

## Evaluation of the genetic relatedness of *Bacteroides fragilis* isolates by TRs analysis

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### ABSTRACT

**Objective(s):** Human gastrointestinal tract harbors a variety of bacteria with vital roles in human health. *Bacteroides fragilis* is considered one of the dominant constituents of gut microflora which can act as an opportunistic pathogen leading to various diseases, including colon cancer, diarrhea, uterine and intrathecal abscesses, septicemia, and pelvic inflammation. In this study, multiple locus variable number of tandem repeats analysis (MLVA) was performed to genetically differentiate 50 *B. fragilis* isolates.

**Materials and Methods:** Eight suitable tandem repeats (TRs) were selected by bioinformatics tools and were then subjected to PCR amplification using specific primers. Finally, MLVA profiles were clustered using BioNumerics 7.6 software package.

**Results:** All VNTR loci were detected in all isolates using the PCR method. Overall, *B. fragilis* isolates were differentiated into 27 distinct MLVA types. The highest diversity index was allocated to TR1, TR2, TR5, TR6, and TR8; with this taken into account, strain type 14 was the most prevalent with 12 strains belonging to this type. Clustering revealed three major clusters of A, B, and C. With regards to the pathogenicity of *B. fragilis* and the outcomes of infections related to this microorganism, it is imperative to study this microorganism isolated from both patients and healthy individuals.

**Conclusion:** This study aimed at evaluating the efficiency of MLVA for the genetic differentiation of *B. fragilis*. The results of this study indicate the promising efficiency of MLVA typing for cluster detection of this bacterium.

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### Introduction

*Bacteroides fragilis* is a Gram-negative, anaerobic bacillus residing in the human gut microflora (1). This anaerobic microorganism is regularly isolated from human infections causing serious complications due to the lack of proper antimicrobial therapy. Two molecular subtypes have been attributed to this microorganism: non-toxigenic *B. fragilis* (NTBF) and enterotoxigenic *B. fragilis* (ETBF). The latter subtype is considered an intestinal microorganism contributing to inflammatory bowel disease and colorectal cancer. Reportedly, antimicrobial resistance in this bacterium is increasing worldwide (2-4).

Gut microflora can play vital roles in human health. The overgrowth of anaerobic gut microbiota, especially *Bacteroides*, can lead to several health outcomes including colon cancer, diarrhea, intrathecal and uterine abscesses, and pelvic inflammation. About 99% of bacterial gut microflora are anaerobic, 20-30% of which are in the *Bacteroides* group. Moreover, recent reports indicate increased antibiotic resistance levels to methicillin, cephalosporins, tetracycline, and clindamycin (5-7).

Bacteria are often in a commensal relationship with humans; however, pathogenic

bacteria can be observed infrequently. Colonization of commensal bacteria is advantageous for human health as it can lead to mucosal and systemic immunity (8, 9).

Gut microbiota can induce maturity of the host immunity and subsequently provide protection against various infections. In spite of the fact that *B. fragilis* constitutes less than 1% of intestinal flora, studies on animal models with colitis have demonstrated that owing to the possession of polysaccharide capsules, this microorganism can rectify the inadequacy of immune system caused by the absence of bacterial colonization (10, 11).

There are two types of polysaccharide capsules, including polysaccharide A (PSA) and polysaccharide B (PSB), both belonging to zwitterion polysaccharides (ZPSs) with both positive and negative charges on each residue. These capsular polysaccharides have been shown to induce TCD4+ immune responses, hence restricting the colonization of other pathogens and the spread of infections (12-14).

In certain conditions, however, *B. fragilis* can cause inflammatory bowel disease, intestinal abscesses, peritonitis, genital infections, deep ulcers, bone marrow infections, pediatric cellulitis and pneumonia, colon cancer, bacteremia, brain abscess, meningitis, and septic

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**Table 1.** Characteristics of variable-number tandem repeat loci used for typing of *Bacteroides fragilis* YCH46 isolate

| TRs | Repeat motif   | TR Size  | Genomic location     | Function <sup>a</sup>                               | Unit | PI <sup>b</sup> |
|-----|--|----------|----------------------|---|------|-----------------|
| TR1 | AACATCCGGATGTTTAAATATAT  | 23(bp)   | 349742--<br>349830   | non-coding region                                   | 4    | 0               |
| TR2 | GAAAACCATCAAGAAAGACATCTTTGGAGATACTGTCATTGA<br>GGACAATCGCGTAATAG  | 60 (bp)  | 1664955--<br>1665296 | hypothetical protein                                | 6    | 0               |
| TR3 | ACGATAAGCGGTGA   | 14 (bp)  | 1762135--<br>1762195 | non-coding region                                   | 4    | 0               |
| TR4 | GAAGTGTAAAAGTAACAATCCGTCAAAGGAGACAGTGAAGGA<br>AAGCCATAAGGCATATACGGTTC<br>ACTGCCATTCTCCATTTGCA              | 86 (bp)  | 3424647--<br>3425269 | hypothetical protein                                | 7    | 1               |
| TR5 | AGCCGAAGTTACGGTGCTGCGT   | 22 (bp)  | 3745326--<br>3745553 | non-coding region                                   | 10   | 0               |
| TR6 | ATGACACAGTAA   | 12 (bp)  | 3978553--<br>3978616 | hypothetical protein                                | 5    | 0               |
| TR7 | TCCTGACCGTCTTTACCATCGGTACCG  | 27 (bp)  | 4278063--<br>4278232 | hypothetical protein                                | 6    | 0               |
| TR8 | CGGACGATAGGGACGGTCCACCTTACGATTATATGAAGGA<br>CGTTGCCGACGGTCCGCATAAG<br>AACGCTGAGGACGATCACCACTTCGCTGTAAAAACG | 102 (bp) | 4586247--<br>4586699 | ribosomal large subunit<br>pseudouridine synthase B | 4    | 0               |

<sup>a</sup> The role of TR-harboring gene, <sup>b</sup> Percent Indels  
TR: Tandem repeats

arthritis. Recent advances in molecular typing and investigating genomic polymorphism have significantly improved our understanding of bacterial evolution, pathogenicity, and reproduction. Today, Pulsed Field Gel Electrophoresis (PFGE) is considered the gold standard method for the epidemiological studies of *B. fragilis* in a short period. In this technique, banding patterns of bacterial whole genome are compared after being restricted by a unique-cutting DNA enzyme (15).

Considering high costs and difficulty in analysis, PFGE should be replaced by other typing techniques (16). Another typing technique is Multi Locus Sequence Typing (MLST), which uses the sequencing of seven housekeeping genes and is both expensive and time-consuming (17). Another frequently used typing method is multiple locus variable number of tandem repeats analysis (MLVA) typing which is according to variable copy numbers of tandem repeats (VNTR). This method has been employed to discriminate bacterial species, including *Escherichia coli* (18, 19), *Listeria* (20), *Brucella* (20), and *Staphylococci*, and to determine any genetic relatedness among the isolates.

This PCR-based technique identifies the number of replicates in a specific locus of bacterial genomes. After selecting the desired loci and designing specific primers, PCR is performed for the extracted bacterial DNA. Then, the size of PCR products is determined by electrophoresis and the number of repeats is counted by sequencing (21).

Due to the difficulties and limitations of studying anaerobic bacteria in Iran, few studies have investigated the genetic characteristics and typing of these bacteria. This study aimed at investigating MLVA for *B. fragilis* as a novel technique for typing and genetic differentiation of this microorganism. For this aim, suitable tandem repeats were selected to determine genetic diversity and conduct phylogenetic analysis.

## Materials and Methods

### Bacterial collection and identification

In total, 50 non-toxicogenic *B. fragilis* isolates were

attained from the previous study (22) and were stored in the microbial bank in the Department of Microbiology, Iran University of Medical Sciences, Tehran, Iran.

### Identification of VNTR loci

The sequence of the genome of *B. fragilis* YCH46 was obtained using GeneBank NCBI and tandem repeat sequences were analyzed using Tandem Repeats Finder (TRF version 4.09) which have been illustrated in Table 1 (23).

### Primer design

Suitable specific primers were designed using Oligo 7, AlleleID, Primer3, and Oligo Analyser software packages. Table 2 shows the oligonucleotide primers and flanking regions of every VNTR locus. Annealing temperatures of the primers were determined *in silico* using the Primer-BLAST tool in the NCBI website.

### Data analysis

MLVA profiles were clustered using the BioNumerics 7.6 software package, with UPGMA (Unweighted Pair

**Table 2.** Primers and their characteristics in the current study

| TRs | Primer sequences 5'→3'                                  | PP <sup>a</sup> (bp) | Flanking (bp) | Reference     |
|-----|---|----------------------|---------------|---------------|
| TR1 | F= TGAATACATTTCTTTTGGCTCT<br>R=CTAGACCTTCTTGTATATCTCCAT | 208                  | 119           | in this study |
| TR2 | F= CCCTCGGATAACAGGGAGTT<br>R= TGCTTTTCCCATGATTATCTTC    | 498                  | 156           | in this study |
| TR3 | F= CTGTTCAATTTCCGACAGCA<br>R= GCGGCTACTGATCTTTTAGCA     | 161                  | 141           | in this study |
| TR4 | F= TCCGTCCTGATACGGATTCT<br>R= AATCTGCCCTTCCATACCC       | 694                  | 71            | in this study |
| TR5 | F= AGCACGTAACCGAAATCACA<br>R= ACGTCGGAAAAGGAGATG        | 285                  | 60            | in this study |
| TR6 | F= ACAGCAGTGTTCAAACGTCAA<br>R= GGTTCGACAGATTGAGA        | 150                  | 86            | in this study |
| TR7 | F= GTCGTAACGCTCTGTCCA<br>R= ATGGCAGAAAAGGAGACGAT        | 245                  | 56            | in this study |
| TR8 | F= TACGACGTTCCGACGTGAG<br>R= GGCCGTGATGTAACAGAAG        | 550                  | 97            | in this study |

<sup>a</sup> PCR product length in *Bacteroides fragilis* isolate  
TR: Tandem repeats



**Table 3.** Simpson's Diversity and Hunter-Gaston Diversity

| Locus | Diversity index | Confidence interval | K | Max (PI) |
|-------|-----------------|---------------------|---|----------|
| TR:5  | 0.737           | 0.723 - 0.752       | 4 | 0.333    |
| TR:1  | 0.661           | 0.651 - 0.672       | 3 | 0.373    |
| TR:8  | 0.654           | 0.638 - 0.671       | 3 | 0.412    |
| TR:2  | 0.650           | 0.610 - 0.690       | 4 | 0.490    |
| TR:6  | 0.617           | 0.587 - 0.648       | 3 | 0.490    |
| TR:4  | 0.498           | 0.491 - 0.506       | 2 | 0.529    |
| TR:3  | 0.498           | 0.491 - 0.506       | 2 | 0.529    |
| TR:7  | 0.457           | 0.420 - 0.494       | 2 | 0.647    |

  

| Locus | Diversity index | Confidence interval | K | Max (PI) |
|-------|-----------------|---------------------|---|----------|
| TR:5  | 0.752           | 0.738 - 0.767       | 4 | 0.333    |
| TR:1  | 0.675           | 0.664 - 0.685       | 3 | 0.373    |
| TR:8  | 0.667           | 0.651 - 0.684       | 3 | 0.412    |
| TR:2  | 0.663           | 0.623 - 0.703       | 4 | 0.490    |
| TR:6  | 0.630           | 0.599 - 0.661       | 3 | 0.490    |
| TR:4  | 0.508           | 0.501 - 0.516       | 2 | 0.529    |
| TR:3  | 0.508           | 0.501 - 0.516       | 2 | 0.529    |
| TR:7  | 0.466           | 0.429 - 0.503       | 2 | 0.647    |

Diversity Index (for VNTR data)=indicates any variation in the number of repeats at every locus. Within the of 0.0 (indicative of no diversity) to 1.0 (indicative of complete diversity)  
 Confidence Interval=The level of precision in the diversity Index, indicated as 95% upper & lower cases  
 K=Number of different repeats at this locus in sample set.  
 max(pi)=Fraction of samples with the highest repeat numbers in this locus (within the range of 0.0 to 1.0)  
 TR: Tandem repeats

individuals in Tehran, Iran. For a better understanding of the features and varieties of the isolates, *B. fragilis* isolates were analyzed by MLVA typing, which is considered a valuable method for determining the diversity of bacterial populations in clinical isolates. MLVA is an inexpensive, uncomplicated, and efficient method whose results can be attained within a short period, usually faster than MLST and PFGE techniques (25).

Furthermore, over the past few years, typing has been inclined towards molecular techniques resulting in the development of new techniques such as MLVA. Thus, this new technique can be a promising substitute for previous techniques, including ribotyping, serotyping, and RFLP. *B. fragilis* is an anaerobic pathogen commonly isolated from clinical specimens with different virulence factors. Among the diseases caused by *Bacteroides* are cerebrospinal angiomas, meningitis, septic arthritis, inflammatory bowel, intestinal diseases, and soft tissue infections (26, 27).

Owing to the evolution and adaptation of *B. fragilis*, like other human bacterial flora, quantitative diversity for this bacterium was not observed in this study. A significant relationship was found between MLVA types and strains isolated from stools of different individuals. The limited number of isolates makes it difficult to interpret epidemiological data. Further studies are

required to assess the efficacy of MLVA assay in *B. fragilis* especially in the toxigenic strains.

## Conclusion

This technique can provide quick and valuable information for researchers to evaluate pathogenicity, evolution, and epidemiological studies of this microorganism.

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## Conflicts of Interest

The authors declare that they have no competing interests.

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