | TT GG | 3 (4%) | 5 (1%) |
|     | CT GG | 11 (16%) | 23 (17%) |
|     | CC GC | 1 (1%) | 31 (23%) |
|     | TT GC | 31 (45%) | 3 (2%) |
|     | CC TT | 0 | 18 (14%) |
|     | CT CC | 0 | 4 (3%) |
|     | TT CC | 0 | 0 |
|     | CC CC | 0 | 7 (5%) |
| -819 (IL-10) and -592 (IL-10) | CC CC | 28 (41%) | 84 (63%) | 819C and 592A (0.00754) |
|     | TT CA | 0 | 0 |
|     | CT CA | 24 (35%) | 43 (32%) |
|     | CC CA | 9 (13%) | 1 (1%) |
|     | CC AA | 0 | 0 |
|     | TT CC | 8 (11%) | 5 (4%) |
|     | TT AA | 0 | 0 |
|     | CT AA | 0 | 0 |
|     | CT CC | 0 | 0 |
| -238 (TNFα) and -590 (IL-4) | GG CC | 17 (25%) | 79 (59%) | 238A and 590T (0.0311) |
|     | GA CC | 3 (4%) | 2 (1%) |
|     | GG CT | 42 (61%) | 46 (34%) |
|     | GA CT | 3 (4%) | 4 (3%) |
|     | GG TT | 4 (6%) | 0 |
|     | GA TT | 0 | 0 |
| -308 (TNFα) and -590 (IL-4) | GG CC | 12 (17%) | 61 (45%) | 308A and 590T (0.0361) |
|     | GA CC | 8 (12%) | 20 (15%) |
|     | GG CT | 23 (33%) | 36 (27%) |
|     | GA CT | 22 (32%) | 12 (9%) |
|     | GG TT | 2 (3%) | 2 (2%) |
|     | GA TT | 2 (3%) | 2 (2%) |
| -308 (TNFα) and -592 (IL-10) | GG CC | 19 (27%) | 56 (42%) | 308A and 592A (0.00471) |
|     | GA CC | 9 (13%) | 28 (21%) |
|     | GG CA | 14 (20%) | 38 (29%) |
|     | GA CA | 19 (27%) | 6 (4%) |
|     | GA AA | 4 (6%) | 5 (4%) |
|     | GG GA | 0 | 0 |
| -308 (TNFα) and -137 (IL-18) | GG GC | 20 (29%) | 42 (32%) | 308A and 137C (0.0294) |
|     | GA GC | 23 (33%) | 10 (7%) |
|     | GG GG | 17 (25%) | 51 (38%) |
|     | GA GG | 9 (13%) | 19 (14%) |
|     | GG CC | 0 | 6 (5%) |
|     | GA CC | 0 | 5 (4%) |
research on Columbian patients with RA [16], no associations were discovered between C-592A and G-1082A polymorphisms and RA.

SNPs associated with RA: IL-18

According to received data: G-137C (IL-18) is significantly associated with RA. G allele in G-137C polymorphism is related to a high risk of RA development. G-137C is located in a non-coding region of IL-18 and is responsible for cytokine expression. G allele is related to low transcription rate of IL-18 [28,29]. IL-18 has an anti-inflammatory activity by suppression of macrophage secretion of IL-1, TNFα and IL-6, preventing migration of neutrophils to an inflamed tissue, decreasing adhesion of leukocytes to endothelial cells. Because of these functions low production of IL-8 must support RA development and G in G-137C site is a high risk factor of the disease. Interestingly, in the study of Chinese population no association of G-137C (IL-18) and RA was discovered [17].

SNPs associated with RA: TNFα

We discovered a strong association between G-308A (TNFα) and RA. G-308A (TNFα) is located in a non-coding region and is related to cytokine expression rate. Single nucleotide replacement of A instead of G in -308 position is associated with TNFα overexpression [30-32]. TNFα is a member of pro-inflammatory cytokines and provides the most important functions during the beginning of inflammation; it activates leukocytes, assists adhesion and transmigration of leukocytes to the inflamed tissue. It also stimulates differentiation and proliferation of B-cells: activates transcription of other anti-inflammatory cytokines genes. TNFα overexpression may lead to RA development by initiation and support of inflammation process. The role of TNFα in RA development may also be connected with its ability to induce osteoclasts and chondrocytes activation. According to earlier studies of Holland and French patients with RA, there is no association between G-308A (TNFα) and RA [33,34]. Nevertheless: for Ireland patients this association was reported [35].

Combined genotypes associated with RA

We also conducted an analysis of frequencies of studied cytokines genotypes combinations among patients with RA and the control group (see tables 4). The following combinations of genotypes are significantly associated (p<0.05) with RA: -390 C/T (IL-4) & -137 G/C (IL-18); -819 C/C (IL-10) & -592 C/A (IL-10); -238 G/A (TNFα) & -590 C/T (IL-4); -308 A (TNFα) & -592 A (IL-10); -308 G/A (TNFα) & -137 G/C (IL-18); -308 G/A (TNFα) & -590 C/T (IL-4).

Conclusions

We conclude that four genotypes and six combinations of genotypes of studied cytokines are associated with RA in Russian ethnic group.

Competing Interests

The authors declare that they have no competing interests.

Authors’ Contributions

NES carried out the molecular genetic studies, participated in the primer design and drafted the manuscript. SAM participated in the design of the study and performed the statistical analysis. VVI participated in the data analysis and helped to draft the manuscript. DYT participated in the design of the study. DVR conceived of the study, and participated in its design and coordination and helped to draft the manuscript. All authors read and approved the final manuscript.

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References

1. Firestein GS (2003) Evolving concepts of rheumatoid arthritis Nature 423: 356-361.
2. Maini RN (1994) Pathogenesis of Rheumatoid Arthritis. Internal. Zeitschrift fur arztlliche Fortbildung 23: 59-63.
3. MacGregor AJ, Snieder H, Rigby AS, Koskennuo M, Kaprio J, et al. (2000) Characterizing the quantitative genetic contribution to rheumatoid arthritis using data from twins. Arthritis Rheum 43: 30-37.
4. Morel J, Roch-Bras F, Molinari N, Sany J, Eliaou J, et al. (2004) HLA-DMB0103 and HLA-DMB0104 alleles as novel prognostic factors in rheumatoid arthritis. Ann Rheum Dis 63: 1581-1586.
5. Goeb V, Thomas-L-Ottelier M, Daveau R, Charlonet R, Fardelle C, et al. (2009) Candidate autoantigens identified by mass spectrometry in early rheumatoid arthritis are chaperones and citrullinated glycolytic enzymes. Arthritis Res Ther 11: R38.
6. Sakurai N, Kuriowa T, Ikeuchi H, Hiramatsu N, Maeshima A, et al. (2008) Expression of IL-19 and its receptors in RA: potential role for syndovial hyperplasia formation. Rheumatology 47: 815-820.
7. Micalef MJ, Ohtsuki T, Kohno K, Tanabe F, Ushio S, et al. (1996) Interferon-inducing factor enhances T helper 1 cell production by stimulated human T cells: synergism with interleukin-12 for interferon-production. Eur J Immunol 26: 1647-1651.
8. Gleichmann E, Pals LS, Rollin AG, Radaszkiewicz T, Gleichmann H (1984) Graftversus- host reactions: clues to the etiopathology of a spectrum of immunological diseases. Trends Immunol 5: 324-332.
9. Schett G, Tohidast-Akrad M, Smolen JS, Schmid BJ, Steiner CW, et al. (2000) Activation: differential localization: and regulation of the stress-activated protein kinases: extracellular signal-regulated kinase: c-Jun N-terminal kinase: and p38 mitogen-activated protein kinase: in synovial tissue and cells in rheumatoid arthritis. Arthritis Rheum 43: 2501-2512.
10. Kobayashi K, Takahashi N, Jimi E, Udagawa N, Takami M, et al. (2000) Tumor necrosis factor alpha stimulates osteoclast activation by a mechanism independent of the ODF/RANKL-RANK interaction. J Exp Med 191: 275-286.
11. Fuller K, Owens JM, Jagger CJ, Wilson A, Moss R, et al. (1993) Macrophage colony-stimulating factor stimulates survival and chemoattractant behavior in isolated osteoclasts. J Exp Med 178: 1733-1744.
12. Dayer JM, Arend WP (1997) Cytokines and growth factors. In Textbook of Rheumatology. (5th edn) Kelley Philadelphia: Saunders.
13. Romas E, Martin TJ (1997) Cytokines in the pathogenesis of osteoporosis. Osteoporos Int. 7: S47-S53.
14. Okamura H, Tsutsui H, Komatsu T, Yutsudo M, Hakura A, et al. (1995) Cloning of a new cytokine that induces IFN-γ production by T cells. Nature 378: 89-91.
15. Arman A, Yilmaz B, Coker A, Ircan N, Direskeneli H (2006) Interleukin-1 receptor antagonist (IL-1RN) and interleukin-1B gene polymorphisms in Turkish patients with rheumatoid arthritis. Clin Exp Rheumatol 24: 643-648.
16. Moreno OM, Gonzalez CI, Saabli DL, Otero W, Badillo R, et al. (2007) Polymorphisms of IL-10 gene promoter and rheumatoid arthritis in a Colombian population. Biomedica 27: 56-65.
17. Huang XZ, Zhuang JH, Ren YG, Zhou LJ, Zhou Q (2007) Association of interleukin-6 and interleukin-18 gene polymorphisms with rheumatoid arthritis in Guangdong Han population. Nan Fang Yi Ke Da Xue Xue Bao 27: 1661-1664.
18. Vavrincec J, Cinek O, Vavrincova P, Slavcev T, Malcova H (2003) Association of single nucleotide polymorphisms within cytokine genes to juvenile idiopathic arthritis in Czech children. Arthritis Res Ther 5: 63.
19. Plenge RM, Padyukov L, Remmers EF, Purcell S, Lee AT, et al. (2005) Replication of Putative Candidate–Gene Associations with Rheumatoid Arthritis in 14,000 Samples from North America and Sweden: Association of Susceptibility with PTEN22: CTLA4: and PADI4. Am J Hum Genet 77: 1044-1060.
20. Toluoso B, Pietrapertosa D, Morelli A, De Santis M, Gremese E, et al. (2006) IL-1B and IL-1RN gene polymorphisms in rheumatoid arthritis: relationship with protein plasma levels and response to therapy. Pharmacogenomics 7: 683-695.
21. Rosenwaasser LJ, Klemm DJ, Dresback JK, Inamura H, Mascali JJ, et al. (1995) Promoter polymorphisms in the chromosome 5 gene cluster in asthma and atopy. Clin Exp Allergy 25: 74-78.
22. Moreno O, González CI, Saaib DE, Otero W, Badillo R, et al. (2007) Polymorphisms in the IL4 and IL4RA genes in Colombian patients with rheumatoid arthritis. J Rheumatol 34: 36-42.

23. Fishman D, Faulds G, Jeffery R, Mohamed-Ali V, Yudkin JS, et al. (1998) The effect of novel polymorphisms in the interleukin-6 (IL-6) gene on IL-6 transcription and plasma IL-6 levels: and an association with systemic-onset juvenile chronic arthritis. J Clin Invest 102: 1369-1376.

24. Pascual M, Nieto A, Mataran L, Balsa A, Pascual-Salcedo D, et al. (2000) IL-6 promoter polymorphisms in rheumatoid arthritis. Genes Immun 1: 338-340.

25. Dahlqvist SR, Arlestig L, Sikstram C, Linghult S (2002) Tumor necrosis factor receptor type II (exon 6) and interleukin-6 (-174) gene polymorphisms are not associated with family history but tumor necrosis factor receptor type II is associated with hypertension in patients with rheumatoid arthritis from northern Sweden. Arthritis Rheum 46: 3096-3098.

26. Summers AM, Summers CW, Drucker DB, Barson A, Hajeer AH, et al. (2000) Association of IL-10 genotype with sudden infant death syndrome. Hum Immunol 61: 1270-1273.

27. Zhang X, He P, Deng L, Lin J (2007) Interleukin-10 gene promoter polymorphisms and their protein production in peritoneal fluid in patients with endometriosis. Mol Hum Reprod 13: 135-140.

28. Xu Q, Tin SK, Sivalingam SP, Thumboo J, Koh DR, et al. (2007) Interleukin-18 promoter gene polymorphisms in Chinese patients with systemic lupus erythematosus: association with CC genotype at position -607. Ann Acad Med Singapore 36: 91-95.

29. Giedraitis V, He B, Huang WX, Hillert J (2001) Cloning and mutation analysis of the human IL-18 promoter: a possible role of polymorphisms in expression regulation. J Neuroimmunol 112: 146-152.

30. Kroeger KM, Carville KS, Abraham LJ (1997) The -308 tumor necrosis factor promoter polymorphism effects transcription. Mol Immunol 34: 391-399.

31. Wilson AG, Symons JA, McDowell TL, McDevitt HO, Duff GW (1997) Effects of a polymorphism in the human tumor necrosis factor promoter on transcriptional activation. Proc Natl Acad Sci USA 94: 3195-3199.

32. Bouma G, Crusius JBA, Oudkerk Pool M, Klomman JJ, von Blomberg BM, et al. (1996) Secretion of tumor necrosis factor alpha and lymphotxin alpha in relation to polymorphism in the TNF genes and HLA-DR alleles. Relevance for inflammatory Bowel Disease. Scand J Immunol 43: 456-463.

33. Brinkman BM, Hulzinga TW, Kurbans SA, van der Velde EA, Schreuder GM, et al. (1997) Tumour necrosis factor alpha gene polymorphisms in rheumatoid arthritis: association with susceptibility to: or severity of: disease? Br J Rheumatol 36: 516-521.

34. Marotte H, Farge P, Gaudin P, Alexandre C, Mougin B, et al. (2006) The association between periodontal disease and joint destruction in rheumatoid arthritis extends the link between the HLA-DR shared epitope and severity of bone destruction. Ann Rheum Dis 65: 905-909.

35. Waldron-Lynch F, Adams C, Amos C, Zhu DK, McDermott MF, et al. (2001) Tumour necrosis factor 5' promoter single nucleotide polymorphisms influence susceptibility to rheumatoid arthritis (RA) in immunogenetically defined multiplex RA families. Genes Immu 2: 82-87.