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(54) **Titre : PREVENTION, TRAITEMENT ET DIAGNOSTIC DE L'INFECTION A P. GINGIVALIS**
(54) **Title: PREVENTION, TREATMENT AND DIAGNOSIS OF P.GINGIVALIS INFECTION**

(57) **Abrégé/Abstract:**
The invention relates to generation and use of cellular and humoral responses for the prevention and treatment of P. gingivalis related conditions and diseases.

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(54) **Title**: PREVENTION, TREATMENT AND DIAGNOSIS OF P.GINGIVALIS INFECTION

(57) **Abstract**: The invention relates to generation and use of cellular and humoral responses for the prevention and treatment of P. gingivalis related conditions and diseases.

Prevention, treatment and diagnosis of P. gingivalis infection

Field of the invention

The invention relates to peptides and chimeric or fusion proteins and to the use of these proteins to elicit cellular and humoral responses for the prevention and treatment of *P. gingivalis*- related conditions and diseases.

Background of the invention

Chronic periodontitis is an inflammatory disease of the supporting tissues of the teeth leading to resorption of alveolar bone and eventual tooth loss. The disease is a major public health problem in all societies and is estimated to affect up to 15% of the adult population with severe forms affecting 5-6%.

The development and progression of chronic periodontitis has been associated with specific Gram-negative bacteria in subgingival plaque. The presence of *Porphyromonas gingivalis* in subgingival plaque has been strongly associated with disease.

The persistence of *P. gingivalis* in subgingival plaque from periodontitis patients after treatment (scaling and root planing) has been reported to be significantly associated with progressive alveolar bone loss. Furthermore an increase in *P. gingivalis* cell numbers in subgingival plaque has been shown to correlate with disease severity as measured by attachment loss, periodontal pocket depth and bleeding on probing.

Oral infection with *P. gingivalis* has been shown to induce periodontal bone loss in mice, rats and non-human primates. In addition, there has been increasing linkage of periodontal disease, and of *P. gingivalis* infection, with cardiovascular diseases and certain cancers.

A number of virulence factors have been reported to contribute to the pathogenicity of *P. gingivalis* including; LPS, fimbriae, hemagglutinin, hemolysin and extracellular hydrolytic enzymes (especially the Arg-X and Lys-X specific proteinases), otherwise known as "*P. gingivalis* trypsin-like enzymes".

The magnitude of the public health problem is such that there is a need for an antiserum, particularly specific antibodies that provide a strong protective response to *P. gingivalis* infection and means for providing same.

One problem has been that it is not clear how to obtain a strong protective response to *P. gingivalis* infection where there are a plethora of virulence factors to select from.

The relative immunogenicity of epitopes amongst virulence factors is not well understood, nor is the relative immunogenicity of epitopes on a given factor, particularly where it is not clear as to whether further epitopes remain to be identified.

One particular problem has been that many virulence factors are formed from multiple domains and are difficult to express so as to present a conformation approaching that found on *P. gingivalis*. Further, when these domains are expressed as discrete units i.e. in isolation of other virulence factor domains, they tend to fold into a conformation distinguished from that found on *P. gingivalis*.

Further, of the many different options for modifying the immunogenicity of a virulence factor it is not clear which would be most likely to provide for a protective immune response.

In work leading to the present invention the inventors have identified peptides having an amino acid sequence that is the same as, or that shares homology with, an amino acid sequence that forms a region of a *P. gingivalis* trypsin–like enzyme, said region defining a site in said enzyme for cleavage of a peptide bond located C – terminal to Lys or Arg in a peptide containing Lys or Arg, and incorporated such a peptide into a chimeric or fusion protein which, when used as a vaccine, provides better protection against periodontal tissue destruction than purified proteinase-adhesin complex formed from native *P. gingivalis* trypsin-like enzyme or killed whole cells.

Summary of the Invention

In one aspect, the present invention provides a chimeric or fusion protein for inducing an immune response to *P. gingivalis*, the protein including a first peptide joined directly or through a linker to a second peptide, wherein:

(A) said first peptide includes:

(i) part of, or all of a sequence that is the same as, or homologous to the sequence shown in SEQ ID No:1; or

(ii) part of, or all of a sequence that is the same as, or homologous to the sequence shown in SEQ ID No:2 ; and

(B) said second peptide includes:

(i) part of, or all of a sequence that is the same as, or homologous to the sequence of an adhesin domain of the Lys-X-proteinase of *P. gingivalis*; or

(ii) part of, or all of a sequence that is the same as, or homologous to the sequence of an adhesin domain of the Arg-X-proteinase of *P. gingivalis*; or

(iii) part of, or all of a sequence that is the same as, or homologous to the sequence of a HagA adhesin domain of *P. gingivalis*.

In another aspect, the invention provides a chimeric or fusion protein for inducing an immune response to *P. gingivalis*, the protein including a peptide joined directly or through a linker to a polypeptide, wherein:

(A) said peptide includes:

(i) part of, or all of a sequence that is the same as, or homologous to the sequence shown in SEQ ID No:1; or

(ii) part of, or all of a sequence that is the same as, or homologous to the sequence shown in SEQ ID No:2 ; and

(B) said polypeptide includes:

(i) part of, or all of a sequence that is the same as, or homologous to the sequence of an adhesin domain of the Lys-X-proteinase of *P. gingivalis*; or

(ii) part of, or all of a sequence that is the same as, or homologous to the sequence of an adhesin domain of the Arg-X-proteinase of *P. gingivalis*; or

(iii) part of, or all of a sequence that is the same as, or homologous to the sequence of a HagA adhesin domain of *P. gingivalis*.

In another aspect, the invention provides a peptide for inducing an immune response to

P. gingivalis the peptide having a sequence:

(i) that is the same as, or homologous to the sequence shown in one of SEQ ID No: 64 to 66; and

(ii) that is the same as, or homologous to the sequence shown in SEQ ID No: 67 or 68.

In one aspect, the peptide having a sequence that is the same as or homologous to sequence shown in one of SEQ ID No: 64 to 68 may be provided in the form of a chimeric or fusion protein in which the peptide is joined directly or through a linker to a second peptide, wherein the second peptide includes:

(i) part of, or all of a sequence that is the same as, or homologous to the sequence of an adhesin domain of the Lys-X-proteinase of *P. gingivalis*; or

(ii) part of, or all of a sequence that is the same as, or homologous to the sequence of an adhesin domain of the Arg-X-proteinase of *P. gingivalis*; or

(iii) part of, or all of a sequence that is the same as, or homologous to the sequence of a HagA adhesin domain of *P. gingivalis.*

In yet another aspect, the invention provides a composition such as an antigenic composition, particularly a vaccine composition, including a chimeric or fusion protein or peptide as broadly described above, optionally in association with an adjuvant.

In this aspect, the invention also provides a method of preventing or reducing the incidence or severity of a *P. gingivalis* – related condition or disease in a subject, which comprises administering to the subject a chimeric or fusion protein as described above, or a composition as described above.

In this aspect, the invention further provides the use of a chimeric or fusion protein as described above, or a composition as described above, in, or in the manufacture of a medicament for preventing or reducing the incidence or severity of a *P. gingivalis* – related condition or disease in a subject.

In another aspect, the invention provides an antibody, particularly a monoclonal antibody, raised against a chimeric or fusion protein or peptide as broadly described

above.

In this aspect, the invention also provides a method of preventing or reducing the severity of a *P. gingivalis*-related disease or condition in a subject, which comprises administering to the subject an antibody as described above.

In this aspect, the invention further provides the use of an antibody as described above in, or in the manufacture of a medicament for preventing or reducing the incidence or severity of a *P. gingivalis* – related condition or disease in a subject.

In yet another aspect, the invention also provides a nucleic acid molecule including a nucleotide sequence encoding a chimeric or fusion protein as broadly described above, optionally operatively linked to at least one regulatory element.

In this aspect, the invention further provides a vector including such a nucleic acid molecule, as well as a prokaryotic or eukaryotic cell including such a nucleic acid molecule.

In this aspect, the invention also provides a method of preventing or reducing the incidence or severity of a *P. gingivalis*-related condition or disease in a subject, which comprises administering to the subject a nucleic acid molecule as described above, a vector as described above, or a prokaryotic or eukaryotic cell as described above.

In this aspect, the invention further provides the use of a nucleic acid molecule as described above, a vector as described above, or a prokaryotic or eukaryotic cell as described above, in, or in the manufacture of a medicament for preventing or reducing the severity of a *P. gingivalis*-related disease or condition in a subject.

In a further aspect, the invention provides a method for the diagnosis or monitoring of a *P. gingivalis*-related condition or disease in a subject, which comprises use of a chimeric or fusion protein as described above to detect anti-*P. gingivalis* antibodies in a biological sample from said subject.

In this aspect, the invention also provides the use of a chimeric or fusion protein as described above, to detect anti-*P. gingivalis* antibodies in a biological sample from a subject.

In yet another aspect, the invention provides a method for the diagnosis or monitoring of a *P. gingivalis*-related condition or disease in a subject, which comprises use of an

antibody as described above, to detect the presence of *P. gingivalis* in a biological sample from said subject.

In this aspect, the invention also provides the use of an antibody as described above, to detect the presence of *P. gingivalis* in a biological sample from a subject.

In another aspect, the invention provides a use of a peptide having part of, or all of a sequence that is the same as, or homologous to a sequence of a *P. gingivalis* Lys-X or Arg-X proteinase, or a nucleic acid encoding said peptide for the manufacture of a chimeric or fusion protein for inducing an immune response to *P. gingivalis.* In this aspect the peptide may have a sequence shown in one of SEQ ID No: 17, 18, 25 or 26.

Brief description of the drawings

Figure 1 shows a Coomassie blue stain of the SDS-PAGE gel of recombinant Kgp Proteins. Lane 1= KAS2-KLA1, Lane 2=KLA1, Lane 3=KsA1, Lane 4= KAS1-KsA1. Molecular weight markers are indicated as kDa.

Figure 2 shows antibody recognition of KAS2 peptide and formalin killed *P. gingivalis* W50 cells. (A) KAS2 peptide was probed with antisera raised to formalin killed *P. gingivalis* W50 cells (FK-W50), recombinant proteins KAS1-KsA1, KAS2-KLA1, and synthetic KAS2-DT conjugate and PBS in an ELISA. (B) formalin killed *P. gingivalis* W50 cells were probed with antisera raised to formalin killed *P. gingivalis* W50 cells (FK-W50), recombinant proteins KAS1-KsA1, KAS2-KLA1, KLA1 and PBS in an ELISA. Antibody responses are expressed as the ELISA titre OD_{415} obtained minus double the background level, with each titre representing the mean ± standard deviation of three values.

Figure 3 shows *P. gingivalis*-induced horizontal bone loss of maxillae molars of mice immunised with the recombinant proteins and recombinant chimera proteins, formalin-killed P. gingivalis and adjuvant alone (PBS, IFA) or non-orally infected (non-challenged) mice. In this figure KAS2-KLA1 is shown as AS2-LA1, KLA1 is shown as LA1, KAS1-KsA1 is shown as AS1-sA1, KsA1 is shown as sA1. Measurement of bone loss is the mean of the area measured in millimeters squared (mm2) from the cementoenamel junction (CEJ) to the alveolar bone crest (ABC) of the buccal side of

each maxillary molar of both the left and right maxillae. Data was normally distributed as measured by Levene's homogeneity of variance and are presented as mean (n = 12) in mm2 and were analyzed using the One-Way analysis of variance and Dunnett's T3 test. *, indicates group has significantly (P<0.001) less bone loss than control (infected) group. †, indicates group has significantly (P<0.001) more bone loss than the AS2-LA1 group.

Figure 4 shows serum antibody subclass responses of immunised mice in the periodontitis model. Sera from mice; A (pre-oral inoculation) and B (post-oral inoculation) immunised with recombinant proteins KsA1, KLA1, KAS1-KsA1 and KAS2-KLA1 and formalin killed *P. gingivalis* strain W50 were used in the ELISA with the formalin killed *P. gingivalis* strain W50 as the adsorbed antigen. Antibody responses IgG (black bars), IgG1 (grey bars), IgG2a (white bars), IgG2b (horizontal striped bars), IgG3 (diagonal striped bars), are expressed as the ELISA titre (log 2) obtained minus the background level, with each titre representing the mean ± standard deviation of three values.

Figure 5 shows a PEPSCAN analysis of peptide-specific antibody reactivity to overlapping peptides representing the KAS2 peptide sequence 433-468. (A) KAS2 overlapping peptides (offset 1, overlap 7) probed with KAS1-KsA1 (white bars), KAS2-KLA1 (black bars) antisera. (B) KAS2 overlapping peptides (offset , overlap 7) probed with KAS2-DT conjugate antisera. Each bar displays the antibody reactivity (optical density [OD] at 415 nm).

Figure 6. Chimera AS2-LA1 induces an antibody response in outbred mice that recognises P. gingivalis whole cells and the RgpA-Kgp complex. CD1 outbred mice were immunised with chimera AS2-LA1 (50mg/mouse) and the collected sera used in ELISA with AS2-LA1 (A), formalin killed P. gingivalis strain W50 (B) and RgpA-Kgp complex (C) as the absorbed antigens. In this figure KAS2-KLA1 is shown as AS2-LA1. The titre for each immunoglogulin isotype to each antigen was determined and the data expressed as the ELISA titre ('000) obtained minus double the background level, with each titre representing the mean ± standard deviation of three values.

Figure 7. Protein model of the Kgp proteinase. KAS2 [Asn433-Lys468]. (A) KAS4 [Asp388-Val395] (B), KAS5 [Asn510-Asp516] (C) and KAS6 [Ile570-Tyr580] (D).

Detailed description of the embodiments

It will be understood that the invention disclosed and defined in this specification extends to all alternative combinations of two or more of the individual features mentioned or evident from the text or drawings. All of these different combinations constitute various alternative aspects of the invention.

The inventors have found that the regions of *P. gingivalis* trypsin-like enzymes that flank or otherwise define a catalytic or active site for cleavage of a peptide bond are highly immunogenic and indeed sufficient to provide for a humoral response to *P. gingivalis* infection. In particular, it has been found that a chimeric or fusion protein including one or more of these regions provides protection against alveolar bone loss which is greater than that seen for antisera raised against whole cells and other immunogens. The finding is particularly surprising as, to date, the catalytic domain of trypsin-like enzymes of *P. gingivalis* has been found to be relatively weakly immunogenic.

In one aspect, the present invention provides a chimeric or fusion protein for inducing an immune response to *P. gingivalis*, the protein including a first peptide joined directly or through a linker to a second peptide, wherein:

(A) said first peptide includes:

(i) part of, or all of a sequence that is the same as, or homologous to the sequence shown in SEQ ID No:1; or

(ii) part of, or all of a sequence that is the same as, or homologous to the sequence shown in SEQ ID No:2 ; and

(B) said second peptide includes:

(i) part of, or all of a sequence that is the same as, or homologous to the sequence of an adhesin domain of the Lys-X-proteinase of *P. gingivalis*; or

(ii) part of, or all of a sequence that is the same as, or homologous to the sequence of an adhesin domain of the Arg-X-proteinase of *P. gingivalis*; or

(iii) part of, or all of a sequence that is the same as, or homologous to the sequence of a HagA adhesin domain of *P. gingivalis*.

As used herein, the term "peptide" is used to refer to an amino acid sequence of up to

about 40 amino acid residues, preferably from 5 to 40 amino acid residues.

In one embodiment, a polypeptide is used in place of or in other words instead of the "second peptide". The term "polypeptide" is used to refer to an amino acid sequence of at least about 40 amino acid residues.

Thus, in another aspect there is provided a chimeric or fusion protein for inducing an immune response to *P. gingivalis*, the protein including a peptide joined directly or through a linker to a polypeptide, wherein:

(A) said peptide includes:

(i) part of, or all of a sequence that is the same as, or homologous to the sequence shown in SEQ ID No:1; or

(ii) part of, or all of a sequence that is the same as, or homologous to the sequence shown in SEQ ID No:2 ; and

(B) said polypeptide includes:

(i) part of, or all of a sequence that is the same as, or homologous to the sequence of an adhesin domain of the Lys-X-proteinase of *P. gingivalis*; or

(ii) part of, or all of a sequence that is the same as, or homologous to the sequence of an adhesin domain of the Arg-X-proteinase of *P. gingivalis*; or

(iii) part of, or all of a sequence that is the same as, or homologous to the sequence of a HagA adhesin domain of *P. gingivalis.*

In another aspect, the invention provides a peptide for inducing an immune response to *P. gingivalis* selected from the group consisting of:

(i) a sequence that is the same as or homologous to the sequence shown in one of SEQ ID No: 64 to 66; and

(ii) a sequence that is the same as or homologous to the sequence shown in SEQ ID No: 67 or 68.

In an aspect of the invention, where the peptide has a sequence of SEQ ID No: 64 to 68, the peptide may be provided in the form of a chimeric or fusion protein in which the

peptide is joined directly or through a linker to a second peptide. In an embodiment, the second peptide of the chimeric or fusion protein includes:

(i) part of, or all of a sequence that is the same as, or homologous to the sequence of an adhesin domain of the Lys-X-proteinase of *P. gingivalis*; or

(ii) part of, or all of a sequence that is the same as, or homologous to the sequence of an adhesin domain of the Arg-X-proteinase of *P. gingivalis*; or

(iii) part of, or all of a sequence that is the same as, or homologous to the sequence of a HagA adhesin domain of *P. gingivalis.*

In the above described embodiment a polypeptide is used in place of, or in other words instead of the second peptide. Thus, in another aspect there is provided a chimeric or fusion protein for inducing an immune response to *P. gingivalis*, the protein including a peptide joined directly or through a linker to a polypeptide, wherein:

(A) said peptide includes:

(i) a sequence that is the same as or homologous to the sequence shown in one of SEQ ID No: 64 to 66; or

(ii) a sequence that is the same as or homologous to the sequence shown in SEQ ID No: 67 or 68.; and

(B) said polypeptide includes:

(i) part of, or all of a sequence that is the same as, or homologous to the sequence of an adhesin domain of the Lys-X-proteinase of *P. gingivalis*; or

(ii) part of, or all of a sequence that is the same as, or homologous to the sequence of an adhesin domain of the Arg-X-proteinase of *P. gingivalis*; or

(iii) part of, or all of a sequence that is the same as, or homologous to the sequence of a HagA adhesin domain of *P. gingivalis.*

As used herein, a reference to a "homologue" of a peptide or polypeptide is a reference to a peptide or polypeptide having an amino acid sequence that shares homology or

that is homlogous to, or that has identity with the amino acid sequence of the first-mentioned peptide or polypeptide, preferably at least 90% sequence identity, more preferably at least 95% and even more preferably at least 98% sequence identity when the comparison is performed by a BLAST algorithm wherein the parameters of the algorithm are selected to give the largest match between the respective sequences over the entire length of the respective reference sequences. Sequence identity refers to exact matches between the amino acids of two sequences which are being compared. Such a homologue may derive from a naturally occurring variant or isolate of the Lys-X-proteinase or Arg-X-proteinase of *P. gingivalis*. Alternatively, it may be a "conservative-substitution" variant of a peptide or polypeptide from the Lys-X-proteinase or Arg-X-proteinase of *P. gingivalis* in which one or more amino acid residues have been changed without altering the overall conformation and function of the peptide or polypeptide; including, but by no means limited to, replacement of an amino acid with one having similar properties. Amino acids with similar properties are well known in the art. For example, polar/hydrophilic amino acids which may be interchangeable include asparagine, glutamine, serine, cysteine, threonine, lysine, arginine, histidine, aspartic acid and glutamic acid; nonpolar/hydrophobic amino acids which may be interchangeable include glycine, alanine, valine, leucine, isoleucine, proline, tyrosine, phenylalanine, tryptophan and methionine; acidic amino acids which may be interchangeable include aspartic acid and glutamic acid and basic amino acids which may be interchangeable include histidine, lysine and arginine. Preferably such conservative-substitution variants have less than 20, more preferably less than 15, more preferably less than 10, and most preferably less than 5 amino acid changes.

A region of a *P. gingivalis* trypsin-like enzyme – especially a Lys-X-proteinase (Kgp) or Arg-X-proteinase (RgpA) - that defines a site in an enzyme for cleavage of a peptide bond can be determined following the teaching of the specification herein, particularly in relation to Figure 7 and Example 9, which exemplify the process for predicting three-dimensional conformation of the catalytic site as it appears on *P. gingivalis* for Lys-X-proteinase. Example 10 provides methodology for modelling of the Arg-X-proteinase three-dimensional conformation.

In certain embodiments, the chimeric or fusion protein, or first or second peptide components thereof may be formed from a peptidomimetic. A peptidomimetic is a

molecule that mimics one or more characteristics of a given peptide, for example conformation, and that consists of amino acid residues, some of which may not be naturally occurring.

Having identified the immunogenic regions of the catalytic site, the inventors have determined the sequence of various peptide immunogens against which a humoral response can be raised. In particular, 'six' regions that flank or otherwise define the catalytic site have been defined as follows: KAS1/RAS1, KAS2/RAS2, KAS3/RAS3, KAS4/RAS4, KAS5/RAS5 and KAS6 (see Table 1). With this information, the inventors have been able to interrogate protein sequence databases to determine peptides that share homology with amino acid sequences that form regions that flank a catalytic site and hence that represent immunogenic epitopes found on *P. gingivalis*. The sequence of these peptides are identified by the following structural formula:

Table 1. Sequences that flank the active site of Kgp and RgpA.

Region	Kgp Lys – X (numbering according to SEQ ID No.62)	Kgp Lys – X Consensus	RgpA Arg –X (numbering according to SEQ ID No.61)	RgpA Arg –X Consensus
PAS1K/ PAS1R	PAS1K (432-453)	LNTGVSFANYTAHGS ETAWADP (SEQ ID NO: 30)	PAS1R (426-446)	FNGGISLANYTGHGSET AWGT (SEQ ID NO: 34)
KAS1/ RAS1	KAS1 (432-454)	LNTGV[G/S]FANYTAH GSET[S/A]WADP[S/L] (SEQ ID NO: 27)	RAS1 (426-448)	FNGGISL[V/A]NYTGHG SETAWGTSH (SEQ ID NO: 31)
KAS2/ RAS2	KAS2 (433-468)	NTGV[G/S]FANYTAHG SET[S/A]WADP[S/L][L/ V]T[A/T][T/S]Q[V/L]KAL TNK[D/N]K (SEQ ID NO: 28)	RAS2 (427-462)	NGGISL[V/A]NYTGHGS ETAWGTSHFGTTHVKQ LTNSNQ (SEQ ID NO: 32)
KAS3/RA S3	KAS3 (436-455)	V[G/S]FANYTAHGSET[S/A]WADP[S/L][L/V] (SEQ ID NO: 29)	RAS3 (430-449)	ISL[V/A]NYTGHGSETA WGTSHF (SEQ ID NO: 33)
KAS4/ RAS4	KAS4 (388-395)	D[S/Y][Y/S]WN[P/S][K/ Q][I/V] (SEQ ID NO: 64)	RAS4 (379-386)	EGGPSADN (SEQ ID NO: 67)
KAS5/ RAS5	KAS5 (510-516)	NSYWGED (SEQ ID NO: 65)	RAS5 (508-514)	[N/D]Q[S/Y]WA[S/P]P (SEQ ID NO: 68)
KAS6	KAS6 (570-580)	IGN[V/I]THIGAHY (SEQ ID NO: 66)		

The inventors have found that chimeric proteins including these peptides have a number of utilities. For example, as described herein, some produce a humoral response that is highly protective for treatment or prevention of bone loss as observed in chronic periodonitis. The peptides may also be used in a diagnostic assay wherein they can detect or monitor specificities in an individual's serum, thereby indicating whether or not the individual is infected and if so, whether treatments are required or if provided, whether they have been effective.

It will be understood that the region of a *P. gingivalis* trypsin-like enzyme that defines a site in the enzyme for cleavage of a peptide bond located C – terminal to Lys or Arg, does not comprise a complete sequence of the Lys-X-proteinase or Arg-X-proteinase.

As used herein, the terms "heterologous protein" or "chimeric or fusion protein" are used to refer to a protein that is composed of functional units, domains, sequences or regions of amino acids derived from different sources or that are derived from the same source and that have been assembled so as to have an organisation that is distinguished from that observed in a molecule from which the unit, domain, sequence or region is derived or related to. A common feature of the chimeric or fusion proteins of the invention is that they contain at least one peptide having an amino acid sequence that is the same as or that shares homology with a sequence of a *P. gingivalis* trypsin-like enzyme that defines a catalytic site for cleavage of a peptide bond.

In a preferred embodiment, where the first peptide comprises a peptide from the Kgp[432-468] region, it is preferably (i) a peptide which comprises a sequence selected from VSFANYT and VGFANYT, more preferably a sequence selected from GVSFANYT, GVGFANYT, VSFANYTA and VGFANYTA; or (ii) a peptide which comprises a sequence selected from ETAWAD, ETSWAD, TAWADP and TSWADP, preferably a sequence selected from SETAWAD, SETSWAD, ETAWADP, ETSWADP, TAWADPL and TSWADPL, more preferably a sequence selected from GSETAWAD, GSETSWAD, SETAWADP, SETSWADP, ETAWADPL, ETSWADPL, TAWADPLL and TSWADPLL. More preferably, this peptide is selected from the KAS1[432-454], KAS2[433-468] and KAS3[436-455] peptides shown in Table 1. Alternatively, the first peptide may be the PAS1K[432-453] peptide, also known as PAS1(K48), disclosed in International Patent Application No. PCT/AU98/00311 (WO 98/049192). The sequence identifiers corresponding to these peptides are shown in Table 3.

Similarly, in another preferred embodiment, where the first peptide comprises a peptide from the RgpA[426-462] region, this peptide is preferably selected from the RAS1[426-448], RAS2[427-462] and RAS3[430-449] peptides shown in Table 1. Alternatively, the first peptide may be the PAS1R[426-446] peptide, also known as PAS1(R45), disclosed in International Patent Application No. PCT/AU98/00311 (WO 98/049192).

In the chimeric or fusion protein of the invention, the second peptide may be a peptide from an adhesin domain of a *P. gingivalis* trypsin–like enzyme, such as Lys-X-proteinase (Kgp) or Arg-X-proteinase (RgpA) or HagA (see Table 2). These domains are sometimes also known as hemagglutinins. In the Lys-X-proteinase, the preferred domains are KA1, KA2, KA3, KA4, KA5 as identified in Table 2. In the Arg-X-proteinase, the preferred domains are RA1, RA2, RA3 and RA4 as identified in Table 2. In HagA, the preferred domains are HagA1, HagA1* and HagA1**.

Table 2. Adhesin domains of the Kgp and RgpA proteinases.

	A1	sA1	LA1	A2	A3	A4	A5
Kgp Lys-X proteinase SEQ ID No. 62	KA1 (738-1099) SEQ ID NO: 35	KsA1 (759-989) SEQ ID NO: 36	KLA1 (751-1056) SEQ ID NO: 37	KA2 (1157-1275) SEQ ID NO: 40	KA3 (1292 -1424) SEQ ID NO: 41	KA4 (1427 - 1546) SEQ ID NO: 42	KA5 (1548-1732) SEQ ID NO: 43
RgpA Arg-X proteinase SEQ ID No. 61	RA1 (720-1081) SEQ ID NO: 38	RsA1 (831-971) SEQ ID NO: 39	–	RA2 (1139-1257) SEQ ID NO: 44	RA3 (1274-1404) SEQ ID NO: 45	RA4 (1432-1706) SEQ ID NO: 46	–
HagA SEQ ID NO. 63	HagA1 (26-351) (SEQ ID NO: 80), HagA1* (366-625) (SEQ ID NO: 81), HagA1** (820-1077) (SEQ ID NO:82) or HagA1** (1272-1529) (SEQ ID NO:82)						

In addition to improving the humoral response to a peptide of the invention such as KAS1, KAS2, KAS3, KAS4, KAS5 and KAS6 or RAS1, RAS2 and RAS3, RAS4 and RAS5 when included with such a peptide in a chimeric or fusion protein, the adhesin domain also contains immunogenic epitopes, hence leading to the production of multiple specificities to elicit a protective immunogenic response. The finding that the immunogenic epitopes of the adhesin domain are retained in a form approaching that in a *P. gingivalis* trypsin –like enzyme when provided in the chimeric or fusion protein of the invention is unanticipated.

It will be understood that in these embodiments of the invention the chimeric or fusion protein may contain any one or more of the peptides selected from KAS1/RAS1, KAS2/RAS2, KAS3/RAS3, KAS4/RAS4, KAS5/RAS5 and KAS6/RAS6 together with any one or more adhesin domains of a *P. gingivalis* trypsin-like enzyme, in particular with any one or more of Lys-X-proteinase adhesin domains (KA1, KA2, KA3, KA4 and KA5) or Arg-X-proteinase adhesin domains (RA1, RA2, RA3 and RA4) or HagA domains HagA1, HagA1* and HagA1**.

It will also be understood that it is not necessary for the adhesin domain to be a complete domain as observed in a *P. gingivalis* trypsin-like enzyme. For example the adhesin domain may be a fragment of such a domain, in particular, preferred fragments are the KsA1 and KLA1 domain fragments of the Lys-X-proteinase A1 domain (see Table 2). Where the domain is a fragment of an adhesin domain it generally contains one or more adhesin domain specific epitopes.

The sequence identifiers corresponding to the adhesin related peptides are shown in Table 3.

In one embodiment the second peptide or polypeptide includes a sequence shown in one or more of SEQ ID No: 69 to 79 or one or more of 83 to 85.

The chimeric or fusion protein of the present invention may also include one or more additional peptides selected from the Kgp[432-468] region of the Lys-X-proteinase and/or one or more additional peptides selected from the RgpA[426-462] region of the Arg-X-proteinase.

In preferred embodiments of the present invention, the chimeric or fusion protein includes one or more of KAS1, KAS2, KAS3, KAS4, KAS5 and KAS6, or one or more of RAS1, RAS2, RAS3, RAS4 and RAS5, together with KsA1 or KLA1.

Thus in certain embodiments, the chimeric or fusion protein may include at least one further peptide wherein said further peptide includes:

(i) part of, or all of a sequence that is the same as, or homologous to the sequence shown in SEQ ID No:1 ; or

(ii) part of, or all of a sequence that is the same as, or homologous to the sequence shown in SEQ ID No:2; or

(iii) part of, or all of a sequence that is the same as, or homologous to the sequence of an adhesin domain of the Lys-X-proteinase of *P. gingivalis*; or

(iv) part of, or all of a sequence that is the same as, or homologous to the sequence of an adhesin domain of the Arg-X-proteinase of *P. gingivalis*; or

(v) part of, or all of a sequence that is the same as, or homologous to the sequence of a HagA adhesin domain of *P. gingivalis.*

Other examples of domains, units, sequences or regions that may be included in a chimeric or fusion protein as described herein include domains for binding to receptors or ligands such as Fc binding regions or Fc receptors, domains for improving half-life such as albumin or domains for facilitating expression or purification of the chimeric or fusion protein.

In the chimeric or fusion proteins of the present invention, the C-terminal residue of the first peptide may be covalently linked to the N-terminal residue of an adhesin domain polypeptide, or the N-terminal residue of the first peptide may be covalently linked to the C-terminal residue of an adhesin domain polypeptide. In this arrangement, the first peptide and adhesin domain polypeptide, are said to be "directly linked" or "adjacent".

In other embodiments, the chimeric or fusion protein includes a linker for linking the first peptide to an adhesin domain polypeptide. The linker may be any linker able to join a peptide to a polypeptide, including both amino acid and non-amino acid linkers. Preferably, the linker is non-immunogenic. Suitable linkers may be up to 15 amino acids in length, although less than five amino acids is preferred. The linker may function

to bring the first peptide and adhesin domain polypeptide into a closer spatial arrangement than normally observed in a *P. gingivalis* trypsin-like enzyme. Alternatively, it may space the first peptide and adhesin domain polypeptide apart.

The chimeric or fusion proteins of the invention may be produced by recombinant expression systems (such as recombinant DNA technology) or by chemical synthesis (such as solid phase peptide synthesis). These techniques are well known in the art.

The heterologous or chimeric protein is particularly advantageous because it improves the humoral response obtained over that obtained using the first or second peptide components of the chimeric or fusion protein alone.

The inventors have found that chimeric proteins including these peptides have a number of utilities. For example, as described herein, some produce a humoral response that is highly protective for treatment or prevention of bone loss as observed in chronic periodontitis. The peptides may also be used in a diagnostic assay wherein they can detect or monitor specificities in an individual's serum, thereby indicating whether or not the individual is infected and if so, whether treatments are required or if provided, whether they have been effective.

In one embodiment, the chimeric or fusion protein induces a protective immune response, typically a response that at least minimises or limits connective tissue damage otherwise associated with *P. gingivalis* infection. In one embodiment the protective response at least minimises or limits *P.gingivalis* induced bone loss. A model system for measuring bone loss mediated by *P. gingivalis* infection is discussed herein. Typically the protective immune response is predominantly a humoral reponse. In certain embodiments the protective immune response also includes a cellular response.

The present invention also provides a composition including a chimeric or fusion protein as broadly described above. Typically the composition is antigenic or immunogenic. More particularly, the invention provides a composition suitable for eliciting a protective or therapeutic immune response against *P. gingivalis* infection, including the chimeric or fusion protein, optionally in association with an adjuvant. Such a composition may also include another component for modulating or potentiating the immune response. One embodiment, the composition takes the form of a vaccine.

Various adjuvants are known for use in conjunction with vaccine compositions. The adjuvants aid by modulating the immune response and in attaining a more durable and higher level of immunity using smaller amounts of vaccine antigen or fewer doses than if the vaccine antigen were administered alone. Examples of adjuvants include incomplete Freund's adjuvant (IFA), Adjuvant 65 (containing peanut oil, mannide monooleate and aluminium monostearate), oil emulsions, Ribi adjuvant, the pluronic polyols, polyamines, Avridine, Quil A, saponin, MPL, QS-21, mineral gels such as aluminium salts and calcium salts, nanoparticles such as hydroxyapatite, calcium phosphate, aluminium salts, sugar oligomers and polymers such as mannan, chitosan. Other examples include oil in water emulsions such as SAF-1, SAF-0, MF59, Seppic ISA720, and other particulate adjuvants such ISCOMs™ and ISCOM matrix™. An extensive but not exhaustive list of other examples of adjuvants are listed in Cox and Coulter 1992 [In: Wong WK (ed.) *Animals parasite control utilising technology*. Bocca Raton; CRC press, 1992; 49-112]. In addition to the adjuvant, the vaccine composition may include conventional pharmaceutically acceptable carriers, excipients, fillers, buffers or diluents as appropriate. One or more doses of the vaccine composition containing adjuvant may be administered prophylactically to prevent periodontitis or therapeutically to treat already present periodontitis.

In a preferred composition, the chimeric or fusion protein is combined with a mucosal adjuvant and administered via the oral, buccal or nasal route. Examples of mucosal adjuvants are nanoparticles, cholera toxin and heat labile *E. coli* toxin, the non-toxic B subunits of these toxins, genetic mutants of these toxins which have a reduced toxicity. Other methods which may be utilised to deliver the antigenic protein orally/buccally/nasally include incorporation or absorption of the protein into or onto particles of biodegradable polymer (such as acrylates or polyesters) or nanoparticles (such as hydroxyapatite) by microencapsulation to aid uptake of the microspheres from the gastrointestinal tract or other mucosal surfaces and to protect degradation of the proteins. Liposomes, ISCOMs™, hydrogels are examples of other potential methods which may be further enhanced by the incorporation of targeting molecules such as LTB, CTB or lectins for delivery of the antigenic protein to the mucosal immune system. In addition to the antigenic protein and the mucosal adjuvant or delivery system, the vaccine composition may include conventional pharmaceutically acceptable carriers,

excipients, fillers, coatings, dispersion media, antibacterial or antifungal agents, and buffers or diluents as appropriate.

In this aspect, the invention also provides a method of preventing or reducing the incidence or severity of a *P. gingivalis*–related condition or disease in a subject, which comprises administering to the subject a chimeric or fusion protein as described above, or an composition as described above.

The subject may be a human or other animal subject, and is preferably a human.

Typically, the *P. gingivalis*-related condition or disease is chronic periodontis, however it may also be bone loss, especially alveolar bone loss, or coronary artery disease.

Many methods are known for administration of a vaccine composition to a human or animal subject, including but not limited to intradermal, intramuscular, intraperitoneal, intravenous, subcutaneous, intranasal, sub-lingual, buccal and oral administration. These routes of administration are particularly useful for vaccination.

In another aspect, the invention provides an antibody, preferably a monoclonal antibody, raised against a chimeric or fusion protein as broadly described above.

These antibodies may be produced by standard techniques, and may be used in passive immunisation of a subject. Accordingly, in this aspect, the invention also provides a method of preventing or reducing the severity of a *P. gingivalis*-related disease or condition in a subject, which comprises administering to the subject an antibody as described above.

In a further aspect, the present invention provides a nucleic acid molecule including a nucleotide sequence encoding a chimeric or fusion protein as broadly described above, optionally operatively linked to at least one regulatory element. In one embodiment the nucleic acid is provided in isolated or substantially purified form.

The nucleic acid molecule may, for example, be inserted into a suitable expression vector for production of the chimeric protein as a recombinant protein by insertion of the expression vector into a prokaryotic or eukaryotic host cell. Successful expression of the recombinant protein requires that the expression vector contains the necessary regulatory elements for transcription and translation which are compatible with, and recognised by the particular host cell system used for expression. A variety of host cell

systems may be utilized to express the recombinant protein, which include, but are not limited to bacteria transformed with a bacteriophage vector, plasmid vector, or cosmid DNA; yeast containing yeast vectors; fungi containing fungal vectors; insect cell lines infected with virus (e.g. baculovirus); and mammalian cell lines transfected with plasmid or viral expression vectors, or infected with recombinant virus (e.g. vaccinia virus, adenovirus, adeno-associated virus, retrovirus, etc).

Using methods known in the art of molecular biology, various promoters and enhancers can be incorporated into the expression vector, to increase the expression of the recombinant protein, provided that the increased expression of the amino acid sequences is compatible with (for example, non-toxic to) the particular host cell system used.

The selection of the promoter will depend on the expression system used. Promoters vary in strength, i.e. ability to facilitate transcription. Generally, it is desirable to use a strong promoter in order to obtain a high level of transcription of the coding nucleotide sequence and expression into recombinant protein. For example, bacterial, phage, or plasmid promoters known in the art from which a high level of transcription have been observed in a host cell system including *E. coli* include the lac promoter, trp promoter, recA promoter, ribosomal RNA promoter, the P_R and P_L promoters, lacUV5, ompF, bla, lpp, and the like, may be used to provide transcription of the inserted nucleotide sequence encoding amino acid sequences.

Other control elements for efficient transcription or translation include enhancers, and regulatory signals. Enhancer sequences are DNA elements that appear to increase transcriptional efficiency in a manner relatively independent of their position and orientation with respect to a nearby coding nucleotide sequence. Thus, depending on the host cell expression vector system used, an enhancer may be placed either upstream or downstream from the inserted coding sequences to increase transcriptional efficiency. Other regulatory sites, such as transcription or translation initiation signals, can be used to regulate the expression of the coding sequence.

In another embodiment, the vector may be a viral or bacterial vaccine vector, and used to provide a recombinant viral vaccine, a recombinant bacterial vaccine, a recombinant attenuated bacterial vaccine, or an inactivated recombinant viral vaccine. Vaccinia virus

is the best known example, in the art, of an infectious virus that is engineered to express vaccine antigens derived from other organisms. The recombinant live vaccinia virus, which is attenuated or otherwise treated so that it does not cause disease by itself, is used to immunize the host. Subsequent replication of the recombinant virus within the host provides a continual stimulation of the immune system with the vaccine antigens thereby providing long lasting immunity.

Other live vaccine vectors include: adenovirus, cytomegalovirus, and preferably the poxviruses such as vaccinia [Paoletti and Panicali, U.S. Patent No. 4,603,112] and attenuated *Salmonella* strains [Stocker *et al.,* U.S. Patent No. 5,210,035; 4,837,151; and 4,735,801; and Curtiss *et al.,* 1988, *Vaccine* 6:155-160]. Live vaccines are particularly advantageous because they continually stimulate the immune system which can confer substantially long-lasting immunity. When the immune response is protective against subsequent *P.* gingivalis infection, the live vaccine itself may be used in a preventive vaccine against *P. gingivalis.* In particular, the live vaccine can be based on a bacterium that is a commensal inhabitant of the oral cavity. This bacterium can be transformed with a vector carrying a recombinant chimeric protein and then used to colonise the oral cavity, in particular the oral mucosa. Once colonised in the oral mucosa, the expression of the recombinant protein will stimulate the mucosal associated lymphoid tissue to produce neutralising antibodies. To further illustrate this embodiment, using molecular biological techniques well known in the art, nucleotide sequences encoding the chimeric proteins of this invention may be inserted into the vaccinia virus genomic DNA at a site which allows for expression of epitopes but does not negatively affect the growth or replication of the vaccinia virus vector. The resultant recombinant virus can be used as the immunogen in a vaccine formulation. The same methods can be used to construct an inactivated recombinant viral vaccine formulation except that the recombinant virus is inactivated, such as by chemical means known in the art, prior to use as an immunogen and without substantially affecting the immunogenicity of the expressed immunogen. The inactivated recombinant-vaccine may be formulated with a suitable adjuvant in order to enhance the immunological response to the vaccine antigens.

The invention also provides for the use of a nucleic acid molecule including a nucleotide sequence encoding a chimeric or fusion protein of this invention directly as the vaccine

formulation. Nucleotide sequences encoding the chimeric proteins, operatively linked to one or more regulatory elements, can be introduced directly to vaccinate an individual ("direct gene transfer") against pathogenic strains of *P. gingivalis*. Direct gene transfer into a vaccinated individual, resulting in expression of the genetic material by the vaccinated individual's cells such as vascular endothelial cells as well as the tissue of the major organs, has been demonstrated by techniques in the art such as by injecting intravenously an expression plasmid:cationic liposome complex [Zhu *et al.*, 1993, *Science* 261:209-211]. Other effective methods for delivering vector DNA into a target cell are known in the art. In one example, purified recombinant plasmid DNA containing viral genes has been used to inoculate (whether parenterally, mucosally, or via gene-gun immunization) vaccines to induce a protective immune response [Fynan *et al.* 1993, *Proc Natl Acad Sci USA* 90:11478-11482]. In another example, cells removed from an individual can be transfected or electroporated by standard procedures known in the art, resulting in the introduction of the recombinant vector DNA intro the target cell. Cells containing the recombinant vector DNA may then be selected for using methods known in the art, such as by use of a selection marker expressed in the vector, and the selected cells may then be re-introduced into the individual to express the recombinant protein.

In this aspect, the invention further provides a method of preventing or reducing the incidence or severity of a *P. gingivalis*-related condition or disease in a subject, which comprises administering to the subject a nucleic acid molecule as described above, a vector as described above, or a prokaryotic or eukaryotic cell as described above.

In other embodiments there is provided a pharmaceutical composition including a chimeric or fusion protein or an antibody as described above. The composition may further include diluent, excipient, or carrier or chemotherapeutic agent for treatment of a *P. gingivalis*-related condition or disease and may be adapted for oral administration. The compositions of this invention may be incorporated in lozenges, or in chewing gum or other products, e.g. by stirring into a warm gum base or coating the outer surface of a gum base, illustrative of which are jelutong, rubber latex, vinylite resins, etc., desirably with conventional plasticizers or softeners, sugar or other sweeteners or such as glucose, sorbitol and the like.

An oral composition of this invention which contains the above-mentioned pharmaceutical composition may be prepared and used in various forms applicable to the mouth such as dentifrice including toothpastes, toothpowders and liquid dentifrices, mouthwashes, troches, chewing gums, dental pastes, gingival massage creams, gargle tablets, dairy products and other foodstuffs. An oral composition according to this invention may further include additional well known ingredients depending on the type and form of a particular oral composition.

In certain preferred forms of the invention the oral composition may be substantially liquid in character, such as a mouthwash or rinse. In such a preparation the vehicle is typically a water-alcohol mixture desirably including a humectant as described below. Generally, the weight ratio of water to alcohol is in the range of from about 1:1 to about 20:1. The total amount of water-alcohol mixture in this type of preparation is typically in the range of from about 70 to about 99.9% by weight of the preparation. The alcohol is typically ethanol or isopropanol. Ethanol is preferred.

The pH of such liquid and other preparations of the invention is generally in the range of from about 5 to about 9 and typically from about 5.0 to 7.0. The pH can be controlled with acid (e.g. citric acid or benzoic acid) or base (e.g. sodium hydroxide) or buffered (as with sodium citrate, benzoate, carbonate, or bicarbonate, disodium hydrogen phosphate, sodium dihydrogen phosphate, etc).

In other desirable forms of this invention, the pharmaceutical composition may be substantially solid or pasty in character, such as toothpowder, a dental tablet or a toothpaste (dental cream) or gel dentifrice. The vehicle of such solid or pasty oral preparations generally contains dentally acceptable polishing material.

In a toothpaste, the liquid vehicle may comprise water and humectant typically in an amount ranging from about 10% to about 80% by weight of the preparation. Glycerine, propylene glycol, sorbitol and polypropylene glycol exemplify suitable humectants/carriers. Also advantageous are liquid mixtures of water, glycerine and sorbitol. In clear gels where the refractive index is an important consideration, about 2.5 - 30% w/w of water, 0 to about 70% w/w of glycerine and about 20-80% w/w of sorbitol are preferably employed.

Toothpaste, creams and gels typically contain a natural or synthetic thickener or gelling agent in proportions of about 0.1 to about 10, preferably about 0.5 to about 5% w/w. A suitable thickener is synthetic hectorite, a synthetic colloidal magnesium alkali metal silicate complex clay available for example as Laponite (e.g. CP, SP 2002, D) marketed by Laporte Industries Limited. Laponite D is, approximately by weight 58.00% SiO_2, 25.40% MgO, 3.05% Na_2O, 0.98% Li_2O, and some water and trace metals. Its true specific gravity is 2.53 and it has an apparent bulk density of 1.0 g/ml at 8% moisture.

Other suitable thickeners include Irish moss, iota carrageenan, gum tragacanth, starch, polyvinylpyrrolidone, hydroxyethylpropylcellulose, hydroxybutyl methyl cellulose, hydroxypropyl methyl cellulose, hydroxyethyl cellulose (e.g. available as Natrosol), sodium carboxymethyl cellulose, and colloidal silica such as finely ground Syloid (e.g. 244). Solubilizing agents may also be included such as humectant polyols such propylene glycol, dipropylene glycol and hexylene glycol, cellosolves such as methyl cellosolve and ethyl cellosolve, vegetable oils and waxes containing at least about 12 carbons in a straight chain such as olive oil, castor oil and petrolatum and esters such as amyl acetate, ethyl acetate and benzyl benzoate.

It will be understood that, as is conventional, the oral preparations will usually be sold or otherwise distributed in suitable labelled packages. Thus, a bottle of mouth rinse will have a label describing it, in substance, as a mouth rinse or mouthwash and having directions for its use; and a toothpaste, cream or gel will usually be in a collapsible tube, typically aluminium, lined lead or plastic, or other squeeze, pump or pressurized dispenser for metering out the contents, having a label describing it, in substance, as a toothpaste, gel or dental cream.

Organic surface-active agents may be used in the compositions of the present invention to achieve increased prophylactic action, assist in achieving thorough and complete dispersion of the active agent throughout the oral cavity, and render the instant compositions more cosmetically acceptable. The organic surface-active material is preferably anionic, non-ionic or ampholytic in nature and preferably does not interact with the active agent. It is preferred to employ as the surface-active agent a detersive material which imparts to the composition detersive and foaming properties. Suitable examples of anionic surfactants are water-soluble salts of higher fatty acid

monoglyceride monosulfates, such as the sodium salt of the monosulfated monoglyceride of hydrogenated coconut oil fatty acids, higher alkyl sulfates such as sodium lauryl sulfate, alkyl aryl sulfonates such as sodium dodecyl benzene sulfonate, higher alkylsulfo-acetates, higher fatty acid esters of 1,2-dihydroxy propane sulfonate, and the substantially saturated higher aliphatic acyl amides of lower aliphatic amino carboxylic acid compounds, such as those having 12 to 16 carbons in the fatty acid, alkyl or acyl radicals, and the like. Examples of the last mentioned amides are N-lauroyl sarcosine, and the sodium, potassium, and ethanolamine salts of N-lauroyl, N-myristoyl, or N-palmitoyl sarcosine which should be substantially free from soap or similar higher fatty acid material. Examples of water-soluble non-ionic surfactants suitable for use are condensation products of ethylene oxide with various reactive hydrogen-containing compounds reactive therewith having long hydrophobic chains (e.g. aliphatic chains of about 12 to 20 carbon atoms), which condensation products ("ethoxamers") contain hydrophilic polyoxyethylene moieties, such as condensation products of poly (ethylene oxide) with fatty acids, fatty alcohols, fatty amides, polyhydric alcohols (e.g. sorbitan monostearate) and polypropyleneoxide (e.g. Pluronic materials).

The surface active agent is typically present in amount of about 0.1-5% by weight. It is noteworthy, that the surface active agent may assist in the dissolving of the active agent of the invention and thereby diminish the amount of solubilizing humectant needed.

Various other materials may be incorporated in the oral preparations of this invention such as whitening agents, preservatives, silicones, chlorophyll compounds and/or ammoniated material such as urea, diammonium phosphate, and mixtures thereof. These adjuvants, where present, are incorporated in the preparations in amounts which do not substantially adversely affect the properties and characteristics desired.

Any suitable flavouring or sweetening material may also be employed. Examples of suitable flavouring constituents are flavouring oils, e.g. oil of spearmint, peppermint, wintergreen, sassafras, clove, sage, eucalyptus, marjoram, cinnamon, lemon, and orange, and methyl salicylate. Suitable sweetening agents include sucrose, lactose, maltose, sorbitol, xylitol, sodium cyclamate, perillartine, AMP (aspartyl phenyl alanine, methyl ester), saccharine, and the like. Suitably, flavour and sweetening agents may each or together comprise from about 0.1% to 5% more of the preparation.

Compositions intended for oral use may be prepared according to any method known in the art for the manufacture of pharmaceutical compositions and such compositions may contain one or more agents selected from the group consisting of sweetening agents, flavouring agents, colouring agents and preserving agents in order to provide pharmaceutically elegant and palatable preparations. Tablets contain the active ingredient in admixture with non-toxic pharmaceutically acceptable excipients which are suitable for the manufacture of tablets. These excipients may be for example, inert diluents, such as calcium carbonate, sodium carbonate, lactose, calcium phosphate or sodium phosphate; granulating and disintegrating agents, for example, corn starch, or alginic acid; binding agents, for example starch, gelatin or acacia, and lubricating agents, for example magnesium stearate, stearic acid or talc. The tablets may be uncoated or they may be coated by known techniques to delay disintegration and absorption in the gastrointestinal tract or periodontal pocket and thereby provide a sustained action over a longer period. For example, a time delay material such as glyceryl monostearate or glyceryl distearate may be employed.

Formulations for oral use may also be presented as hard gelatin capsules wherein the active ingredient is mixed with an inert solid diluent, for example, calcium carbonate, calcium phosphate or kaolin, or as soft gelatin capsules wherein the active ingredient is mixed with water or an oil medium, for example peanut oil, liquid paraffin or olive oil.

Aqueous suspensions contain the active materials in admixture with excipients suitable for the manufacture of aqueous suspensions. Such excipients are suspending agents, for example sodium carboxymethylcellulose, methylcellulose, hydropropyl methylcellulose, sodium alginate, polyvinylpyrrolidone, gum tragacanth and gum acacia; dispersing or wetting agents may be a naturally-occurring phosphatide, for example, lecithin, or condensation products of an alkylene oxide with fatty acids, for example polyoxyethylene stearate, or condensation products of ethylene oxide with long chain aliphatic alcohols, for example heptadecaethyleneoxycetanol, or condensation products of ethylene oxide with partial esters derived from fatty acids and a hexitol such as polyoxyethylene sorbitol monooleate, or condensation products of ethylene oxide with partial esters derived from fatty acids and hexitol anhydrides, for example polyethylene sorbitan monooleate.

The aqueous suspensions may also contain one or more preservatives or antimicrobial agents, for example benzoates, such as ethyl, or n-propyl p-hydroxybenzoate another example is chlorhexidine gluconate, one or more colouring agents, one or more flavouring agents, and one or more sweetening agents, such as sucrose or saccharin.

Oily suspensions may be formulated by suspending the active ingredients in a vegetable oil, for example arachis oil, olive oil, sesame oil or coconut oil, or in a mineral oil such as liquid paraffin. The oily suspensions may contain a thickening agent, for example beeswax, hard paraffin or cetyl alcohol. Sweetening agents such as those set forth above, and flavouring agents may be added to provide palatable oral preparations. These compositions may be preserved by the addition of an anti-oxidant such as ascorbic acid.

In a further aspect, the present invention provides a method for the diagnosis or monitoring of a *P. gingivalis*-related condition or disease in a subject, which comprises use of a chimeric or fusion protein as described above to detect anti-*P. gingivalis* antibodies in a biological sample from said subject.

In yet another aspect, the invention provides a method for the diagnosis or monitoring of a *P. gingivalis*-related condition or disease in a subject, which comprises use of an antibody as described above, to detect the presence of *P. gingivalis* in a biological sample from said subject.

In yet another aspect, the invention provides a peptide for inducing an immune response to *P. gingivalis* including the sequence shown in one of SEQ ID No: 17, 18, 25 and 26. In one embodiment, the peptide has a sequence that is homologous to one of SEQ ID No: 17, 18, 25 and 26. The peptide may have a length of 5 to 40 amino acids.

In yet another aspect, the invention provides a nucleic acid encoding a peptide having a sequence shown in one of SEQ ID No: 17, 18, 25 and 26.

In yet another aspect, the invention provides a use of a peptide having a sequence shown in one of SEQ ID No: 17, 18, 25 and 26, or a nucleic acid encoding a peptide having a sequence shown in one of SEQ ID No: 17, 18, 25 and 26, for the manufacture of a chimeric or fusion protein for inducing an immune response to *P. gingivalis*.

In yet another aspect, the invention provides a use of a peptide having a sequence shown in one of SEQ ID No: 17, 18, 25 and 26, or a nucleic acid encoding a peptide having a sequence shown in one of SEQ ID No: 17, 18, 25 and 26, for inducing an immune response to *P. gingivalis*. In one embodiment, the peptide is administered simultaneously or sequentially with a second peptide including:

(i) part of, or all of a sequence that is the same as, or homologous to the sequence of an adhesin domain of the Lys-X-proteinase of *P. gingivalis*; or

(ii) part of, or all of a sequence that is the same as, or homologous to the sequence of an adhesin domain of the Arg-X-proteinase of *P. gingivalis*; or

(iii) part of, or all of a sequence that is the same as, or homologous to the sequence of a HagA adhesin domain of *P. gingivalis*.

Table 3

SEQ ID NO:	Amino acid sequence	Fragment
1	LNTGV[G/S]FANYTAHGSET[S/A]WADP[S/L][L/V]T[A/T][T/S]Q[V/L]KALTNK[D/N]K	Kgp[432-468]
2	FNGGISL[V/A]NYTGHGSETAWGTSHFGTTHVKQLTNSNQ	RgpA[426-462]
3	VSFANYT	
4	VGFANYT	
5	GVSFANYT	
6	GVGFANYT	
7	VSFANYTA	
8	VGFANYTA	
9	ETAWAD	
10	ETSWAD	
11	TAWADP	
12	TSWADP	

13	SETAWAD	
14	SETSWAD	
15	ETAWADP	
16	ETSWADP	
17	TAWADPL	
18	TSWADPL	
19	GSETAWAD	
20	GSETSWAD	
21	SETAWADP	
22	SETSWADP	
23	ETAWADPL	
24	ETSWADPL	
25	TAWADPLL	
26	TSWADPLL	
27	LNTGV[G/S]FANYTAHGSET[S/A]WADP[S/L]	KAS1
28	NTGV[G/S]FANYTAHGSET[S/A]WADP[S/L][L/V]T[A/T][T/S]Q[V/L]KALTNK[D/N]K	KAS2
29	V[G/S]FANYTAHGSET[S/A]WADP[S/L][L/V]	KAS3
30	LNTGVSFANYTAHGSETAWADP	PAS1K
31	FNGGISL[V/A]NYTGHGSETAWGTSH	RAS1
32	NGGISL[V/A]NYTGHGSETAWGTSHFGTTHVKQLTNSNQ	RAS2
33	ISL[V/A]NYTGHGSETAWGTSHF	RAS3
34	FNGGISLANYTGHGSETAWGT	PAS1R
35	ANEAKVVLAADNVWGDNTGYQFLLDADHNTFGSVIPATG PLFTGTASSNLYSANFEYLIPANADPVVTTQNIIVTGQGEV VIPGGVYDYCITNPEPASGKMWIAGDGGNQPARYDDFTF EAGKKYTFTMRRAGMGDGTDMEVEDDSPASYTYTVYRD GTKIKEGLTATTFEEDGVAAGNHEYCVEVKYTAGVSPKV CKDVTVEGSNEFAPVQNLTGSSVGQKVTLKWDAPNGTP NPNPNPNPNPGTTLSESFENGIPASWKTIDADGDGHGW KPGNAPGIAGYNSNGCVYSESFGLGGIGVLTPDNYLITPA	KA1

	LDLPNGGKLTFWVCAQDANYASEHYAVYASSTGNDASN FTNALLEETITA	
36	FLLDADHNTFGSVIPATGPLFTGTASSNLYSANFEYLIPAN ADPVVTTQNIIVTGQGEVVIPGGVYDYCITNPEPASGKMW IAGDGGNQPARYDDFTFEAGKKYTFTMRRAGMGDGTDM EVEDDSPASYTYTVYRDGTKIKEGLTATTFEEDGVAAGN HEYCVEVKYTAGVSPKVCKDVTVEGSNEFAPVQNLTGS SVGQKVTLKWDAPNGTPNPNPNPNPNPGTTLSESF	KsA1
37	WGDNTGYQFLLDADHNTFGSVIPATGPLFTGTASSNLYS ANFEYLIPANADPVVTTQNIIVTGQGEVVIPGGVYDYCITN PEPASGKMWIAGDGGNQPARYDDFTFEAGKKYTFTMRR AGMGDGTDMEVEDDSPASYTYTVYRDGTKIKEGLTATTF EEDGVAAGNHEYCVEVKYTAGVSPKVCKDVTVEGSNEF APVQNLTGSSVGQKVTLKWDAPNGTPNPNPNPNPNPGT TLSESFENGIPASWKTIDADGDGHGWKPGNAPGIAGYNS NGCVYSESFGLGGIGVLTPDNYLITPALDLPNGG	KLA1
38	SGQAEIVLEAHDVWNDGSGYQILLDADHDQYGQVIPSDT HTLWPNCSVPANLFAPFEYTVPENADPSCSPTNMIMDGT ASVNIPAGTYDFAIAAPQANAKIWIAGQGPTKEDDYVFEA GKKYHFLMKKMGSGDGTELTISEGGGSDYTYTVYRDGT KIKEGLTATTFEEDGVATGNHEYCVEVKYTAGVSPKVCK DVTVEGSNEFAPVQNLTGSAVGQKVTLKWDAPNGTPNP NPNPNPNPNPGTTTLSESFENGIPASWKTIDADGDGHG WKPGNAPGIAGYNSNGCVYSESFGLGGIGVLTPDNYLIT PALDLPNGGKLTFWVCAQDANYASEHYAVYASSTGNDA SNFTNALLEETITA	RA1
39	DDYVFEAGKKYHFLMKKMGSGDGTELTISEGGGSDYTYT VYRDGTKIKEGLTATTFEEDGVATGNHEYCVEVKYTAGV SPKVCKDVTVEGSNEFAPVQNLTGSAVGQKVTLKWDAP NGTPNPNPNPNPNPNPGTTTLSESF	RsA1
40	ADFTETFESSTHGEAPAEWTTIDADGDGQGWLCLSSGQ LDWLTAHGGSNVVSSFSWNGMALNPDNYLISKDVTGAT	KA2

	KVKYYYAVNDGFPGDHYAVMISKTGTNAGDFTVVFEETP NGIN	
41	PQSVWIERTVDLPAGTKYVAFRHYNCSDLNYILLDDIQFT MGGSPTPTDYTYTVYRDGTKIKEGLTETTFEEDGVATGN HEYCVEVKYTAGVSPKKCVNVTVNSTQFNPVQNLTAEQ APNSMDAILKWNAPAS	KA3
42	AEVLNEDFENGIPASWKTIDADGDGNNWTTTPPPGGSSF AGHNSAICVSSASYINFEGPQNPDNYLVTPELSLPGGGTL TFWVCAQDANYASEHYAVYASSTGNDASNFANALLEEVL TA	KA4
43	TVVTAPEAIRGTRAQGTWYQKTVQLPAGTKYVAFRHFGC TDFFWINLDDVVITSGNAPSYTYTIYRNNTQIASGVTETTY RDPDLATGFYTYGVKVVYPNGESAIETATLNITSLADVTA QKPYTLTVVGKTITVTCQGEAMIYDMNGRRLAAGRNTVV YTAQGGHYAVMVVVDGKSYVEKLAVK	KA5
44	ADFTETFESSTHGEAPAEWTTIDADGDGQGWLCLSSGQ LDWLTAHGGTNVVSSFSWNGMALNPDNYLISKDVTGAT KVKYYYAVNDGFPGDHYAVMISKTGTNAGDFTVVFEETP NGIN	RA2
45	PQSVWIERTVDLPAGTKYVAFRHYNCSDLNYILLDDIQFT MGGSPTPTDYTYTVYRDGTKIKEGLTETTFEEDGVATGN HEYCVEVKYTAGVSPKKCVNVTVNSTQFNPVKNLKAQP DGGDVVLKWEAPSA	RA3
46	ANEAKVVLAADNVWGDNTGYQFLLDADHNTFGSVIPATG PLFTGTASSDLYSANFESLIPANADPVVTTQNIIVTGQGEV VIPGGVYDYCITNPEPASGKMWIAGDGGNQPARYDDFTF EAGKKYTFTMRRAGMGDGTDMEVEDDSPASYTYTVYRD GTKIKEGLTETTYRDAGMSAQSHEYCVEVKYTAGVSPKV CVDYIPDGVADVTAQKPYTLTVVGKTITVTCQGEAMIYDM NGRRLAAGRNTVVYTAQGGYYAVMVVVDGKSYVEKLAI K	RA4

SEQ ID NO:	Nucleotide sequence	
47	GACCATGGCTCATCACCATCACCATCACAATACCGG AGTCAGCTTTGCA	KAS2-FOR
48	GACTCGAGTTATTTGTCCTTATTAGTGAGTGCTTTC	KAS2-REV
49	GACCATGGCTTGGGGAGACAATACGGGTTAC	KLA1-FOR
50	GACTCGAGACCTCCGTTAGGCAAATCC	KLA1-REV
51	CCGTATTGTCTCCCCATTTGTCCTTATTAGTGAGTGC TTTC	KAS2-KLA1-REV
52	CACTAATAAGGACAAATGGGGAGACAATACGGGTTA C	KAS2-KLA1-FOR
53	CATGGATCTGAGACCGCATGGGCTGATCCACTTTTC TTGTTGGATGCCGAT	KAS1-KsA1-FOR1
54	CCATGGCTTTGAATACCGGAGTCAGCTTTGCAAACT ATACAGCGCATGGATCTGAGACCGCA	KAS1-KsA1-FOR2
55	CTCGAGGAATGATTCGGAAAGTGTT	KAS1-KsA1-REV
56	CCATGGCTGATTATAGCTGGAATTCCCAGGTAGTCA GCTTTGCAAACTATACA	multi-FOR1
57	CTTTGCAAACTATACAGCGCATGGATCTGAGACCGC ATGGGCTGATCCACTT	multi-FOR2
58	ATGGGCTGATCCACTTCTGAATTCTTATTGGGGCGA GATCGGCAATATTACC	multi-FOR3

59	GATCGGCAATATTACCCATATTGGTGCTCATTACGC TTGGGGAGACAATACG	multi-FOR4
60	CTCGAGACCTCCGTTAGGCAAATCCAATGCCGGTGT TATCAGATAGTTGTCA	multi-REV

SEQ ID NO:	Amino acid sequence	Full length
61	MKNLNKFVSIALCSSLLGGMAFAQQTELGRNPNVRLLES TQQSVTKVQFRMDNLKFTEVQTPKGIGQVPTYTEGVNL SEKGMPTLPILSRSLAVSDTREMKVEVVSSKFIEKKNVLI APSKGMIMRNEDPKKIPYVYGKTYSQNKFFPGEIATLDD PFILRDVRGQVVNFAPLQYNPVTKTLRIYTEITVAVSETSE QGKNILNKKGTFAGFEDTYKRMFMNYEPGRYTPVEEKQ NGRMIVIVAKKYEGDIKDFVDWKNQRGLRTEVKVAEDIA SPVTANAIQQFVKQEYEKEGNDLTYVLLIGDHKDIPAKITP GIKSDQVYGQIVGNDHYNEVFIGRFSCESKEDLKTQIDRT IHYERNITTEDKWLGQALCIASAEGGPSADNGESDIQHE NVIANLLTQYGYTKIIKCYDPGVTPKNIIDAFNGGISLANYT GHGSETAWGTSHFGTTHVKQLTNSNQLPFIFDVACVNG DFLFSMPCFAEALMRAQKDGKPTGTVAIIASTINQSWAS PMRGQDEMNEILCEKHPNNIKRTFGGVTMNGMFAMVEK YKKDGEKMLDTWTVFGDPSLLVRTLVPTKMQVTAPAQI NLTDASVNVSCDYNGAIATISANGKMFGSAVVENGTATI NLTGLTNESTLTLTVVGYNKETVIKTINTNGEPNPYQPVS NLTATTQGQKVTLKWDAPSTKTNATTNTARSVDGIRELV LLSVSDAPELLRSGQAEIVLEAHDVWNDGSGYQILLDAD HDQYGQVIPSDTHTLWPNCSVPANLFAPFEYTVPENAD PSCSPTNMIMDGTASVNIPAGTYDFAIAAPQANAKIWIAG QGPTKEDDYVFEAGKKYHFLMKKMGSGDGTELTISEGG GSDYTYTVYRDGTKIKEGLTATTFEEDGVATGNHEYCVE VKYTAGVSPKVCKDVTVEGSNEFAPVQNLTGSAVGQKV	RgpA

	TLKWDAPNGTPNPNPNPNPNPGTTTLSESFENGIPA SWKTIDADGDGHGWKPGNAPGIAGYNSNGCVYSESFG LGGIGVLTPDNYLITPALDLPNGGKLTFWVCAQDANYAS EHYAVYASSTGNDASNFTNALLEETITAKGVRSPEAMRG RIQGTWRQKTVDLPAGTKYVAFRHFQSTDMFYIDLDEVE IKANGKRADFTETFESSTHGEAPAEWTTIDADGDGQGW LCLSSGQLDWLTAHGGTNVVSSFSWNGMALNPDNYLIS KDVTGATKVKYYYAVNDGFPGDHYAVMISKTGTNAGDF TVVFEETPNGINKGGARFGLSTEADGAKPQSVWIERTVD LPAGTKYVAFRHYNCSDLNYILLDDIQFTMGGSPTPTDY TYTVYRDGTKIKEGLTETTFEEDGVATGNHEYCVEVKYT AGVSPKKCVNVTVNSTQFNPVKNLKAQPDGGDVVLKW EAPSAKKTEGSREVKRIGDGLFVTIEPANDVRANEAKVV LAADNVWGDNTGYQFLLDADHNTFGSVIPATGPLFTGTA SSDLYSANFESLIPANADPVVTTQNIIVTGQGEVVIPGGV YDYCITNPEPASGKMWIAGDGGNQPARYDDFTFEAGKK YTFTMRRAGMGDGTDMEVEDDSPASYTYTVYRDGTKIK EGLTETTYRDAGMSAQSHEYCVEVKYTAGVSPKVCVDY IPDGVADVTAQKPYTLTVVGKTITVTCQGEAMIYDMNGR RLAAGRNTVVYTAQGGYYAVMVVVDGKSYVEKLAIK	
62	MRKLLLLIAASLLGVGLYAQSAKIKLDAPTTRTTCTNNSF KQFDASFSFNEVELTKVETKGGTFASVSIPGAFPTGEVG SPEVPAVRKLIAVPVGATPVVRVKSFTEQVYSLNQYGSE KLMPHQPSMSKSDDPEKVPFVYNAAAYARKGFVGQELT QVEMLGTMRGVRIAALTINPVQYDVVANQLKVRNNIEIEV SFQGADEVATQRLYDASFSPYFETAYKQLFNRDVYTDH GDLYNTPVRMLVVAGAKFKEALKPWLTWKAQKGFYLDV HYTDEAEVGTTNASIKAFIHKKYNDGLAASAAPVFLALVG DTDVISGEKGKKTKKVTDLYYSAVDGDYFPEMYTFRMS ASSPEELTNIIDKVLMYEKATMPDKSYLEKVLLIAGADYS WNSQVGQPTIKYGMQYYYNQEHGYTDVYNYLKAPYTG CYSHLNTGVSFANYTAHGSETAWADPLLTTSQLKALTNK	Kgp

	DKYFLAIGNCCITAQFDYVQPCFGEVITRVKEKGAYAYIG SSPNSYWGEDYYWSVGANAVFGVQPTFEGTSMGSYDA TFLEDSYNTVNSIMWAGNLAATHAGNIGNITHIGAHYYW EAYHVLGDGSVMPYRAMPKTNTYTLPASLPQNQASYSI QASAGSYVAISKDGVLYGTGVANASGVATVSMTKQITEN GNYDVVITRSNYLPVIKQIQVGEPSPYQPVSNLTATTQG QKVTLKWEAPSAKKAEGSREVKRIGDGLFVTIEPANDVR ANEAKVVLAADNVWGDNTGYQFLLDADHNTFGSVIPAT GPLFTGTASSNLYSANFEYLIPANADPVVTTQNIIVTGQG EVVIPGGVYDYCITNPEPASGKMWIAGDGGNQPARYDD FTFEAGKKYTFTMRRAGMGDGTDMEVEDDSPASYTYTV YRDGTKIKEGLTATTFEEDGVAAGNHEYCVEVKYTAGVS PKVCKDVTVEGSNEFAPVQNLTGSSVGQKVTLKWDAPN GTPNPNPNPNPNPGTTLSESFENGIPASWKTIDADGDG HGWKPGNAPGIAGYNSNGCVYSESFGLGGIGVLTPDNY LITPALDLPNGGKLTFWVCAQDANYASEHYAVYASSTGN DASNFTNALLEETITAKGVRSPKAIRGRIQGTWRQKTVDL PAGTKYVAFRHFQSTDMFYIDLDEVEIKANGKRADFTET FESSTHGEAPAEWTTIDADGDGQGWLCLSSGQLDWLT AHGGSNVVSSFSWNGMALNPDNYLISKDVTGATKVKYY YAVNDGFPGDHYAVMISKTGTNAGDFTVVFEETPNGINK GGARFGLSTEANGAKPQSVWIERTVDLPAGTKYVAFRH YNCSDLNYILLDDIQFTMGGSPTPTDYTYTVYRDGTKIKE GLTETTFEEDGVATGNHEYCVEVKYTAGVSPKKCVNVT VNSTQFNPVQNLTAEQAPNSMDAILKWNAPASKRAEVL NEDFENGIPASWKTIDADGDGNNWTTTPPPGGSSFAGH NSAICVSSASYINFEGPQNPDNYLVTPELSLPGGGTLTF WVCAQDANYASEHYAVYASSTGNDASNFANALLEEVLT AKTVVTAPEAIRGTRAQGTWYQKTVQLPAGTKYVAFRH FGCTDFFWINLDDVVITSGNAPSYTYTIYRNNTQIASGVT ETTYRDPDLATGFYTYGVKVVYPNGESAIETATLNITSLA DVTAQKPYTLTVVGKTITVTCQGEAMIYDMNGRRLAAGR	

	NTVVYTAQGGHYAVMVVVDGKSYVEKLAVK	
63	MRKLNSLFSLAVLLSLLCWGQTAAAQGGPKTAPSVTHQ AVQKGIRTSKAKDLRDPIPAGMARIILEAHDVWEDGTGY QMLWDADHNQYGASIPEESFWFANGTIPAGLYDPFEYK VPVNADASFSPTNFVLDGTASADIPAGTYDYVIINPNPGII YIVGEGVSKGNDYVVEAGKTYHFTVQRQGPGDAASVVV TGEGGNEFAPVQNLQWSVSGQTVTLTWQAPASDKRTY VLNESFDTQTLPNGWTMIDADGDGHNWLSTINVYNTAT HTGDGAMFSKSWTASSGAKIDLSPDNYLVTPKFTVPEN GKLSYWVSSQEPWTNEHYGVFLSTTGNEAANFTIKLLEE TLGSGKPAPMNLVKSEGVKAPAPYQERTIDLSAYAGQQ VYLAFRHFGCTGIFRLYLDDVAVSGEGSSNDYTYTVYRD NVVIAQNLTATTFNQENVAPGQYNYCVEVKYTAGVSPKV CKDVTVEGSNEFAPVQNLTGSAVGQKVTLKWDAPNGTP NPNPGTTTLSESFENGIPASWKTIDADGDGNNWTTTPPP GGSSFAGHNSAICVSSASYINFEGPQNPDNYLVTPELSL PNGGTLTFWVCAQDANYASEHYAVYASSTGNDASNFA NALLEEVLTAKTVVTAPEAIRGTRVQGTWYQKTVQLPAG TKYVAFRHFGCTDFFWINLDDVEIKANGKRADFTETFES STHGEAPAEWTTIDADGDGQGWLCLSSGQLGWLTAHG GTNVVASFSWNGMALNPDNYLISKDVTGATKVKYYYAV NDGFPGDHYAVMISKTGTNAGDFTVVFEETPNGINKGG ARFGLSTEANGAKPQSVWIERTVDLPAGTKYVAFRHYN CSDLNYILLDDIQFTMGGSPTPTDYTYTVYRDGTKIKEGL TETTFEEDGVATGNHEYCVEVKYTAGVSPKECVNVTVD PVQFNPVQNLTGSAVGQKVTLKWDAPNGTPNPNPGTTT LSESFENGIPASWKTIDADGDGNNWTTTPPPGGTSFAG HNSAICVSSASYINFEGPQNPDNYLVTPELSLPNGGTLTF WVCAQDANYASEHYAVYASSTGNDASNFANALLEEVLT AKTVVTAPEAIRGTRVQGTWYQKTVQLPAGTKYVAFRH FGCTDFFWINLDDVEIKANGKRADFTETFESSTHGEAPA EWTTIDADGDGQGWLCLSSGQLDWLTAHGGTNVVASF	HagA

	SWNGMALNPDNYLISKDVTGATKVKYYYAVNDGFPGDH YAVMISKTGTNAGDFTVVFEETPNGINKGGARFGLSTEA NGAKPQSVWIERTVDLPAGTKYVAFRHYNCSDLNYILLD DIQFTMGGSPTPTDYTYTVYRDGTKIKEGLTETTFEEDG VATGNHEYCVEVKYTAGVSPKECVNVTVDPVQFNPVQN LTGSAVGQKVTLKWDAPNGTPNPNPGTTTLSESFENGIP ASWKTIDADGDGNNWTTTPPPGGTSFAGHNSAICVSSA SYINFEGPQNPDNYLVTPELSLPNGGTLTFWVCAQDAN YASEHYAVYASSTGNDASNFANALLEEVLTAKTVVTAPE AIRGTRVQGTWYQKTVQLPAGTKYVAFRHFGCTDFFWI NLDDVEIKANGKRADFTETFESSTHGEAPAEWTTIDADG DGQGWLCLSSGQLGWLTAHGGTNVVASFSWNGMALN PDNYLISKDVTGATKVKYYYAVNDGFPGDHYAVMISKTG TNAGDFTVVFEETPNGINKGGARFGLSTEANGAKPQSV WIERTVDLPAGTKYVAFRHYNCSDLNYILLDDIQFTMGG SPTPTDYTYTVYRDGTKIKEGLTETTFEEDGVATGNHEY CVEVKYTAGVSPKECVNVTINPTQFNPVQNLTAEQAPNS MDAILKWNAPASKRAEVLNEDFENGIPASWKTIDADGDG NNWTTTPPPGGSSFAGHNSAICVSSASYINFEGPQNPD NYLVTPELSLPGGGTLTFWVCAQDANYASEHYAVYASS TGNDASNFANALLEEVLTAKTVVTAPEAIRGTRVQGTWY QKTVQLPAGTKYVAFRHFGCTDFFWINLDDVVITSGNAP SYTYTIYRNNTQIASGVTETTYRDPDLATGFYTYGVKVVY PNGESAIETATLNITSLADVTAQKPYTLTVVGKTITVTCQG EAMIYDMNGRRLAAGRNTVVYTAQGGHYAVMVVVDGK SYVEKLAVK	

SEQ ID NO:	Amino acid sequence	Fragment
64	D[S/Y][Y/S]WN[P/S][K/Q][I/V]	KAS4

65	NSYWGED	KAS5
66	IGN[V/I]THIGAHY	KAS6
67	EGGPSADN	RAS4
68	[N/D]Q[S/Y]WA[S/P]P	RAS5
69	PVSNLTATTQGQKVTLKWDAPST	ABM1 - $RgpA_{cat}$
70	PVSNLTATTQGQKVTLKWEAPSA	ABM1-Kgpcat
71	PVQNLTGSSVGQKVTLKWDAPST	ABM1-KgpA1
72	PVQNLTGSAVGQKVTLKWDAPNG	ABM1 – RgpA1 & RgpAA3
73	PVKNLKAQPDGGDVVLKWEAPSA	ABM1 – HagAA1*/**
74	PVQNLTAEQAPNSMDAILKWNAP	ABM1 – KgpA3 & HagAA3
75	PVQNLTQWSVSGQTVTLTWQAPAS	ABM2 - HagAA1
76	YTYTVYRDGTKIKEGLTETTFEEDGVA	ABM2 – ABM2 - RgpAA4
77	YTYTVYRDNVVIAQNLTATTFNQENVA	ABM2 - HagA1*
78	YTYTVYRDGTKIKEGLTA/ETTFEEDGVA	ABM2 All other adhesins
79	$PNGTP(NP)_{1-6}GTT(T)LSESF$	ABM3- All adhesins
80	GGPKTAPSVTHQAVQKGIRTSKAKDLRDPIPAGMARIILE	HagA1

	AHDVWEDGTGYQMLWDADHNQYGASIPEESFWFANGTI PAGLYDPFEYKVPVNADASFSPTNFVLDGTASADIPAGTY DYVIINPNPGIIYIVGEGVSKGNDYVVEAGKTYHFTVQRQ GPGDAASVVVTGEGGNEFAPVQNLQWSVSGQTVTLTW QAPASDKRTYVLNESFDTQTLPNGWTMIDADGDGHNWL STINVYNTATHTGDGAMFSKSWTASSGAKIDLSPDNYLVT PKFTVPENGKLSYWVSSQEPWTNEHYGVFLSTTGNEAA NFTIKLLEETLGSG	[26-351]
81	APAPYQERTIDLSAYAGQQVYLAFRHFGCTGIFRLYLDDV AVSGEGSSNDYTYTVYRDNVVIAQNLTATTFNQENVAPG QYNYCVEVKYTAGVSPKVCKDVTVEGSNEFAPVQNLTG SAVGQKVTLKWDAPNGTPNPNPGTTTLSESFENGIPASW KTIDADGDGNNWTTTPPPGGSSFAGHNSAICVSSASYIN FEGPQNPDNYLVTPELSLPNGGTLTFWVCAQDANYASE HYAVYASSTGNDASNFANALLEEVLTA	HagA1* [366-625]
82	PQSVWIERTVDLPAGTKYVAFRHYNCSDLNYILLDDIQFT MGGSPTPTDYTYTVYRDGTKIKEGLTETTFEEDGVATGN HEYCVEVKYTAGVSPKECVNVTVDPVQFNPVQNLTGSA VGQKVTLKWDAPNGTPNPNPGTTTLSESFENGIPASWKT IDADGDGNNWTTTPPPGGTSFAGHNSAICVSSASYINFE GPQNPDNYLVTPELSLPNGGTLTFWVCAQDANYASEHY AVYASSTGNDASNFANALLEEVLTA	HagA1** [820-1077] or HagA1** [1272-1529]
83	PYQPVSNLTATTQGQ	ABM1[436-450]
84	EGLTATTFEEDGVAA	ABM2 [672-686]
85	GTPNPNPNPNPNPNPGT	ABM3 [455-471]

The invention is further illustrated by the following Examples which are included by way of exemplification and not limitation of the invention.

Example 1

Methods and materials.

Bacterial strains and growth conditions. Lyophilised cultures of *Porphyromonas gingivalis* W50 were grown anaerobically at 37°C on lysed horse blood agar plates supplemented with 5 μg/ml haemin, 0.5 μg/ml cysteine (HB agar, < 10 passages). After 3-4 days colonies were used to inoculate brain heart infusion medium containing 5 μg/ml haemin, 0.5 μg/ml cysteine (1). Batch cultures were grown anaerobically in a MK3 Anaerobic Workstation (Don Whitley Scientific Ltd., Adelaide, Australia). Cells were harvested during exponential growth phase by centrifugation (7500 g, 30 min, 4°C) and washed twice with PG buffer (50 mM Tris-HCl, 150 mM NaCl, 5 mM $CaCl_2$, and 5 mM cysteine-HCl, pH 8.0) in the anaerobic workstation. Growth of batch cultures was monitored at 650 nm using a spectrophotometer (model 295E, Perkin-Elmer). Culture purity was checked routinely by Gram stain, microscopic examination and using a variety of biochemical tests according to Slots (2).

Construction of pET28 constructs containing adhesin sequences and adhesin sequences with N-terminal addition of Kgp proteinase sequences. Kgp residues representing peptides and chimeric peptides of the active site (AS) and KgpA1 adhesin (A1) domains were over-expressed in *E. coli* as recombinant (r) proteins with hexa-His tags using pET expression vectors (Novagen). The r-proteins expressed were rKAS2, and rKLA1 and the r-chimeric proteins were rKAS2-KLA1, rKAS1-KsA1 and rKAS4-KAS3-KAS5-KAS6-KLA1 (also referred to as multiKAS-KLA1). The amino acid sequences representing the various A1 and AS domains are described in Tables 1 and 2.

The various KAS and KA1 domains of the *kgp* gene were amplified from pNS1 (3.5 kb BamHI *lys* fragment in pUC18) or *P. gingivalis* genomic DNA respectively using primers listed in Table 4, Taq DNA polymerase (Invitrogen) and a PC-960 thermal cycler (Corbett Research Technologies). Primer pairs KAS2-FOR and KAS2-REV and KLA1-FOR and KLA1-REV were used to generate PCR fragments encoding KAS2 and KLA1 respectively using the following reaction conditions: 94°C, 3 minutes, followed by 28

cycles of 94°C, 45 sec (denaturing); 62°C, 40 seconds (annealing) and 72°C, 20 seconds (extension) followed by a final cycle of 72°C, 5 min.

The KAS2-KLA1 chimeric PCR product was produced by gene splicing by overlap extension (SOEing) as follows: PCR products were produced using primer pairs KAS2-FOR and KAS2-KLA1-chimera-REV and KAS2-KLA1-chimera-FOR and KLA1-REV using the conditions described above. The PCR products were then annealed and a final PCR was performed with primers KAS2-FOR and KLA1-REV (94°C, 2 minutes, followed by 28 cycles of 94°C, 30 sec; 50°C, 30 seconds and 72°C, 40 seconds followed by a final cycle of 72°C, 5 min.

For the preparation of the KAS1-KsA1 PCR product, two successive PCR's were conducted using the KAS1-KsA1-REV primer with each of the KAS1-KsA1-FOR primers 1 and, 2 in succession (reaction conditions 94°C for 2 minutes followed by 35 cycles of 94°C, 15 seconds ; 63°C, 30 seconds and 72°C, 2 minutes) to produce the KAS1-KsA1 PCR product. The KAS1-KsA1-FOR1 and KAS1-KsA1-FOR2 primers contain an 3'extension overlapping the 5' of the previous PCR product.

For the preparation of the multiKAS-KLA1 PCR fragment, four successive PCR's were conducted using the multi-REV primer with each of the multi-FOR primers 1, 2, 3 and 4 in succession (reaction conditions were 95°C, 2 minutes followed by 35 cycles of 95°C, 20 seconds; 68°C, 1.5 minutes) to produce the multiKAS-KLA1 PCR product. Each multi-FOR primer contains a 3'extension overlapping the 5' of the previous PCR product.

All of the PCR fragments encoding KAS2, KLA1, KAS2-KLA1, KAS1-KsA1 and multiKAS-KLA1. were purified using PCR purification columns (Qiagen), ligated into the TA cloning vector, pGem-T Easy (Promega) and transformed into *E. coli* JM109 following the manufacturer's protocol. Purified recombinant pGemT-Easy constructs were digested with NcoI and XhoI and directionally cloned into NcoI/XhoI digested pET28b (Novagen) and transformed into the non-expression host, *E. coli* JM109 [DH5α]. The recombinant pET28 constructs were purified and transformed into the *E. coli* expression host, BL21 (DE3) [HMS174(DE3)] (Novagen) and selected on LB

containing 50 μg kanamycin following the manufacturer's instructions. The integrity of each insert was confirmed by DNA sequence analysis.

The oligonucleotide primers (Table 4) have been designed to incorporate restriction enzyme sites, stop codons and hexa-His Tags where necessary. The primers used for the rKAS2, rKLA1 and rKAS2-KLA1 were designed to limit the inclusion of extraneous coding sequence to no more than three amino acids plus the hexa-his tag in r-proteins. The rKAS1 and the rKLA1 were designed to contain a hexa-His tag at the N-terminal and C-terminal ends respectively, so that they may be directly compared to the rKAS2-KLA1 which has a hexa-his tag at both N- and C-termini. In rKAS1-KsA1 and rmultiKAS-KLA1 the His Tags are found at the C-termini.

Table 4 Oligonucleotide primers used for the amplification of the nucleotide sequences encoding the various fragments and chimeras of Kgp A1 and AS

Recombinant (r) protein	Oli	Sequence (5'-3')	Characteristics* (5'-3')
rKAS2	**KAS2-FOR**	GACCATGGCTCATCACCATCACC ATCACAATACCGGAGTCAGCTTT GCA (SEQ ID NO: 47)	GA buffer-NcoI (including ATG start)-CT-$(His)_6$-AS (nt 1992-2012)
	KAS2-REV	GACTCGAGTTATTTGTCCTTATTA GTGAGTGCTTTC (SEQ ID NO: 48)	GA buffer-XhoI-TTA Stop-KAS1 (nt 2099-2075)
rKLA1	**KLA1-FOR**	GACCATGGCTTGGGGAGACAATA CGGGTTAC (SEQ ID NO: 49)	GA buffer-NcoI (including ATG start)-CT–A1 (nt 2946-2966)
	KLA1-REV	GACTCGAGACCTCCGTTAGGCAA ATCC (SEQ ID NO: 50)	GA buffer-XhoI-A1 (nt 3863-3845)
rKAS2-KLA1	**KAS2-KLA1-REV**	CCGTATTGTCTCCCCATTTGTCCT TATTAGTGAGTGCTTTC (SEQ ID NO: 51)	A1 (nt 2961-2946)-KAS1 (nt 2099-2075)
	KAS2-KLA1-FOR	CACTAATAAGGACAAATGGGGAG ACAATACGGGTTAC (SEQ ID NO: 52)	KAS1 (nt 2084-2099)-A1 (nt 2946-2966)
rKAS1-KsA1	**KAS1-KsA1-FOR1**	CATGGATCTGAGACCGCATGGG CTGATCCACTTTTCTTGTTGGATG CCGAT (SEQ ID NO: 53)	AS (nt 2025-2057)-A1 (nt 2970-2987)-
	KAS1-KsA1-FOR2	CCATGGCTTTGAATACCGGAGTC AGCTTTGCAAACTATACAGCGCA TGGATCTGAGACCGCA	NcoI-CT-AS (nt 1989-2042)

		SEQ ID NO: 54)	
	KAS1-KsA1-REV	CTCGAGGAATGATTCGGAAAGTGTT (SEQ ID NO: 55)	XhoI-A1(nt 3663-3644)
rmultiKAS-KLA1	**multi-FOR1**	CCATGGCTGATTATAGCTGGAATTCCCAGGTAGTCAGCTTTGCAAACTATACA (SEQ ID NO: 56)	NcoI-CT-KAS4 (nt 1857-1880)-KAS3 (nt 2001-2021)
	multi-FOR2	CTTTGCAAACTATACAGCGCATGGATCTGAGACCGCATGGGCTGATCCACTT (SEQ ID NO: 57)	KAS3 (nt 2006-2057)
	multi-FOR3	ATGGGCTGATCCACTTCTGAATTCTTATTGGGGCGAGATCGGCAATATTACC (SEQ ID NO: 58)	KAS3 (nt 2042-2060)-KAS5 (nt 2223-2240)-KAS6 (nt 2403-2417)
	multi-FOR4	GATCGGCAATATTACCCATATTGGTGCTCATTACGCTTGGGGAGACAATACG (SEQ ID NO: 59)	G-KAS6 (nt 2403-2435)-GCT (Ala spacer)-A1(nt 2946-2960)
	multi-REV	CTCGAGACCTCCGTTAGGCAAATCCAATGCCGGTGTTATCAGATAGTTGTCA (SEQ ID NO: 60)	Xho-A1 (nt 3863-3818)

* nucleotide (nt) sequence numbers from lysine-specific cysteine proteinase gene sequence accession number U75366

Expression and purification of recombinant proteins. Recombinant proteins were expressed from pET28::KLA1(KAS2, KAS2-LA1, KAS1-SA1, multiKAS-KLA1) constructs by induction with isopropyl β-D-thiogalactosidase (IPTG). All recombinant proteins were produced as 6-His Tag fusion proteins and purified with NI-NTA purification system (Invitrogen) under denaturing conditions. Briefly, *E. coli* (DE3) single colony transformants were used to inoculate 20 mL of Luria-Bertani (LB) broth containing 50 μg/ml kanamycin at 37°C on an orbital shaker overnight. This inoculum

was then used to inoculate 1L of LB containing 50 μg/ml kanamycin. The OD_{600} of this culture was allowed to reach 0.5-0.7 (mid-log phase) before inducing protein expression with isopropyl IPTG at 0.1mM for 2 hours at 37°C with shaking of 200 rpm. Cells were harvested (7,500g) and resuspended in a denaturing binding buffer (8M Urea, 20 mM Sodium Phosphate pH 8.0 & 500 mM NaCl) and sonicated on ice for 3 x 15 s bursts at 30 s intervals using a Branson Sonifer 250 Cell disrupter (Branson Ultronics Corporation, Danbury, CT) with the microtip on setting 3, then centrifuged at 39,000 g for 30 min at 4°C. Recombinant proteins were purified from the supernatant by loading onto a pre-equilibrated Ni-NTA Agarose column and then washing with denaturing washing buffer (8M Urea, 20 mM Sodium Phosphate pH 6.0 & 500 mM NaCl) to elute unbound proteins. The column was then washed using 10 volumes of binding buffer B and the recombinant protein was eluted with denaturing elution buffer (8M Urea, 20mM Sodium Phosphate pH 6.0, 500mM NaCl & 0.5 M Imidazole). Purified protein was dialyzed against 2M Urea-PBS and stored at -80°C.

Recombinant protein samples were analysed by SDS-PAGE and their molecular masses determined using ProtParam on-line (http://au.expasy.org/tools/protparam.html). Protein concentration of all samples was determined by the Bio-Rad Protein Assay using BSA as a standard.

Immunisation and the mouse periodontitis model. The mouse periodontitis experiments were performed as described previously (3) and were approved by the University of Melbourne Ethics Committee for Animal Experimentation. BALB/c mice 6-8 weeks old (12 mice per group) housed in microisolators were immunized subcutaneously (s.c. 100 μL) with either 50 μg of one of the recombinant proteins or RgpA-Kgp complex, 2 x 10^9 formalin killed cells of *P. gingivalis* strain W50 or PBS; each antigen was emulsified in incomplete Freund's adjuvant (IFA). After 30 days the mice were boosted with antigen (s.c. injection, emulsified in IFA) and then bled from the retrobulbar plexus 12 days later. Four days after the second immunisation mice were given kanamycin (Sigma-Aldrich, New South Wales, Australia) at 1 mg/ml in deionized water ad libitum for 7 days. Three days after the antibiotic treatment (2 days after bleeding), mice were orally inoculated four times 2 days apart with 1 x 10^{10} viable *P. gingivalis* W50 (25 μl) in PG buffer (50 mM Tris-HCl, 150 mM NaCl, 5 mM $CaCl_2$, and 5

mM cysteine-HCl, pH 8.0) containing 2% (wt/vol) carboxymethyl cellulose (CMC; Sigma-Aldrich, New South Wales, Australia), and a control group was sham infected with PG buffer containing 2% (wt/vol) CMC alone. The inocula were prepared in the anaerobic chamber and then immediately applied to the gingival margin of the maxillary molar teeth. Two weeks later, mice received another four doses (2 days apart) of 1 x 10^{10} cells of viable *P. gingivalis* W50 (25 µl) in PG buffer containing 2% (wt/vol) CMC. The number of viable bacteria in each inoculum was verified by enumeration on blood agar. Mice were fed a soft powdered diet (Barastock, Australia) and housed in cages fitted with a raised wire mesh bottom to prevent access to bedding. Four weeks after the last dose, mice were bled from the retrobulbar plexus and killed, and the maxillae were removed and cut in half with one half (right) used for alveolar bone loss measurement and the other half (left) used for real-time PCR.

The right half maxillae were boiled (1 min) in deionized water, mechanically defleshed, and immersed in 2% (wt/vol) potassium hydroxide (16 h, 25°C). The half maxillae were then washed (two times with deionized water) and immersed in 3% (wt/vol) hydrogen peroxide (6 h, 25°C). After the half maxillae were washed (two times with deionized water), they were stained with 0.1% (wt/vol) aqueous methylene blue, and a digital image of the buccal aspect of each half maxilla was captured with an Olympus DP12 digital camera mounted on a dissecting microscope, using OLYSIA BioReport software version 3.2 (Olympus Australia Pty Ltd., New South Wales, Australia) to assess horizontal bone loss. Horizontal bone loss is loss occurring in a horizontal plane, perpendicular to the alveolar bone crest (ABC) that results in a reduction of the crest height. Each half maxilla was aligned so that the molar buccal and lingual cusps of each tooth image were superimposed, and the image was captured with a micrometer scale in frame, so that measurements could be standardized for each image. The area from the cementoenamel junction to the ABC for each molar tooth was measured using OLYSIA BioReport software version 3.2 imaging software. Bone loss measurements were determined twice by a single examiner using a randomized and blinded protocol.

Determination of subclass antibody by an ELISA. To determine the subclass antibody responses of mouse sera, enzyme-linked immunosorbent assays (ELISAs) were performed in triplicate using a 5-µg/ml solution of formalin killed *P. gingivalis* W50 in phosphate-buffered saline (PBS) (0.01 M Na_2HPO_4, 1.5 mM KH_2PO_4, 0.15 M NaCl),

pH 7.0, containing 0.1% (vol/vol) Tween 20 (PBST) to coat wells of flat-bottom polyvinyl microtiter plates (Dynatech Laboratories, McLean, VA). After removal of the coating solution, PBST containing 2% (wt/vol) skim milk powder was added to wells to block the uncoated plastic for 1 h at room temperature. After the wells were washed four times with PBST, serial dilutions of mouse sera in PBST containing 0.5% (wt/vol) skim milk (SK-PBST) were added to each well and incubated for 16 h at room temperature. After the wells were washed six times with PBST, a 1/2,000 dilution of goat IgG to mouse IgM, IgA, IgG1, IgG2a, IgG2b, or IgG3 (Sigma, New South Wales, Australia) was added in SK-PBST and allowed to bind for 2 h at room temperature. Plates were washed six times in PBST, and a 1/5,000 dilution of horseradish peroxidase-conjugated rabbit anti-goat immunoglobulin (Sigma, New South Wales, Australia) in SK-PBST was added to each well and incubated for 1 h at room temperature. After the wells were washed six times with PBST, bound antibody was detected by the addition of 100 µl of ABTS substrate [0.9 mM 2,2'-azino-bis(3-ethylbenz-thiazoline-6) sulfonic acid in 80 mM citric acid containing 0.005% (vol/vol) hydrogen peroxide, pH 4.0] to each well. The optical density at 415 nm was measured using a microplate reader (Bio-Rad microplate reader, model 450).

SDS-PAGE gel electrophoresis and Western blotting. Recombinant proteins (10 µg) were analysed using the XCell surelock Mini-Cell electrophoresis system. Recombinant proteins were mixed in 20 µl of reducing sample buffer (10% [wt/vol] SDS, 0.05% [wt/vol] bromophenol blue, 25% [vol/vol] glycerol, and 0.05% [vol/vol] 2-mercaptoethanol). The pH was adjusted to pH 8.0 with 1.5 M Tris-HCl, and then the solution was heated for 5 min at 100°C. Recombinant proteins (10 µg/lane) were loaded onto Novex 12% (wt/vol) Tris-glycine precast mini gels, and electrophoresis was performed using a current of 30 to 50 mA and a potential difference of 125 V using a Novex electrophoresis system (Novex, San Diego, CA). Proteins were visualized using 0.25% w/v Coomassie blue R250.

Epitope analysis of the Kgp proteinase active site peptide (KAS-2) sequence. The antibody binding sites for the Lys-specific proteinase active site peptide KAS2 (433-468 SEQ ID No: 28) was determined by synthesising N-terminally biotinylated overlapping eight residue peptides (offset by one, overlapping by seven residues) on a multipin peptide synthesis system (Chiron Technologies, Melbourne, Australia) using standard

solid-phase peptide synthesis protocols for Fmoc chemistry. Biotinylated peptides (5µg/mL) in 0.1 M PBS, pH 7.4 were bound to strepavidin coated plates, overnight at 4°C (Nunc, NSW Australia). After the wells were washed four times with PBST epitope mapping of the plate-bound peptides was carried out by ELISA as per Chiron Technologies instructions using mouse sera at a dilution of 1:1000 in 1% w/v non-fat skim milk powder in 0.1 M PBS, pH 7.4, containing 0.1% v/v Tween 20 (SK-PBST). After the wells were washed six times with PBST, a 1/2,000 dilution of goat IgG to mouse IgG (Sigma, New South Wales, Australia) was added in SK-PBST and allowed to bind for 2 h at room temperature. Plates were washed six times in PBST, and a 1/5,000 dilution of horseradish peroxidase-conjugated rabbit anti-goat immunoglobulin (Sigma, New South Wales, Australia) in SK-PBST was added to each well and incubated for 1 h at room temperature. After the wells were washed six times with PBST, bound antibody was detected by the addition of 100 µl of ABTS substrate [0.9 mM 2,2'-azino-bis(3-ethylbenz-thiazoline-6) sulfonic acid in 80 mM citric acid containing 0.005% (vol/vol) hydrogen peroxide, pH 4.0] to each well. The optical density at 415 nm was measured using a microplate reader (Bio-Rad microplate reader, model 450).

Statistical analysis. The bone loss data were statistically analyzed using a one-way analysis of variance (ANOVA) and Dunnett's T3 test (SPSS for Windows, version 12). The IgA, IgM, and IgG subclass antibody titers were statistically analyzed using Student's *t* test using SPSS software (SPSS for Windows, version 12).

Example 2

Characterisation and purification of the recombinant proteins (KsA1, KLA1, KAS1-KsA1 and KAS2-KLA1). In order to characterise the ability of Kgp adhesin A1 domain fragments and chimera Kgp proteinase and Kgp adhesin A1 domain fragments to protect against *P. gingivalis* infection, we expressed and purified the recombinant proteins:- KsA1, KLA1, KAS1-KsA1 and KAS2-KLA1. Recombinant proteins (KsA1 and KLA1) and recombinant chimera proteins (KAS1-KsA1 and KAS2-KLA1) were purified from inclusion bodies using nickel chelate affinity chromatography and the purified proteins analysed by SDS-PAGE (Fig. 1). Each of the purified recombinant proteins consisted of one major protein band with molecular weights of 40, 36, 31 and 32 kDa

corresponding to KAS2-KLA1, KLA1, KsA1 and KAS1-KsA1, and these weights corresponded to the calculated molecular masses of the His-tag recombinant proteins using ProtParam. To characterize the immunogenicity of the recombinant proteins KsA1, KLA1, KAS1-KsA1 and KAS2-KLA1 were used to immunize mice and the sera was used to probe KAS2 peptide coated plates and formalin killed *P. gingivalis* W50 cells coated plates (Fig 2). Recombinant chimera proteins KAS1-KsA1 and KAS2-KLA1 antisera were found to recognize KAS2 peptide (Fig 2A) at a similar level to KAS2 specific antisera (KAS2-diptheria toxoid conjugate) as well as formalin killed *P. gingivalis* W50 cells (Fig 2B). However, antisera against the recombinant protein KLA1 only recognized killed *P. gingivalis* W50 cells (Fig 2B).

Example 3

Effect of immunization with the recombinant proteins (KsA1, KLA1, KAS1-KsA1 and KAS2-KLA1) on *P. gingivalis* induced alveolar bone loss in the mouse periodontitis model. The recombinant proteins KsA1, KLA1, KAS1-KsA1 and KAS2-KLA1, formalin killed *P. gingivalis* strain W50 and the RgpA-Kgp complex were used to determine and compare the protection induced against *P. gingivalis* induced alveolar bone loss using a modified mouse model of periodontal bone loss based on that reported by Baker *et al* (4). Mice were immunized (days 0 and 30) with either recombinant proteins KsA1, KLA1, KAS1-KsA1 or KAS2-KLA1, RgpA-Kgp complex or formalin killed *P. gingivalis* strain W50 (FK-W50) cells or PBS adjuvant alone and were then orally challenged with viable *P. gingivalis* W50. Immunization with all of the recombinant antigens, RgpA-Kgp complex and FK-W50 cells protected BALB/c mice against *P. gingivalis*-induced alveolar bone loss as these animals exhibited significantly ($p<0.001$) less bone loss compared to the PBS immunized group (Figure 3). However the KAS2-KLA1 immunised mice had significantly less bone loss than mice immunised with KLA1 ($p<0.01$); KsA1 ($p<0.001$), RgpA-Kgp complex ($p<0.001$), FK-W50 cells ($p<0.001$) and non-challenged mice ($p<0.001$). There was no significant difference in bone loss between the KAS2-KLA1 and KAS1-KsA1 immunised mice. Furthermore, KAS1-KsA1 immunised mice exhibited significantly less bone loss than non-challenged mice ($p<0.01$) and RgpA-Kgp complex immunised mice ($p<0.05$), but were not

significantly different from KsA1, KLA1, and FK-W50 immunised mice. There was no significant difference in bone loss between the KsA1, KLA1, RgpA-Kgp complex and FK-W50 immunised mice.

Example 4

Antibody subclass responses induced by immunization with the recombinant proteins (KsA1, KLA1, KAS1-KsA1 and KAS2-KLA1) in the mouse periodontitis models. Prior and post to oral inoculation challenge with viable *P. gingivalis* cells mice were bled and the sera collected by centrifugation. Fig 4 shows the antibody subclass reactivity to formalin-killed *P. gingivalis* W50 cells for each immunogen (KsA1, KLA1, KAS1-KsA1 or KAS2-KLA1 or formalin killed *P. gingivalis* strain W50 (FK-W50) cells) in the mouse periodontitis model. All of the protective immunogens induced a high IgG antibody titre to FK-W50. Furthermore, the predominant antibody subclass each protective immunogen induced was IgG1 with only weakly immunoreactive IgG2a, IgG2b and IgG3 FK-W50-specific antibodies (Fig 4). The predominant antibody subclass induced by each immunogen both pre (Fig 4A) and post–oral inoculation (Fig 4B) was IgG1.

Example 5

Epitope mapping of KAS2 (433-468). Overlapping biotinylated eight residue peptides (offset by one, overlap by seven) for KAS2 (433-468) were synthesised and used to coat streptavidin coated plates. The antibody binding epitopes were then identified using antisera from mice immunized with KAS1-KsA1, KAS2-KLA1 and KAS2-diphtheria toxoid conjugate (Fig 5). A two fold increase in optical density (415nm) above background was considered as a positive antibody response (threshold OD). The antisera recognised the following peptide sequences derived from SEQ ID No.28 viz. KAS1 - KsA1 recognised peptides 435-442, 436-443, 445-452, 446-453 and 447-454 (threshold OD = 0.07, Fig 5A) whereas KAS2 - KLA1 recognised peptides 435-442, 447-454 and 448-455 (threshold ID = 0.07, Fig 5A). This suggests recognition of a number of minimal epitopes viz. peptide 436-442 (VSFANYT and its variant VGFANYT), peptide 447-452 (ETAWAD and its variant ETSWAD), and peptide 448-453 (TAWADP and its variant TSWADP). Peptides which include the peptide 436-442 epitope include

GVSFANYT, GVGFANYT, VSFANYTA and VGFANYTA. Peptides which include the peptide 447-452 and/or 448-453 epitopes include SETAWAD, SETSWAD, ETAWADP, ETSWADP, TAWADPL and TSWADPL, more particularly GSETAWAD, GSETSWAD, SETAWADP, SETSWADP, ETAWADPL, ETSWADPL, TAWADPLL and TSWADPLL.

Example 6

Synthesis of KAS and RAS Peptides for conjugation to a protein.

Peptides were synthesized manually or using a CEM Microwave peptide synthesizer. Standard solid-phase peptide synthesis protocols for Fmoc chemistry were used throughout. Peptides were assembled as the carboxyamide form using Rink-linker derived AM-sure resin (AAPPTEC, KY, USA). Coupling was accomplished with HBTU/HOBt activation using 4 equiv of Fmoc-amino acid and 6 equiv of DIPEA. The Fmoc group was removed by 20% piperidine in 1M HOBt/DMF.

Resins bearing KAS or RAS peptides were swollen in DMF and the N-terminal Fmoc group removed by 2% v/v DBU in DMF containing 2% v/v piperidine. The N-terminal amino group was then derivatised with S-Acetylmercaptoacetic acid (SAMA) group using 5 equiv of SAMA-OPfp and 5 equiv of HOBt. The reaction was monitored by the trinitrobenzene sulphonic acid (TNBSA) test. When a negative TNBSA test was returned the resin was washed (5 x DMF, 3 x DCM and 3 x diethyl ether). The resin was then dried under vacuum. Cleavage of peptides from the resin support was performed using TFA:phenol:TIPS:EDT:water (92:2:2:2:2) cleavage cocktail for 2.5 hours or 4 hours depending on the arginine content of the peptide. After cleavage the resin was removed by filtration and the filtrate concentrated to approximately 1mL under a stream of nitrogen. After the peptide products were precipitated in cold ether, they were centrifuged and washed three times. The peptide precipitates were dissolved in 5 to 10 mL of water containing 0.1% v/v TFA and insoluble residue removed by centrifugation. Peptides were purified by RP-HPLC.

A number of different chemical moieties can be used for derivatising peptides for conjugation to proteins, these would introduced reactive groups such as; halides

(bromo, chloro and iodo), maleimido, succinimidyl, hydrazinyl, oxime, thiol, which would then be used conjugate the derivatised peptide to a protein such as KgpA1 through its native cysteine residues or has been derivatised with the complementary reactive group that allows the chemical ligation to proceed to form a peptide-protein conjugate.

Conjugation of SAMA-Peptides to KA1. To a solution, containing 10mg/mL of recombinant KA1 or other adhesin domain of the RgpA-Kgp complex in phosphate-buffered saline (0.1M sodium phosphate, 0.9% NaCl, pH 7.4) was added 0.1mL of a 1% w/v solution of m-maleimido benzoyl-N-hydroxysuccinimide ester (MBS) in DMF. After 30 min unreacted MBS was removed and MBS-modified KA1 collected by gel filtration using a PD10 column (Pharmacia, NSW, Australia) equilibrated in conjugation buffer (0.1M sodium phosphate, 5mM EDTA; pH 6.0). Purified SAMA-peptide (1.3μmole) was dissolved in 200μL 6M guanidine HCl containing 0.5 M Tris; 2mM EDTA, pH 6.0 and diluted with 800μL MilliQ water and deprotected *in-situ* by addition of 25μL of 2M NH_2OH (40 equiv) dissolved in MilliQ water. The collected MBS-KA1 was immediately reacted with deprotected SAMA-peptide and stirred for one hour at room temperature. The peptide-KA1 conjugate was separated from unreacted peptide by gel filtration using a PD10 column equilibrated in PBS pH 7.4 and lyophilized. The reaction was monitored using the Ellmans test.

Example 7

Preparation of Antibodies. Polyclonal antiserum to recombinant proteins are raised in mice by immunising with the proteins subcutaneously. The mice are immunised at day 0 with 25μg of protein in incomplete Freund's adjuvant and day 30 with 25μg of protein in incomplete Freund's adjuvant. Immunisations are carried out using standard procedures. Polyclonal antisera having a high titre against the proteins are obtained. If desired monoclonal antibodies directed specifically against recombinant proteins are obtained using standard procedures.

EXAMPLE 8

Immunization for the generation of antibodies. BALB/c mice or CD1 (Swiss out bred mices) 6-8 weeks old (10 mice per group) were immunized subcutaneously (s.c. 100 μL) with either 50 μg of the KAS2-LA1 chimera and the antigen emulsified in incomplete Freund's adjuvant (IFA). After 30 days the mice were boosted with antigen (s.c. injection, emulsified in IFA) and 12 days later the mice were killed and cardiac bled to collect sera.

Determination of subclass antibody by an ELISA. To determine the subclass antibody responses of mouse sera, enzyme-linked immunosorbent assays (ELISAs) were performed in triplicate using a 5-μg/ml solution of KAS2-LA1 chimera or formalin killed P. gingivalis W50 or the RgpA-Kgp complex in phosphate-buffered saline (PBS) (0.01 M Na_2HPO_4, 1.5 mM KH_2PO_4, 0.15 M NaCl), pH 7.0, containing 0.1% (vol/vol) Tween 20 (PBST) to coat wells of flat-bottom polyvinyl microtiter plates (Dynatech Laboratories, McLean, VA). After removal of the coating solution, PBST containing 2% (wt/vol) skim milk powder was added to wells to block the uncoated plastic for 1 h at room temperature. After the wells were washed four times with PBST, serial dilutions of mouse sera in PBST containing 0.5% (wt/vol) skim milk (SK-PBST) were added to each well and incubated for 16 h at room temperature. After the wells were washed six times with PBST, a 1/2,000 dilution of goat IgG to mouse IgM, IgA, IgG1, IgG2a, IgG2b, or IgG3 (Sigma, New South Wales, Australia) was added in SK-PBST and allowed to bind for 2 h at room temperature. Plates were washed six times in PBST, and a 1/5,000 dilution of horseradish peroxidase-conjugated rabbit anti-goat immunoglobulin (Sigma, New South Wales, Australia) in SK-PBST was added to each well and incubated for 1 h at room temperature. After the wells were washed six times with PBST, bound antibody was detected by the addition of 100 μl of ABTS substrate [0.9 mM 2,2'-azino-bis(3-ethylbenz-thiazoline-6) sulfonic acid in 80 mM citric acid containing 0.005% (vol/vol) hydrogen peroxide, pH 4.0] to each well. The optical density at 415 nm was measured using a microplate reader (Bio-Rad microplate reader, model 450).

Antibody subclass responses induced by immunization with the recombinant protein KAS2-KLA1 in outbred (CD1, Swiss) mice. CD1 (Swiss) mice were

immunised with the KAS2-LA1 chimera, bled and the sera collected by centrifugation. Fig 6 shows the antibody subclass reactivity to KAS2-LA1 chimera, formalin-killed P. gingivalis W50 cells and the RgpA-Kgp complex. The KAS2-LA1 chimera induced a strong IgG antibody with a predominant IgG1 antibody response that recognised the KAS2-LA1 chimera and cross reacted strongly with FK P. gingivalis W50 cells and the RgpA-Kgp complex (Fig. 6). Furthermore, the KAS2-LA1 chimera induced only weak immunoreactive IgG2a, IgG2b and IgG3 antigen-specific antibodies (Fig 6).

Example 9

Development of a Kgp structural model and Identification of Active Site Surface Accessible Sequences.

Our work has shown that Kgp proteinase active site peptides are highly immunogenic and induce high levels of protection against *P. gingivalis*-induced bone loss. In an attempt to identify further proteinase active site peptides as vaccine candidates a model of the catalytic domain of Kgp was developed using the Orchestrar suite of programs within Sybyl7.3 (Fig 7). The model is based on PDB structure 1crv of the RgpB protease from P. gingivalis, the proteins have a 23.58% pairwise identity and the Z-score is 25.09 (a high-confidence model). The Meta-PPisp protein interaction server predicts two protein-protein interaction surfaces for Kgp: the substrate binding surface (as in RgpB), and a second surface unique to Kgp. The major differences between the RgpB and Kgp models are in the loops that frame the second interaction surface and a 19-residue gap (Val526 to Phe545) that couldn't be modeled in Kgp that falls within the second interaction surface. Figure 7 shows the Kgp model with the thicker ribbons showing surface accessible sequences around the proteinase active site of Kgp, the surface accessible sequences were found to be Asp388-Gln394, Leu421-Ala423, Ala443-Glu447 with Ala451, Asn510-Trp513, and Ile570-Gly577 with Tyr580. From the model (Fig 6) it is evident that along with KAS2 (A) three other sequences KAS4 (Asp388-Val395) (B), KAS5 (Asn510-Asp516) (C) and KAS6 (Ile570-Tyr580) (D) are prominent and of sufficient length to be vaccine targets. Thus a recombinant chimera protein can be produced that has each of these peptides in sequence and joined on to the N-terminus of KLA1 to produce multiKAS-KLA1, that can be used to induce an immune response and hence to protect against *P. gingivalis* related diseases or conditions.

Example 10

Process for modelling Arg-X- proteinase to identify immunogenic regions flanking the catalytic site.

The Arg-X proteinase three dimensional structure was determined according to the methods of Eichinger A, Beisel HG, Jacob U, Huber R, Medrano FJ, Banbula A,

Potempa J, Travis J, Bode W. Crystal structure of gingipain R: an Arg-specific bacterial cysteine proteinasewith a caspase-like fold. EMBO J. 1999 Oct 15;18(20):5453-62

Example 11

The following is an example of a toothpaste formulation containing antibodies.

Ingredient	% w/w
Dicalcium phosphate dihydrate	50.0
Glycerol	20.0
Sodium carboxymethyl cellulose	1.0
Sodium lauryl sulphate	1.5
Sodium lauroyl sarconisate	0.5
Flavour	1.0
Sodium saccharin	0.1
Chlorhexidine gluconate	0.01
Dextranase	0.01
Goat serum containing specific antibodies	0.2
Water	balance

Example 12

The following is an example of a toothpaste formulation.

Ingredient	% w/w
Dicalcium phosphate dihydrate	50.0
Sorbitol	10.0
Glycerol	10.0
Sodium carboxymethyl cellulose	1.0
Sodium lauryl sulphate	1.5
Sodium lauroyl sarconisate	0.5
Flavour	1.0
Sodium saccharin	0.1
Sodium monofluorophosphate	0.3
Chlorhexidine gluconate	0.01
Dextranase	0.01
Bovine serum containing specific antibodies	0.2
Water	balance

Example 13

The following is an example of a toothpaste formulation.

Ingredient	% w/w
Dicalcium phosphate dihydrate	50.0
Sorbitol	10.0
Glycerol	10.0
Sodium carboxymethyl cellulose	1.0
Lauroyl diethanolamide	1.0
Sucrose monolaurate	2.0
Flavour	1.0
Sodium saccharin	0.1
Sodium monofluorophosphate	0.3
Chlorhexidine gluconate	0.01
Dextranase	0.01
Bovine milk Ig containing specific antibodies	0.1
Water	balance

Example 14

The following is an example of a toothpaste formulation.

Ingredient	% w/w
Sorbitol	22.0
Irish moss	1.0
Sodium Hydroxide (50%)	1.0
Gantrez	19.0
Water (deionised)	2.69
Sodium Monofluorophosphate	0.76
Sodium saccharine	0.3
Pyrophosphate	2.0
Hydrated alumina	48.0
Flavour oil	0.95
Mouse monoclonal antibodies	0.3
sodium lauryl sulphate	2.00

Example 15

The following is an example of a liquid toothpaste formulation.

Ingredient	% w/w
Sodium polyacrylate	50.0
Sorbitol	10.0
Glycerol	20.0
Flavour	1.0
Sodium saccharin	0.1
Sodium monofluorophosphate	0.3
Chlorhexidine gluconate	0.01
Ethanol	3.0
Equine Ig containing specific antibodies	0.2
Linolic acid	0.05
Water	balance

Example 16

The following is an example of a mouthwash formulation.

Ingredient	% w/w
Ethanol	20.0
Flavour	1.0
Sodium saccharin	0.1
Sodium monofluorophosphate	0.3
Chlorhexidine gluconate	0.01
Lauroyl diethanolamide	0.3
Rabbit Ig containing specific antibodies	0.2
Water	balance

Example 17

The following is an example of a mouthwash formulation.

Ingredient	% w/w
Gantrez S-97	2.5
Glycerine	10.0
Flavour oil	0.4
Sodium monofluorophosphate	0.05
Chlorhexidine gluconate	0.01
Lauroyl diethanolamide	0.2
Mouse monoclonal antibodies	0.3
Water	balance

Example 18

The following is an example of a lozenge formulation.

Ingredient	% w/w
Sugar	75-80
Corn syrup	1-20
Flavour oil	1-2
NaF	0.01-0.05
Mouse monoclonal antibodies	0.3
Mg stearate	1-5
Water	balance

Example 19

The following is an example of a gingival massage cream formulation.

Ingredient	% w/w
White petrolatum	8.0
Propylene glycol	4.0
Stearyl alcohol	8.0
Polyethylene Glycol 4000	25.0
Polyethylene Glycol 400	37.0
Sucrose monostearate	0.5
Chlorohexidine gluconate	0.1
Mouse monoclonal antibodies	0.3
Water	balance

Example 20

The following is an example of a chewing gum formulation.

Ingredient	% w/w
Gum base	30.0
Calcium carbonate	2.0
Crystalline sorbitol	53.0
Glycerine	0.5
Flavour oil	0.1
Mouse monoclonal antibodies	0.3
Water	balance

Example 21

The following is an example of a pharmaceutical formulation

Ingredient	% w/w
Humanised specific monoclonal antibodies	10
Sterile phosphate buffered saline	90

Example 22

The following is an example of a periodontal gel formulation.

Ingredient	% w/w
Pluronic F127	20.0
Stearyl alcohol	8.0
Specific antibodies	3.0
Colloidal silicon dioxide (Aerosil 200)	1.0
Chlorhexidine gluconate	0.1
Water	balance

It should be understood that while the invention has been described in details herein, the examples are for illustrative purposed only. The scope of the claims should not be limited by the preferred embodiments, but should be given the broadest interpretation consistent with the description as a whole.

References

1. McKee, A. S., A. S. McDermid, A. Baskerville, A. B. Dowsett, D. C. Ellwood, and P. D. Marsh. 1986. Effect of hemin on the physiology and virulence of *Bacteroides gingivalis* W50. *Infect. Immun.* 52:349-355.

2. Slots, J. 1982. *Importance of black-pigmented Bacteroides in human periodontal disease. Host parasite interactions in periodontal diseases*. American Society for Microbiology.

3. O'Brien-Simpson, N. M., R. Pathirana, R. A. Paolini, Y.-Y. Chen, P. D. Veith, T. V., R. N. Pike, N. Alley, and E. C. Reynolds. 2005. An immune response directed to proteinase and adhesin functional epitopes protects against Porphyromonas gingivalis-induced bone loss. *Journal of Immunology* 175:3980-3989.

4. Baker, P. J., R. T. Evans, and D. C. Roopenian. 1994. Oral infection with Porphyromonas gingivalis and induced alveolar bone loss in immunocompetent and severe combined immunodeficient mice. *Arch Oral Biol* 39:1035-1040.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A recombinant chimeric or recombinant fusion protein for inducing an immune response to *Porphyromonas gingivalis* (*P. gingivalis)*, the protein comprising (A) a first peptide joined directly or through a linker to (B) a second polypeptide, wherein:

(A) said first peptide comprises a region of a *P. gingivalis* trypsin-like enzyme, wherein the region comprises an amino acid sequence selected from the group consisting of: SEQ ID NOs: 1, 2 and 27-34; and

(B) said second polypeptide comprises a region of an adhesin domain of *P. gingivalis,* wherein the region comprises an amino acid sequence selected from the group consisting of SEQ ID NOs: 35, 36, and 37;

wherein the linker, when present, functions to bring the first peptide and second polypeptide into closer spatial arrangement than in a *P. gingivalis* trypsin-like enzyme; and

wherein said chimeric or fusion protein is capable of inducing an immune response to *P. gingivalis*.

2. The recombinant chimeric or recombinant fusion protein according to claim 1, wherein the linker is up to 15 amino acids in length.

3. The recombinant chimeric or recombinant fusion protein according to claim 1, wherein the linker is less than 5 amino acids in length.

4. The recombinant chimeric or recombinant fusion protein according to any one of claims 1 to 3, wherein:

(a) said first peptide comprises the sequence shown in one of SEQ ID NOs:27 to 30; and

(b) said second polypeptide comprises the sequence shown in SEQ ID NOs:36 or 37.

5. The recombinant chimeric or recombinant fusion protein according to any one of claims 1 to 4, wherein:

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(a) said first peptide consists of the sequence shown in one of SEQ ID NOs:27 to 30; and

(b) said second polypeptide consists of the sequence shown in SEQ ID NOs:36 or 37.

6. The recombinant chimeric or recombinant fusion protein according to any one of claims 1 to 4, wherein said first peptide comprises the sequence shown in SEQ ID NO:28 and said second polypeptide consists of the sequence shown in SEQ ID NO:37.

7. The recombinant chimeric or recombinant fusion protein according to any one of claims 1 to 4, wherein said first peptide comprises the sequence shown in SEQ ID NO: 27 and said second polypeptide consists of the sequence shown in SEQ ID NO:36.

8. The recombinant chimeric or recombinant fusion protein according to any one of claims 1 to 5, wherein said first peptide consists of the sequence shown in SEQ ID NO:28 and said second polypeptide consists of the sequence shown in SEQ ID NO:37.

9. The recombinant chimeric or recombinant fusion protein according to any one of claims 1 to 5, wherein said first peptide consists of the sequence shown in SEQ ID NO: 27 and said second polypeptide consists of the sequence shown in SEQ ID NO:36.

10. The recombinant chimeric or recombinant fusion protein according to any one of claims 1 to 9, wherein the C-terminal residue of said first peptide is covalently linked directly or through the linker to the N-terminal residue of said second polypeptide.

11. The recombinant chimeric or recombinant fusion protein according to any one of claims 1 to 9, wherein the N-terminal residue of said first peptide is covalently linked directly or through the linker to the C-terminal residue of said second polypeptide.

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12. A composition comprising the recombinant chimeric or recombinant fusion protein according to any one of claims 1 to 11, and an adjuvant.

13. Use of the recombinant chimeric or recombinant fusion protein according to any one of claims 1 to 11, or the composition according to claim 12 in the manufacture of a medicament for preventing or reducing the incidence or severity of periodontal disease in a subject.

14. Use of the recombinant chimeric or recombinant fusion protein according to any one of claims 1 to 11, or the composition according to claim 12 for preventing or reducing the incidence or severity of periodontal disease in a subject.

15. An antibody specifically raised against the recombinant chimeric or recombinant fusion protein according to any one of claims 1 to 11, wherein the antibody specifically binds to said chimeric or fusion protein.

16. The antibody according to claim 15, which is a monoclonal antibody.

17. Use of the antibody according to claim 15 or claim 16 in the manufacture of a medicament for preventing or reducing the incidence or severity of periodontal disease in a subject.

18. Use of the antibody according to claim 15 or claim 16 for preventing or reducing the incidence or severity of periodontal disease in a subject.

19. A nucleic acid molecule comprising a sequence encoding the recombinant chimeric or recombinant fusion protein according to any one of claims 1 to 11.

20. The nucleic acid molecule according to claim 19, wherein said sequence is operatively linked to at least one regulatory element.

21. A vector comprising the nucleic acid molecule according to claim 19 or claim 20.

22. The vector according to claim 21, which is a viral or bacterial vaccine vector.

23. A prokaryotic or eukaryotic cell, comprising the nucleic acid molecule according to claim 19 or claim 20, or the vector according to claim 21 or claim 22.

24. Use of the nucleic acid molecule according to claim 19 or claim 20, the vector according to claim 21 or claim 22, or the prokaryotic or eukaryotic cell according to claim 23 in the manufacture of a medicament for preventing or reducing the severity of periodontal disease in a subject.

25. Use of the nucleic acid molecule according to claim 19 or claim 20, or the vector according to claim 21 or claim 22, for preventing or reducing the severity of periodontal disease in a subject.

26. Use of the recombinant chimeric or recombinant fusion protein according to any one of claims 1 to 11, to detect anti-*P. gingivalis* antibodies in a biological sample from a subject.

27. Use of the antibody according to claim 15 or claim 16, to detect the presence of *Porphyromonas gingivalis* (*P. gingivalis*) in a biological sample from a subject.

28. Use of the recombinant chimeric or recombinant fusion protein according to any one of claims 1 to 11 or the composition according to claim 12 for immunizing a non-human animal to raise an antiserum or antibody against *P. gingivalis*.

FIG 1/7

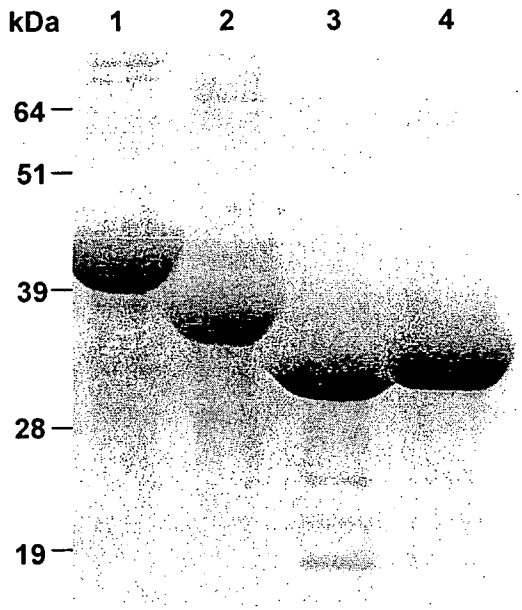
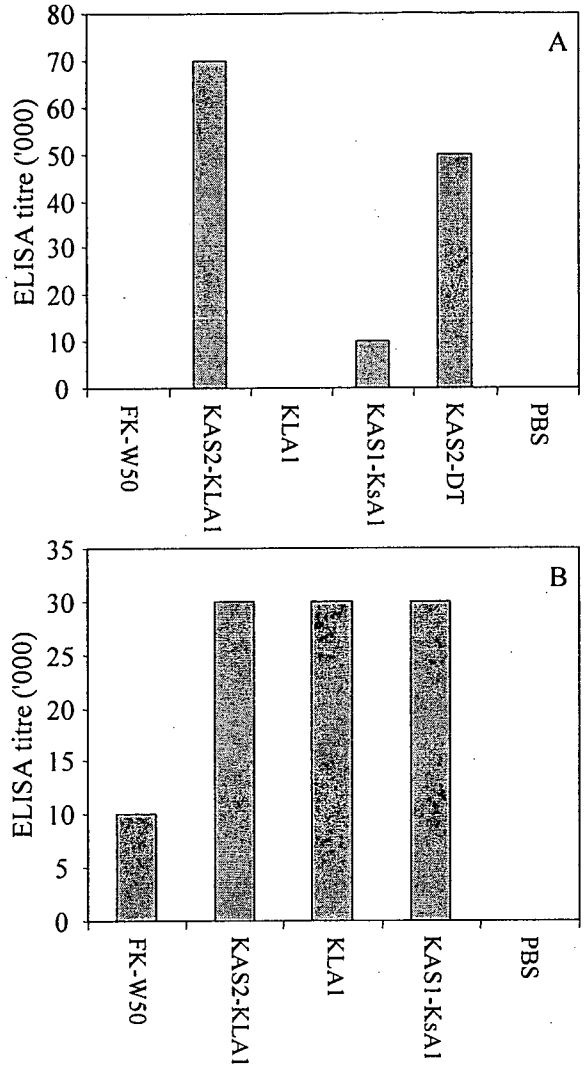


Fig 1.

FIG 2/7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PBS
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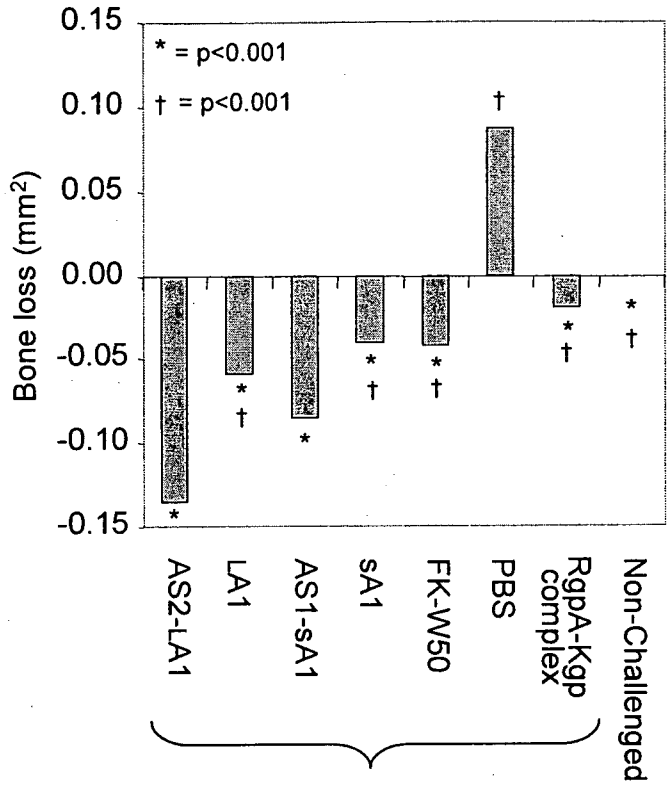
Fig. 2.

FIG 3/7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† = p<0.001
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PBS
RgpA-Kgp complex
Non-Challenged

Fig. 3

FIG 4/7

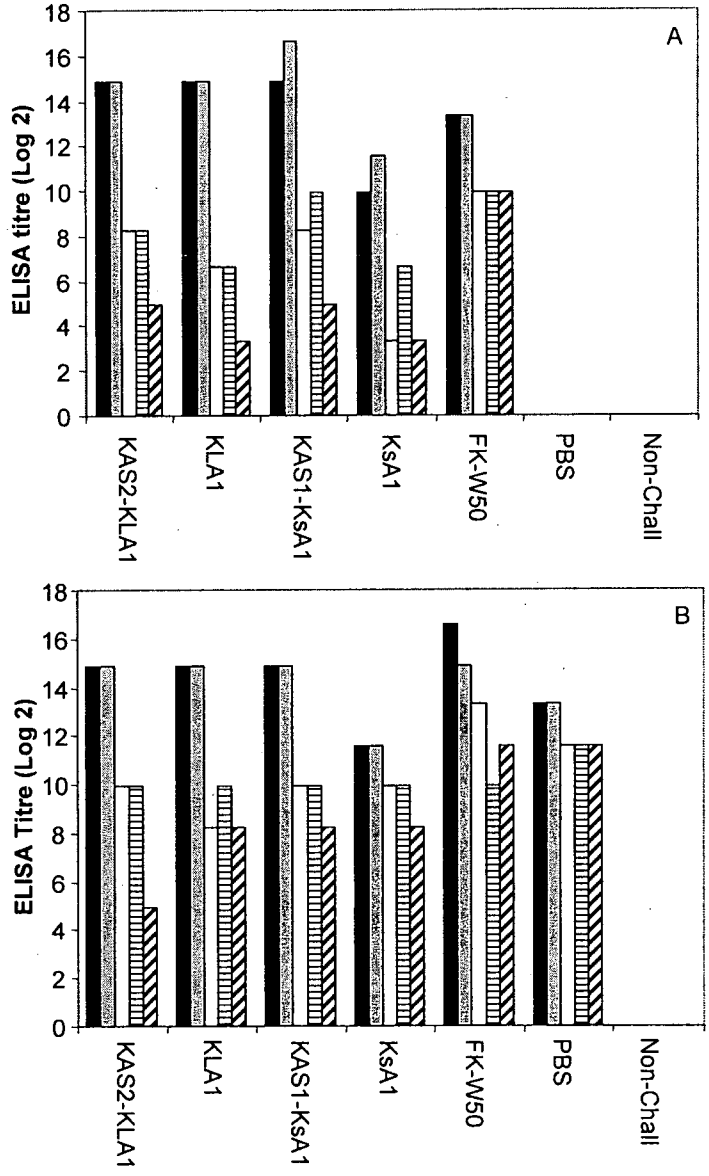
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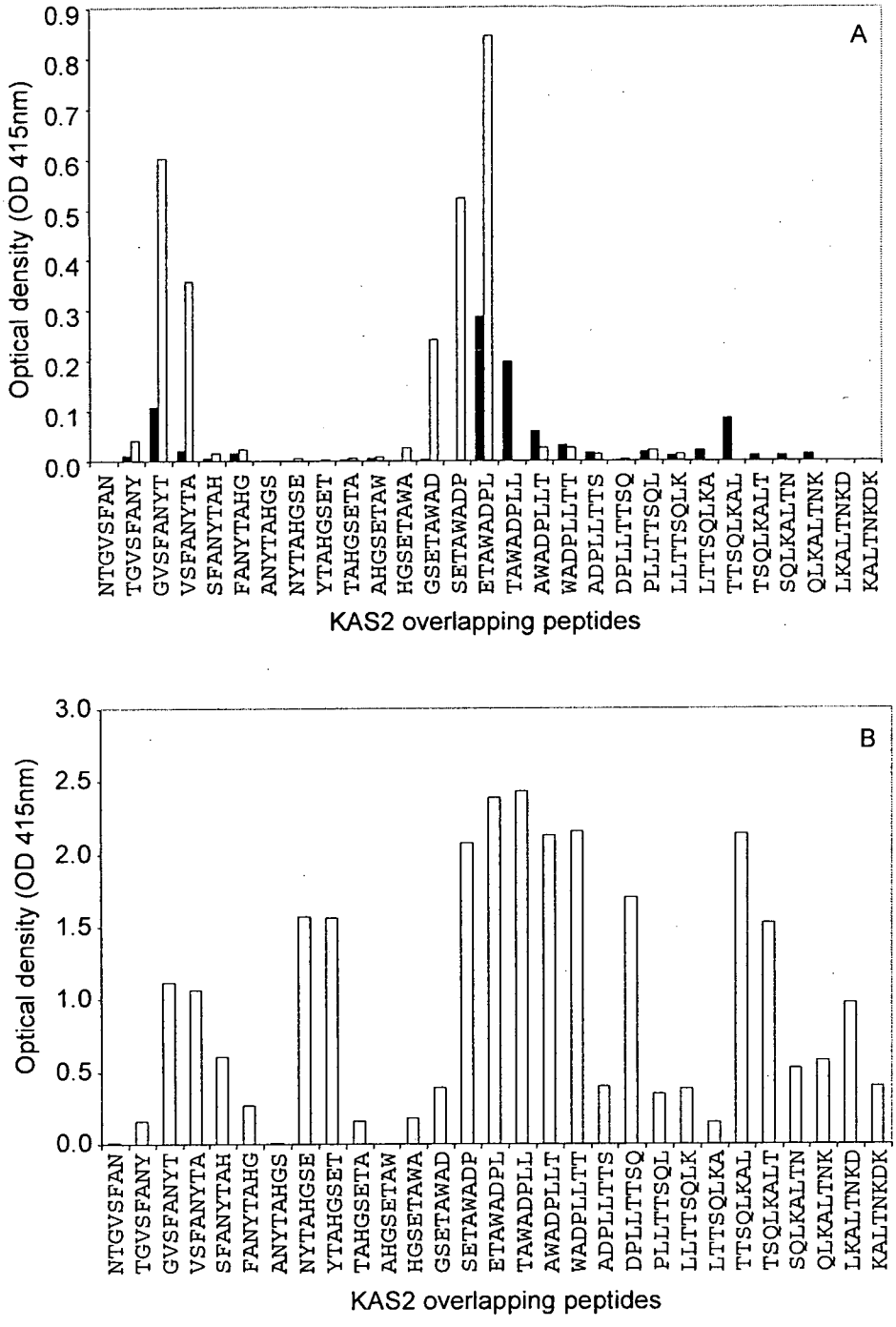
Fig 4.

FIG 5/7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0.9
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GVSFANYT
VSFANYTA
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NYTAHGSE
YTAHGSET
TAHGSETA
AHGSETAW
HGSETAWA
GSETAWAD
SETAWADP
ETAWADPL
TAWADPLL
AWADPLLT
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ADPLLTTS
DPLLTTSQ
PLLTTSQL
LLTTSQLK
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TTSQLKAL
TSQLKALT
SQLKALTN
QLKALTNK
LKALTNKD
KALTNKDK
KAS2 overlapping peptides
B
Optical density (OD 415nm)
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1.0
1.5
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2.5
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NTGVSFAN
TGVSFANY
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SFANYTAH
FANYTAHG
ANYTAHGS
NYTAHGSE
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TAHGSETA
AHGSETAW
HGSETAWA
GSETAWAD
SETAWADP
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WADPLLTT
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PLLTTSQL
LLTTSQLK
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KAS2 overlapping peptides

Fig 5.

FIG 6/7

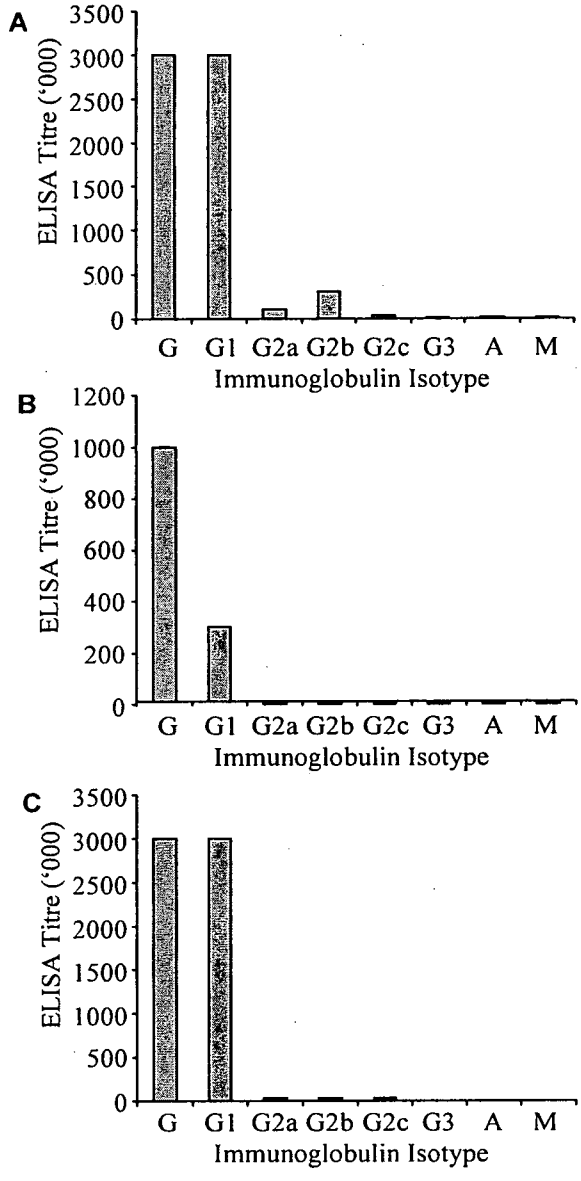

Figure 6

FIG 7/7

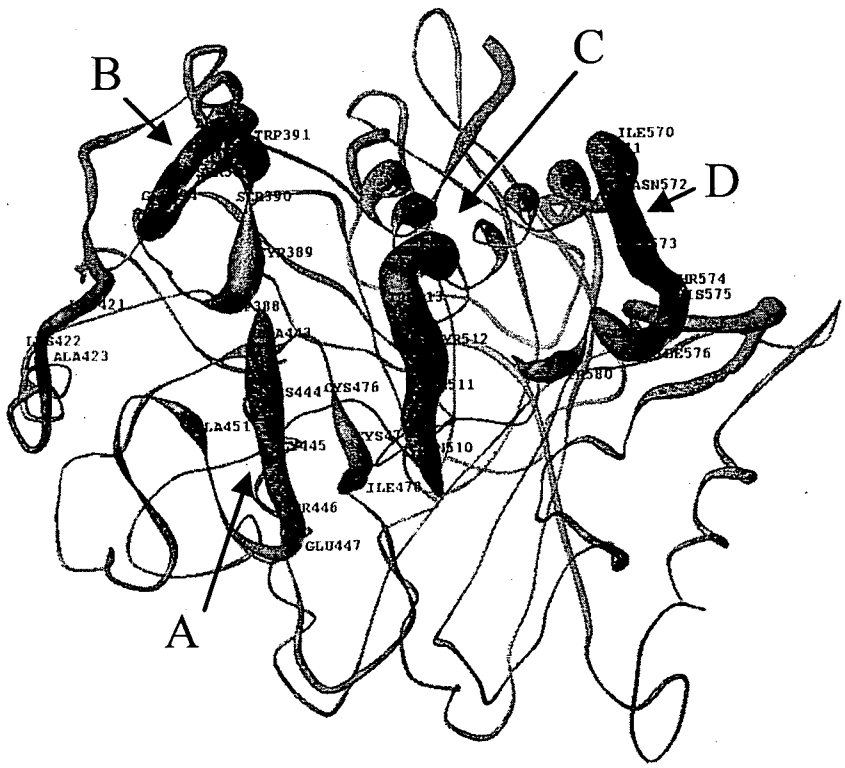

Fig. 7