

**METHOD AND SYSTEM FOR PROVIDING FEEDBACK DATA
USEFUL IN PROSTHODONTIC PROCEDURES ASSOCIATED WITH
THE INTRA ORAL CAVITY**

Abstract

Feedback data useful in prosthodontic procedures associated with the intra oral cavity is provided. First, a 3D numerical model of the target zone in the intra oral cavity is provided, and this is manipulated so as to extract particular data that may be useful in a particular procedure, for example data relating to the finish line or to the shape and size of a preparation. The relationship between this data and the procedure is then determined, for example the clearance between the preparation and the intended crown. Feedback data, indicative of this relationship, is then generated, for example whether the preparation geometry is adequate for the particular type of prosthesis.

[0001] This application claims the benefit of prior U.S. provisional patent application No. 60/630,572 filed Nov. 26, 2004, the contents of which are hereby incorporated by reference in their entirety.

FIELD OF THE INVENTION

[0002] This invention relates to a system and method for providing feedback information that facilitates and that may provide guidance for prosthodontic procedures in the intra oral cavity, i.e., procedures involving the installation and definition of dental prostheses. In particular, the invention relates to such systems and methods that are computerized.

BACKGROUND OF THE INVENTION

[0003] Prosthodontics is the dental speciality concerned with artificial replacements of missing parts of the mouth and jaws, in particular of teeth and parts thereof.

[0004] In prosthodontic procedures designed to implant a dental prosthesis in the intra oral cavity, the dental site at which the prosthesis is to be implanted in many cases needs to be measured accurately and studied carefully, so that a prosthesis such as a crown or bridge, for example, can be properly designed and dimensioned to fit in place. A good fit is of the highest importance to enable mechanical stresses to be properly transmitted between the prosthesis and the jaw, and to prevent infection of the gums and so on via the interface between the prosthesis and the dental site.

1 [0005] In the prior art, the dental site is prepared by the dental practitioner, and
2 a positive model of the site is constructed using known methods. Alternatively,
3 the dental site may be scanned to provide 3D data of the site. In either case, the
4 virtual or real model of the site is sent to the dental lab, which manufactures the
5 prosthesis based on the model. However, if the model is deficient or undefined
6 in certain areas, or if the preparation is not optimal for receiving the prosthesis,
7 the dental technician has a more difficult job ahead than otherwise, and may
8 result in less than optimal design for the prosthesis. In some circumstances, the
9 model is rejected and the dental practitioner must re-scan the dental site, or must
10 rework the preparation, so that a suitable prosthesis may be produced.

11 SUMMARY OF THE INVENTION

12 [0006] Herein, "dental material" refers to any material associated with dental
13 structures of the intra oral cavity, including but limited to natural dental materials
14 such as for example enamel, dentine, pulp, dental roots, and non-natural dental
15 materials such as for example metallic and non-metallic filings, restorations,
16 crowns, bridges, copings, preparations, and so on.

17 [0007] Herein, "dental clinic" refers to the interface between a dental
18 practitioner and a patient, and thus includes any physical entity, in particular a
19 clinic, in which there is interaction between a dental patient and a dental
20 practitioner. While "dental practitioner" typically refers to a dentist, doctor or
21 dental technician, it—also includes herein all other caregivers that may interact
22 with a dental patient during the course of a dental treatment. While "dental
23 patient" typically refers to —a person requiring the dental services of a dental
24 practitioner, it also includes —herein any person regarding whom it is desired to
25 create a 3D numerical model— of the intra oral cavity thereof, for example for
26 the purpose of practicing the same or for carrying out research.

27 [0008] The term "prosthesis" is herein taken to include any restoration ~~and/or~~
28 veneering, including any onlays, such as crowns and bridges, for example, and
29 inlays, such as caps, for example, and any other artificial partial or complete
30 denture.

31 [0009] While the term "preparation" typically refers to the stump (including
32 the finish line and shoulder) that is left of the tooth that is to be replaced by the
33 prosthesis—typically a crown—and on which the crown is to be mounted,
34 the term herein also includes artificial stumps, pivots, cores and posts, or other
35 devices that may be implanted in the intraoral cavity in such a position or in a
36 position that is optimal for implanting the crown.

37 [0010] The term "prosthodontic procedure" refers, inter alia, to any procedure
38 involving the intraoral cavity and directed to the design, manufacture or
39 installation of a dental prosthesis at a dental site within the intraoral cavity, or a

1 real or virtual model thereof, or directed to the design and preparation of the
2 dental site to receive such a prosthesis.

3 [0011] The term "numerical entity" is used herein synonymously with virtual
4 model and other such terms, and relates to a virtual representation of a real object,
5 typically a dentition or at least a part of intraoral cavity, or of a real model thereof,
6 for example.

7 [0012] The present invention, in a first aspect thereof, relates to a method for
8 providing feedback data useful in at least one prosthodontic procedure associated
9 with the intra oral cavity, comprising:

10 [0013] (a) providing at least one numerical entity representative of the three-
11 dimensional surface geometry of at least part of the intra-oral cavity;

12 [0014] (b) manipulating -said entity to provide desired data of a type useful in at
13 least a first said procedure;

14 [0015] (c) determining at least one relationship between said desired data and
15 said first procedure; and

16 [0016] (d) generating feedback data representative of said at least one
17 relationship.

18 [0017] Typically, in the said prosthodontic procedure, dental material has been
19 previously removed from said part of the intra-oral cavity by means of a second
20 procedure.

21 [0018] Optionally, step (c) comprises testing an adequacy of said desired data for
22 performing said first procedure according to at least one predetermined
23 parameter, and step (d) comprises generating feedback data representative of said
24 adequacy.

25 [0019] The method is typically directed at a said first procedure comprising
26 mounting at least one dental prosthesis with respect to a dental preparation
27 comprised in said intraoral cavity and provided prior to step (a).

28 [0020] In a first embodiment of the invention, said desired data relates to the
29 geometry of a finish line associated with said dental preparation. -Step (c)
30 comprises determining whether or not the said finish line geometry is suitable for
31 receiving a prosthesis according to predetermined -parameters; said feedback data
32 in step (d) comprises a suitable message advising whether or not said finish line
33 geometry is suitable, according to said determination in step (c). In step (c) it may
34 be determined that the said finish line geometry is not suitable for receiving a

1 prosthesis according to predetermined parameters, and in such a case the method
2 may further comprise the step:

3 [0021] (e) providing suggested changes to said finish line geometry such as to
4 provide a new finish line geometry that is suitable for receiving a prosthesis
5 according to predetermined parameters.

6 [0022] The suggested changes may be calculated according to predetermined
7 rules.- Further, the suggested changes may be displayed on a two-dimensional
8 representation of said dental preparation, wherein said new finish line geometry
9 is superimposed over said representation. The location of said existing finish line
10 geometry may be highlighted with respect to said new finish line geometry.

11 [0023] The method may further comprise repeating steps (a) to (d) after further
12 material has been removed from the preparation to conform a finish line thereof
13 to said new finish line geometry.

14 [0024] The method may further comprise repeating steps (a) to (d) concurrently
15 with each step of a material removal operation, said material removal operation
16 being adapted to conform a finish line of said preparation to said new finish line
17 geometry, wherein step (e) is performed at each step of said material removal
18 operation.

19 [0025] In a second embodiment, the desired data relates to an insertion path
20 geometry for said prosthesis with respect to said dental preparation and
21 surrounding dental tissues. Step (c) comprises determining whether or not the
22 said insertion path geometry is suitable for enabling said prosthesis to be mounted
23 with respect to said dental preparation. -The feedback data may comprise a
24 suitable message advising whether or not said insertion path geometry is suitable,
25 according to said determination in step (c). In step (c) it may be determined that
26 the said insertion path geometry is not suitable for receiving a prosthesis
27 according to predetermined parameters, and the method may then further
28 comprise the step:

29 [0026] (f) providing suggested changes to said dental preparation such as to
30 provide a new insertion path geometry that is suitable for receiving a prosthesis
31 according to predetermined parameters.

32 [0027] The suggested changes may be determined on the basis of identifying
33 overlapping areas between the prosthesis and the preparation, ~~and~~and providing
34 guidance as to corresponding changes required in at least one of said prosthesis
35 and said preparation. Further, the suggested changes may be displayed on a two-
36 dimensional representation of said dental preparation, wherein said new insertion
37 path geometry is superimposed over said representation.

1 [0028] The method may further comprise repeating steps (a) to (d) after further
2 material has been removed from the preparation to conform said preparation to
3 said new insertion path geometry.

4 [0029] The method may further comprise repeating steps (a) to (d) concurrently
5 with each step of a material removal operation, said material removal operation
6 being adapted to said preparation to said new insertion path geometry, wherein
7 step (e) is evaluated at each step of said material removal operation.

8 [0030] The prosthesis in the second embodiment of the invention is typically a
9 crown or bridge.

10 [0031] In a third embodiment of the invention, the desired data relates to at least
11 one predetermined dimension between said dental preparation and said
12 prosthesis. Step (c) comprises determining whether or not the said at least one
13 dimension is suitable for enabling a prosthesis to be received according to
14 predetermined parameters. The at least one dimension typically relates to a
15 characteristic thickness of said prosthesis. The said prosthesis may comprises a
16 ceramic cap that is mountable over a metal coping bonded to said preparation, or
17 a porcelain fused to metal (PFM) cap, for example.

18 [0032] The feedback data typically comprises a suitable message advising
19 whether or not said at least one dimension is suitable, according to said
20 determination in step (c). -In step (c) it may be determined that the said at least
21 one dimension is not suitable for receiving a prosthesis according to
22 predetermined parameters, and further comprises the step:

23 [0033] (e) providing suggested changes to preparation geometry such as to
24 provide a dimension that is suitable for receiving a prosthesis according to
25 predetermined parameters.

26 [0034] The suggested changes may be determined taking into consideration the
27 type of prosthesis to be implanted at said preparation. The suggested changes
28 may be displayed on a two-dimensional representation of said dental preparation,
29 wherein said changes to preparation geometry are superimposed over said
30 representation.

31 [0035] Optionally, the method may further comprise repeating steps (a) to (d)
32 after further material has been removed from the preparation to conform said
33 preparation to said new preparation geometry.

34 [0036] Optionally, the method may further comprise repeating steps (a) to (d)
35 concurrently with each step of a material removal operation, said material
36 removal operation being adapted to conform said ~~-preparation-~~ to said new

1 preparation geometry, wherein step (e) is evaluated at each step of said material
2 removal operation.

3 [\[0037\]](#) For all embodiments, step (a) is typically performed by scanning said at
4 least part of said intra oral cavity using a suitable 3D surface scanner.

5 [\[0038\]](#) According to a second aspect of the invention, in step (c) said relationship
6 may be insufficiently determined due to incomplete definition of numerical entity
7 provided by step (a). The method may then further comprise the step of
8 determining the location of at least one area of said intra oral cavity where 3D
9 definition thereof is required for enabling step (c) to be performed. Said
10 determination of the location of said at least one area may be performed by
11 suitable algorithms. The said at least one area is displayed on a two-dimensional
12 representation of said dental preparation, wherein said at least one area is
13 superimposed over said representation.

14 [\[0039\]](#) The prosthesis typically comprises any one of an inlay, onlay, crown,
15 bridge or restoration.

16 [\[0040\]](#) Optionally, step (b) comprises simulating said procedure first with respect
17 to said numerical entity to provide said desired data.

18 [\[0041\]](#) According to the second aspect of the invention, step (a) comprises the
19 steps of:

20 [\[0042\]](#) scanning a part of said intra-oral cavity to provide a 3D numerical entity
21 thereof;

22 [\[0043\]](#) determining whether a definition of said 3D numerical entity is sufficient
23 for enabling step (c) to be performed;

24 [\[0044\]](#) if said definition is insufficient, advising a user to continue scanning a
25 different part of said intra-oral cavity, and repeating step (ii) until said definition
26 is sufficient, wherein step (v) is performed;

27 [\[0045\]](#) if said definition is sufficient in step (ii), proceeding with step (v);

28 [\[0046\]](#) advising a user that said definition is sufficient, and proceeding with steps
29 (b) to (d).

30 [\[0047\]](#) Optionally, in step (a), said numerical entity further comprises color data
31 of said part of the intra oral cavity, and step (b) comprises differentiating parts of
32 said entity according to whether the said color associated therewith is correlated
33 with soft tissues or hard tissues of the intra oral cavity.

- 1 [0048] Optionally, step (a) may be performed in one location, and at least one of
2 steps (b) to (d) may be performed in at least one different location.
- 3 [0049] Optionally, step (d) is provided substantially in real-time with respect to
4 step (a), or within a short time period thereof, typically in the order of seconds or
5 fractions of a second.
- 6 [0050] According to the second aspect of the invention, a method of providing
7 feedback data useful in at least one prosthodontic procedure associated with the
8 intra oral cavity, comprises:
- 9 [0051] (i) providing at least one numerical entity representative of the three-
10 dimensional surface geometry of at least part of the intra-oral cavity that has been
11 previously modified by means of a first part of said procedure;
- 12 [0052] (ii) manipulating said entity to provide desired data useful in at least a
13 second part of said procedure;
- 14 [0053] (iii) testing adequacy of said desired data for performing said second part
15 of said procedure; and
- 16 [0054] (iv) generating feedback data representative of said adequacy.
- 17 [0055] Typically, the first part of said procedure comprises a dental material
18 removal operation in said intra-oral cavity. Further typically, step (ii) comprises
19 manipulating said entity to determine sufficiency of definition of said numerical
20 entity in step (i) with respect to said first said procedure, and providing
21 sufficiency data representative of said sufficiency, and step (iii) comprises
22 determining at least one relationship between said sufficiency data and said first
23 procedure. In one application of the method according to the second aspect of the
24 invention, the desired data may relate to a measure of surface data definition of
25 said entity.
- 26 [0056] In the third aspect of the invention, the feedback data is essentially used
27 in an interactive manner together with a material removing process to facilitate
28 the performance of a procedure with respect to the intraoral cavity.
- 29 [0057] The present invention also relates to a system for providing feedback data
30 useful in at least one prosthodontic procedure associated with the intra oral cavity
31 comprising:
- 32 [0058] (A) scanner means for providing at least one numerical entity
33 representative of the three-dimensional surface geometry of at least part of the
34 intra-oral cavity;

1 [0059] (B) microprocessor means for manipulating said entity to provide desired
2 data of a type useful in at least a first said procedure, and for determining at least
3 one relationship between said desired data and said first procedure; and

4 [0060] (C) output means for outputting feedback data representative of said at
5 least one relationship generated by said microprocessor means.

6 [0061] The scanner may comprises a confocal scanner, for example. -Preferably,
7 the scanner comprises a capability for providing color data as well as geometrical
8 data of a surface. Typically, the output means comprises a visual and/or audio
9 display means. The microprocessor means is adapted for operation according to
10 the method of the invention.

11 BRIEF DESCRIPTION OF THE DRAWINGS

12 [0062] In order to understand the invention and to see how it may be carried out
13 in practice, a preferred embodiment will now be described, by way of non-
14 limiting example only, with reference to the accompanying drawings, in which:

15 ~~Fig-1~~[0063] FIG. 1 is a block diagram illustrating steps of a method according to
16 the first aspect of the invention.

17 ~~Fig~~[0064] FIG. 2 is a block diagram illustrating elements of a system according
18 to the present invention.

19 ~~Fig~~[0065] FIG. 3 illustrates a numerical entity of the intraoral cavity obtained
20 with the system of ~~Fig~~FIG. 2.

21 ~~Fig~~[0066] FIG. 4 illustrates a virtual crown prosthesis with respect to a virtual
22 preparation area.

23 ~~Fig~~[0067] FIG. 5 illustrates dimensional parameters associated with the crown
24 of ~~Fig-~~FIG. 4.

25 ~~Fig~~[0068] FIG. 6 illustrates the insertion path for a crown prosthesis with respect
26 to a preparation.

27 ~~Fig~~[0069] FIG. 7 illustrates the insertion path for another crown prosthesis with
28 respect to a preparation, constrained to follow the insertion path defined by the
29 internal surface of the prosthesis.

30 ~~Fig~~[0070] FIG. 8 illustrates the insertion path for the prosthesis of ~~Fig~~FIG. 7 with
31 respect to a preparation, constrained to follow the insertion path defined by the
32 external surface of the prosthesis.

1 **Fig[0071]** FIG. 9 illustrates an auxiliary prosthesis for use with the preparation
2 stump having an undercut.

3 **Fig[0072]** FIG. 10 illustrates a bridge prosthesis having a suitable the insertion
4 path with respect to a preparation.

5 **Fig[0073]** FIG. 11 illustrates a bridge prosthesis having a non-suitable insertion
6 path for with respect to a preparation.

7 **Fig[0074]** FIG. 12 is a block diagram illustrating steps of a method according to
8 the second aspect of the invention.

9 DETAILED DESCRIPTION OF THE INVENTION

10 Fig[0075] FIG. 1 illustrates a method 10 for providing feedback data useful in at
11 least one prosthodontic procedure associated with the intra oral cavity, in
12 accordance with a first aspect of the invention. The method comprises the
13 following basic steps:

14 [0076] Step 11: providing at least one numerical entity representative of the
15 three- dimensional surface geometry of at least part of the intra-oral cavity from
16 which dental material has been removed.

17 [0077] Step 12: manipulating said entity to provide desired data of a type useful
18 in at least a first said procedure.

19 [0078] Step 13: determining at least one relationship between said desired data
20 and said first procedure.

21 [0079] Step 14: generating feedback data representative of said at least one
22 relationship.

23 [0080] Thus, in the first aspect of the invention, the feedback data is essentially
24 used to facilitate the performance of a prosthodontic procedure with respect to
25 the intraoral cavity.

26 [0081] Preferably, steps 11 to 14 are carried out in a relatively short space of
27 time, more preferably in real time or close thereto.

28 [0082] For all embodiments, the first step 11 of the method according to the
29 present invention relates to providing at least one numerical entity that is
30 representative of the three-dimensional surface. The said numerical entity is
31 typically at least "three-dimensional", that is, each data point of the data set
32 comprises at least three prime independent variables relating to spatial
33 coordinates of a surface, typically defined along orthogonal Cartesian axes, x, y,
34 z. Alternatively, these variables may be defined along polar axes or any other

1 geometric system in which a surface may be described. Thus, the numerical entity
2 typically comprises a data set having a plurality of at least 3-dimensional arrays
3 – ($\text{---}(x, y, z)$), wherein each array represents the x, y, z, geometrical coordinates.

4 [\[0083\]](#) Any suitable means may be used to provide the numerical entity Fig. [FIG.](#)
5 2 illustrates the main elements of the system 50 according to the present
6 invention, comprising a suitable scanner 31, a microprocessor or computer 52,
7 and a display means 54. According to the invention, digitised three-dimensional
8 (3D) information W (Fig. [FIG.](#) 3) of the patient's intra-oral cavity, or part thereof,
9 is created by the system 50 using scanner 31. Preferably, the 3D digitized data of
10 the intraoral cavity is obtained, including the dentition and associated anatomical
11 structures of a patient. The scanning means 31 may include, for example, a hand-
12 -held scanner that is used by the practitioner or other user to acquire the 3D data.
13 Advantageously, a probe for determining three dimensional structure by confocal
14 focusing of an array of light beams may be used, for example as manufactured
15 under the name of PROSTHOCAD or [as](#) disclosed in WO 00/08415, the contents
16 of which are incorporated herein in their entirety.

17 [\[0084\]](#) The system 50 is typically located at a dental clinic, and may be linked to
18 one or more service centers 23 and/or dental labs 26, via a communication means
19 or network such as for example the Internet or other suitable communications
20 medium such as an intranet, local access network, public switched telephone
21 network, cable network, satellite communication system, and the like, indicated
22 by the cloud at 24. Optionally, it is also possible for some dental labs 26 to be
23 linked to each other, via the same one or a different one of said communication
24 medium, for example when such dental clinics or labs form part of a common
25 commercial entity. Further optionally, such interlinked dental labs 26 may be
26 further linked with other entities, for example a head clinic or head lab,
27 comprising a centralized data base (not shown).

28 [\[0085\]](#) Typically, the design and manufacture of dental appliances for use in the
29 intraoral cavity may be eventually carried out at the dental lab 26 or at the service
30 centre 23, or alternatively one or both of these activities may be shared between
31 the two; in each case the design and manufacture are preferably based on the
32 original 3D data of the oral cavity previously obtained. Thus, exchange of data
33 between the system 50 and the dental lab 26 and/or service center 23 may be
34 useful in creating an optimal geometry for a preparation being made in the
35 intraoral cavity that enables the best prosthesis to be designed therefor, for
36 example.

37 [\[0086\]](#) The dental lab 26 typically comprises a laboratory, or a design or
38 manufacturing entity that may provide direct technical services to the dental
39 clinic in which the system 50 is located. Such services may include, for example,
40 scanning, manufacturing, analyzing the preparation in the intra oral cavity to
41 mark the location of the finish line, for example, as disclosed in USSN [U.S. Ser.](#)

- 1 [No. 10/623,707](#) and [WO 04/008981](#), also assigned to the present assignee, and
2 the contents of which are incorporated herein in their entirety, and so on. The
3 dental lab 26 is typically characterized as being equipped or otherwise able to
4 design part or whole prostheses, and/or to partially manufacture or assemble the
5 same, particularly where close tolerances are relatively less critical. On the other
6 hand, while the service center 23 is also equipped to design part or whole
7 prostheses, and/or to fully or partially manufacture and/or assemble the same, it
8 is particularly suited to do any of these activities where close or tight tolerances
9 are in fact critical and/or difficult to achieve.
- 10 [\[0087\]](#) While the service centre 23 and dental labs 26 may be located in a
11 different geographical zone to the dental clinic, for example, different countries,
12 different cities in the same country, different neighborhoods in the same city, or
13 even different buildings in the same neighborhood, they may also be housed in
14 the same building, and in any case maintain their separate functions and
15 capabilities, as described herein.
- 16 [\[0088\]](#) The system 50 may also be linked to one or more consultation centers 27,
17 also via network 24, wherein such consultation centers 27 may comprise dental
18 experts, for example, that may provide feedback data to the user of system 50,
19 based on data transmitted therefrom to the centers 27, according to the invention.
- 20 [\[0089\]](#) According to the present invention, step 11 is carried out after a material
21 removal operation has been applied to a part of the intra oral cavity. Such a
22 material removal operation may be executed using any suitable machining tool
23 that is adapted for material removal, and may include inter alia mechanical tools
24 such as drills for example, laser tools such as for example laser drills or cutters,
25 ultrasonic tools such as for example ultrasonic cutters, and so on. Alternatively
26 or additionally, the material removal operation may comprise a loss of dental
27 material, occurring, for example, via disease, mechanical forces such as a blow
28 to the teeth for example, and so on.
- 29 [\[0090\]](#) Such a material removal operation may be directed for the purpose of, or
30 may require, prosthodontic procedures, and may include the construction of a
31 dental preparation at a dental site, so as to receive a prosthesis such as a crown,
32 for example, or for providing a dental filling or restoration thereat.
- 33 [\[0091\]](#) Alternatively, the 3D digitized data may be obtained in any other suitable
34 manner, including other suitable intra oral scanning techniques, based on optical
35 methods, direct contact or any other means, applied directly to the patient's
36 dentition. Alternatively, X-ray based, CT based, MRI based, or any other type of
37 scanning of the patient's intra-oral cavity may be used. The dimensional data may
38 be associated with a complete dentition, or of a partial dentition, for example
39 such as a preparation only of the intra oral cavity.

1 [0092] Typically, the 3D digitized data is obtained in a manner such that enables
2 the data to be procured from the patient and analysed according to the invention
3 during a regular visit of a patient to a practitioner.

4 [0093] Thus, advantageously, such a scanner 31 makes use of confocal imaging
5 for providing an accurate three-dimensional representation of the target surface
6 within the intra-oral cavity.

7 [0094] Optionally, the numerical entity may further comprise a fourth prime
8 independent variable, relating to a color parameter that is expressed numerically
9 and is associated with the spatial coordinates. The color parameter may itself be
10 comprised of independent prime color variables—for example relating to the
11 red, blue and green (RGB) components associated with the color parameter.
12 Alternatively, the color parameter may be expressed in terms of the Hue,
13 Saturation and Intensity (HIS). -Alternatively, any other color parameter may be
14 used, including parameters that provide a measure of internal reflectance and
15 translucency, or any other optical property of teeth. Thus, such a numerical entity
16 typically comprises a data set having a plurality of 4-dimensional arrays—(x,
17 y, z, c), wherein each array represents the x, y, z, geometrical coordinates, and
18 wherein c represents the color value, of a point on a surface within the intra-oral
19 cavity. -Any suitable means may be used to provide this numerical entity. -For
20 example, a three-dimensional surface scanner with color capabilities may be
21 used. Thus, advantageously, such a scanner makes use of confocal imaging for
22 providing an accurate three-dimensional representation of the target surface
23 within the intra-oral cavity. -Color values may then added to each data point of
24 this data set by obtaining a two-dimensional color image of the target surface,
25 and then mapping the color values of the two-dimensional image onto the three-
26 dimensional "image", for example as described in co-pending applications
27 assigned to the present assignee, [USSN U.S. Ser. No. 60/580,109](#), entitled
28 **"METHOD FOR PROVIDING DATA ASSOCIATED WITH THE**
29 **INTRAORAL CAVITY"**, and [USSN U.S. Ser. No. 60/580,108](#), entitled
30 **"METHOD AND APPARATUS FOR COLOR IMAGING A THREE-**
31 **DIMENSIONAL STRUCTURE"**. These references are incorporated herein in
32 their entirety by reference thereto.

33 [0095] While only a limited number of embodiments of the present invention
34 according to a first aspect are now described hereinbelow, it may be appreciated
35 that the method of the invention may be used for a very wide variety of
36 applications in which feedback data may be obtained for use in procedures
37 associated with the oral cavity.

38 [0096] There are a number of exemplary procedures for which the method 10 is
39 of particular utility. -In one such example, the procedure relates to the provision
40 of a prosthesis, such as a crown or bridge, for example, and inlays, such as caps,
41 for example, and any other artificial partial or complete denture. -In each case, an

1 area in the intra oral cavity needs to be prepared for receiving the crown, bridge
2 and so on.- In the case of crown prosthesis, one tooth site needs to be prepared,
3 while for a bridge prosthesis, two preparations need to be created, one at each of
4 the abutment teeth for anchoring -the bridge. -Inlays -require -a different type of
5 preparation at the tooth site.

6 [0097] Referring to ~~Fig~~FIG. 4, a virtual representation of such a crown, generally
7 designated 100, has an internal surface 120 and lower edge 130 that needs to be
8 very precisely defined and manufactured to match the preparation 80 and finish
9 line 84, respectively, in the intraoral cavity 200 of a patient. If the crown 100 is
10 to comprise a coping 160, the said internal surface 120 is that of the coping 160.

11 [0098] The crown 100, which may be formed from a plurality of layers,
12 preferably needs to have a natural looking appearance. Further, the dimensions
13 of the crown 100, in particular the definition of the external surface 140 depends
14 on external factors and needs to be such as to enable the crown 100 to fit between
15 the adjacent teeth A, B, and to provide proper occlusion with the teeth D of the
16 facing jaw (~~Fig~~FIG. 3).

17 [0099] At the very least, the external -surface -140 of the crown -is -such -as- to
18 provide certain critical linear dimensions that comply with at least one of the
19 target width or target height of a site or location on the jaw on which the crown
20 is to be fitted.- The target width may include the mesiodistal size of a tooth that
21 is being replaced by the crown 100, and may be defined such as to provide
22 adequate clearance between the crown 100 and adjacent teeth A, B, when the
23 crown 100 is fixed onto the corresponding preparation in the intraoral cavity. The
24 target height of the crown 100 may be defined such as to provide adequate
25 occlusion with the "working side" of the tooth and avoiding interfering contact
26 between the crown and teeth of the opposite jaw when the crown is fixed onto
27 the corresponding preparation 80 in the intraoral cavity.

28 [0100] An outer shape for the external surface 140 may be chosen in a number
29 of ways. -For example, if the original tooth that the crown 100 is replacing is still
30 available, and the outer surface thereof is of a reasonable form, this original tooth
31 may be scanned -and the 3D data of the surface obtained. -If necessary, this 3D
32 data may be considered as a starting point, and the final shape of the external
33 surface 140 is obtained by manipulating this data as required by the technician or
34 other user that is designing the surface 140. Alternatively, if the patient has a
35 reasonably healthy tooth on the same jaw but on the adjacent quadrant at a
36 position corresponding to where the crown is to be fitted, the 3D data of the
37 surface of this tooth is obtained. Optionally, this tooth may be scanned as
38 described herein to obtain the 3D spatial coordinates thereof, unless this data may
39 already be available from the 3D data of the oral cavity 200 stored in the
40 processor 52.- Typically, such 3D-data would need to be transformed to provide
41 a lateral inversion of the coordinates, suitable for a prosthesis in the other half of

1 the jaw. Alternatively, a suitable profile for surface 140 may be chosen and
2 obtained from a library 35 that comprises the 3D spatial profiles of shapes or
3 profiles of the outer surfaces of a plurality of crowns and teeth. If necessary the
4 relative size and shape of the surface 140 may be adjusted by the user to better
5 match the other teeth in the jaw. Then, the chosen surface is adjusted in any
6 suitable manner, either manually, automatically, interactively or in any other
7 manner, in order that the required target dimensions of surface 140 will fit within
8 a control volume that defines the maximum dimensions of the crown 100, as
9 required to conform to the space available in the intra oral cavity 200. In
10 particular, the control volume may be chosen such as to provide adequate
11 clearance between the crown and adjacent teeth, and adequate occlusion with the
12 opposite teeth, when the crown 100 is properly fixed onto the preparation.

13 [0101] The processor 52 also has suitable software to define the inner surface
14 120 according to predetermined parameters. -These parameters take into account
15 the geometries of the external surface of the preparation 80 including finish line
16 84, the spacing required between the coping (if one is to be used with the crown)
17 or the internal surface of the crown (if no coping is used) and the preparation to
18 accommodate the adhesive or cement that is used to provide the bond between
19 the two. The processor 52 may also comprise suitable software to provide the
20 external shape of such a coping 160, and thus provide a complete geometrical
21 representation or 3D data of the coping 160, digitally. The external surface of the
22 coping 160 may be defined in any number of ways. Typically, at least a majority
23 of the external surface of the stump 82 is displaced from the internal surface
24 thereof by a uniform amount to provide an approximately constant thickness
25 throughout. However, the thickness of the coping 160 may vary for a number of
26 reasons. For example, it may be necessary in some cases to provide a coping that
27 is stronger in some parts than in others, reflecting the activity that the crown 100
28 will be expected to engage in—as a molar, incisor, canine and so on.

29 [0102] The design of the external surface 140 and the internal surface 120 may
30 be executed by the processor 52 at the dental clinic, or alternatively at the service
31 center 23, or at the dental lab 26. If at the latter, and if use is made of a library of
32 3D spatial profiles of shapes or profiles of the outer surfaces of a plurality of
33 crowns -and teeth, then the dental lab 26 can make -use of library of the service
34 centre 23, via communications network 24. -Similarly, if the design is carried out
35 at the dental clinic, the processor 52 may also make use of the library of the
36 service centre 23, via communications network 24.- Alternatively, the system 50
37 may have its own digital library 35 of 3D spatial profiles of shapes or profiles of
38 the outer surfaces of a plurality of crowns and teeth, operatively connected to a
39 processor 52 or other computer, as illustrated in FigFIG. 2, which comprises
40 display 54 and user interface 59 such as a mouse and/or keyboard.

41 [0103] Referring to FigFIG. 4, in a first embodiment of the invention, the method 10
42 is adapted for providing feedback data regarding the definition of the finish line

1 84. In particular, it is desired to receive such feedback data referring to the quality and
2 clearness of the finish line 84, and optionally including ~~the~~ shoulder 85.

3 [0104] The finish line 84 may be of any type thereof, for example knife edge,
4 feather edge, chamfer, chamfer bevel, shoulder, shoulder bevel, and so on.
5 Alternatively, the finish line 84 may comprise a combination of different types
6 around the periphery of the preparation, for example part of the finish line for a
7 particular preparation may be knife edge, while another part may be feather edge.

8 [0105] Thus, having scanned the intraoral cavity ~~-200~~, in particular the target
9 zone T including the preparation 80, finish line 84 and (where appropriate)
10 shoulder 85, the processor 52 then manipulates the resulting numerical entity W
11 to identify the finish line 84. This may be done using any suitable algorithm. For
12 this purpose, it may be advantageous for the entity W to also include color
13 components for each surface point defined therein. The differentiation of dental
14 surface color between the hard tissues and the soft tissues may be helpful in
15 automatically defining the finish line, as described in the aforesaid co-pending
16 application entitled "METHOD FOR PROVIDING DATA ASSOCIATED
17 WITH THE INTRAORAL CAVITY"~~.-.~~.". Generally, the shoulder type (e.g.,
18 porcelain shoulder, metal collar and so on) should match and be suitable for the
19 prosthesis it is desired to implant at the dental site.

20 [0106] The geometry of the finish line 84 and optionally shoulder 85 may then
21 be analysed by the processor 52 according to predetermined rules, to establish
22 the relationship between the virtual finish line thus identified, and the function
23 which the finish line 84 and optionally shoulder ~~-85~~ is to play in the mounting of
24 the prosthesis to the preparation. ~~Such~~ rules may comprise, for example one or
25 more of the following~~:-~~—

26 [0107] (a) the finish line is continuous about the full periphery of the preparation;

27 [0108] (b) the thickness of the shoulder 85, i.e., the radial dimension between the
28 edge of the finish line 84 and the preparation 80, lies within a predetermined
29 range;

30 [0109] (c) the thickness of the shoulder 85 is substantially uniform along the
31 periphery thereof;

32 [0110] (d) there are no abrupt changes in slope of the finish line 84 along the
33 periphery thereof;

34 ~~The~~[0111] (e) the type of prosthesis to be implanted.

35 [0112] It may then be established by the processor 52 whether the finish line 84
36 and/or shoulder 85 comply with such rules, and can then provide feedback data

1 to the user. -Such feedback data may take many different forms.- For example, in
2 the positive, i.e., that the finish line, for example, is adequate, the processor 52
3 may be adapted to transmit a signal via display 54.- Such a signal may be an audio
4 or visual signal, such as for example the sound of a bell 51 of a particular
5 frequency or a colored light source 53 such as a green light, which may light up
6 and remain lit, or may blink, or the signal may be more complex, such as for
7 example a message on a screen stating that the finish line is suitable.

8 [\[0113\]](#) In the negative, i.e., in cases where the finish line is not suitable according
9 to the aforesaid rules, for example, the [feedback data may first advise where the](#)
10 [finish line is deficient. For example, if referring to the first rule listed above, there](#)
11 [is a step or discontinuity along the periphery of the finish line, the location and](#)
12 [extent of the same may be alerted to the user. For this purpose, a 3D](#)
13 [representation of the preparation site may be displayed, with the part of the finish](#)
14 [line in question highlighted in a different color to the rest of the finish line and/or](#)
15 [of the preparation and so on. Similarly, if the practitioner is attempting to create](#)
16 [a feather edge finish line \(and this desire should be first inputted to the system 50](#)
17 [in an appropriate manner\), deviations in geometry from this type of finish line—](#)
18 [for example, part of the finish line is chamfered—may also be alerted to the user,](#)
19 [for example by suitably annotating a graphical image of the preparation with](#)
20 [colors and so on.](#)

21 [\[0114\]](#) This also enables the practitioner to check whether the finish line is of the
22 [type he/she wants, or at least how close it is to this ideal.](#)

23 [\[0115\]](#) Further, the feed back data may [also](#) comprise indications to the user as
24 to where to modify the finish line 84 or shoulder 85 to achieve better results. In
25 this context, an image of the numerical entity may be displayed in the display 54,
26 with the finish line 84 and optionally also the shoulder 85 highlighted thereon.
27 Then, the zones of the finish line that require further work may be contrasted with
28 respect to the finish line 84 and/or the shoulder 85, for example by coloring such
29 zones in a different color to the rest of the image. Optionally, zones may be
30 colored differently according to the type of work required. -For example, zones
31 deficient with respect to rule (a) above may be colored in red, while those
32 deficient with respect to rule (b) are colored in blue, and so on.

33 [\[0116\]](#) Thus, suggested- changes to the finish line may be displayed on a two-
34 dimensional representation of said dental preparation, via display 54, wherein
35 said new finish line geometry may be superimposed over said representation.

36 [\[0117\]](#) Modification of the finish line 84 and/or shoulder 85 typically requires a
37 material removing operation, and after doing so, the intra oral cavity 200 may be
38 re-scanned to provide a second numerical entity.- The second numerical entity,
39 in particular the portions thereof relating to the finish line 84 or shoulder 85, may
40 then be analysed as before to determine whether the finish line 84 or shoulder 85

1 are acceptable according to the predetermined rules, and without reference to the
2 original entity W. -Alternatively, the second numerical entity may be compared
3 with the original entity W, and any deviations between the two entities may be
4 highlighted in display 54 in order to facilitate the next cycle of modification to
5 the finish line.

6 [0118] Alternatively, the processor 52 may simply display the numerical entity
7 and the highlighted finish line 84 and/or shoulder 85 on display 54, and this may
8 at times represent sufficient feedback data for enabling the user to inspect the
9 image thus created and to determine in a subjective manner whether the finish
10 line and/or the shoulder are suitable or not. -In all cases, the processor 52 is
11 suitably programmed to enable the numerical entities to be viewed at any suitable
12 angle and ~~let~~/or magnification.

13 [0119] Optionally, the numerical entity W may be transmitted to one or more
14 remote locations, such as for example a service center of dental lab 26, to be
15 analysed there by a computer (not shown), or by a skilled technician or another
16 user. -The computer or skilled technician at the dental lab 26 may then
17 communicate the results of the analysis to the original user via the
18 communication network 24, or a different communication network, for example
19 via cellular phone. These results may be in the form of numerical information
20 that may be displayed, for example, or verbal instructions- on how to proceed.

21 [0120] In a second embodiment of the invention, the method 10 is adapted for
22 providing feedback data regarding the suitability of the preparation to accept a
23 prosthesis of a predetermined type. Alternatively, the method 10 according to this
24 embodiment is adapted for providing feed back data regarding the type of
25 prosthesis that may be suitable for use with the preparation 80. In particular, it is
26 desired to receive such feedback data referring to at least one predetermined
27 dimension, such as for example a characteristic thickness of a prosthesis with
28 respect to the geometry of the preparation and the adjacent teeth A and B.

29 [0121] Thus, having scanned the intraoral cavity 200, in particular the target zone
30 including the preparation 80 and adjacent teeth A and B, as described above,
31 mutatis mutandis, the processor 52 then manipulates the resulting numerical
32 entity W to identify the external surface 125 of the stump 82 of preparation 80
33 (~~Fig~~(FIG. 4). This may be done, for example, by first identifying the finish line
34 and optionally shoulder, for example as described above, and then isolating the
35 coping surface enclosed by the perimeter defined by the finish line and/or
36 shoulder. Then, an external crown surface 140 is chosen or designed for the
37 crown, such as to fit properly in the space between the adjacent teeth A, B, as
38 described hereinbefore. Then the relationship between the external surface 125
39 (which is typically closely correlated to the internal surface 120 of the crown
40 100) or of the internal surface 120, and the external surface 140 may then be
41 analysed by the processor 52 according to predetermined rules. This serves to

1 establish the relationship between the thickness (referred to collectively herein
2 as t) of the walls of crown 100, and the material from which the real crown (based
3 on such a virtual crown 100) is to be produced as a function of the external surface
4 140 of the stump. Typically, such a relationship is dependent on the material from
5 which the real crown is to be made. Referring to ~~Fig~~FIG. 5, such rules may
6 comprise, for example one or more of the following:-:—

7 [0122] the occlusal-gingival thickness t1 between the apex 121 of the outer
8 surface 125 (or of the inner surface 120) and the apex 141 of the crown 100;

9 [0123] the mesial-distal thicknesses t2, t4, between the outer surface 125 (or of
10 the inner surface 120) and the external surface 140 of the crown 100 at various
11 occlusal-gingival distances;

12 [0124] the labial-lingual thickness t3 t5, between the outer surface 125 (or of the
13 inner surface 120) and the external surface 140 of the crown 100 at various
14 occlusal-gingival distances. The suitability of the stump 82 itself may also be
15 analysed by suitable rules, to determine, for example, if it has sufficient
16 mechanical strength to support the crown or other prosthesis thereon. For
17 example, the volume of the stump and/or other critical thicknesses thereof may
18 be determined by the processor 52. In another example, the stump may be
19 analysed to determine whether there are any discontinuities or undercuts that
20 would provide insertion path problems, and these may be highlighted and brought
21 to the attention of the user.

22 [0125] It may then be established by the processor 52 whether the geometry of
23 the stump 82 complies with such rules, and can then provide suitable feedback
24 data to the user. -Such feedback data may take many different forms. For
25 example, in the positive, i.e., that the stump 82 is adequate, the processor may be
26 adapted to send a corresponding signal to display 54. Such a signal may be an
27 audio or visual signal, such as for example the sound of a bell of a particular
28 frequency or a colored light such as a green light, which may light up and remain
29 lit, or may blink, or the signal may be more complex, such as a message on a
30 screen stating that the finish line is suitable. -Of course such a signal should be
31 different from that provided with respect to the first embodiment described
32 above, when both are available to the user.

33 [0126] In the negative, i.e., in cases where the stump 82 is not suitable according
34 to the aforesaid rules, for example, the feed back data may comprise indications
35 to the user as follows:-:—

36 [0127] To advise the user as to where to modify the stump 82 to achieve better
37 results. In this context, an image of the numerical entity W^z may be displayed in
38 the display 54, with the stump highlighted thereon. Then, the zones of the stump
39 that require further work may be contrasted with respect to the stump 82, for

1 example by coloring such zones in a different color. -Optionally, zones may be
2 colored differently according to the type of work required. For example, zones
3 deficient with respect to rule (a) above may be colored in red, while those
4 deficient with respect to rule (b) are colored in blue, and so on.

5 [\[0128\]](#) To advise the user that the stump 82, as is, provides a crown thickness
6 that is too thick, and that therefore a filing composition needs to be added at least
7 to some portions of the stump. -The display 54 can then show where to add the
8 composition, and when this is done, the intra oral cavity 200 may be rescanned
9 to determine how and where to modify the stump. -Alternatively, if the stump 84
10 is totally unsuitable the processor 52 provides a suitable signal to be displayed
11 by display 54, and it may be necessary to replace the stump 84 with a pivot, core
12 or post.

13 [\[0129\]](#) To advise the user that although the stump is unsuitable for use with a
14 prosthesis made from one material (pre-defined), it may be suitable if the stump
15 is made from a different material. For example, a stump made from PFM
16 (Porcelain Fused Metal) can be thinner than a whole ceramic crown. -Therefore,
17 if a PFM crown was originally decided upon, it may be advisable to switch to a
18 whole ceramic crown, and the processor 52 can determine whether the stump 82
19 would be suitable for such a crown.

20 [\[0130\]](#) Optionally, a contour or occlusion map of the target zone T may be
21 provided, for example as disclosed in U.S. Pat. No. 6,334,853 and EP 0984739,
22 the contents of which are incorporated in their entirety herein, and which
23 references are also assigned to the present assignee. Such a dental occlusion map
24 is indicative of distances between opposite regions on facing surfaces of opposite
25 dental surfaces of the upper jaws of the mouth, for example the preparation 80
26 and the opposed tooth D. The occlusion map may be created by manipulating the
27 entity W so as to determine the distances between opposite regions on the
28 opposite dental surfaces of the upper and lower jaws of the target zone T, and
29 then setting up a correspondence between the determined distances and regions
30 on a mapping surface. Accordingly, it is possible to provide, for example, a
31 colored contour map showing the occlusion distances with respect to the
32 preparation 80, for example, and from this determine whether and what parts of
33 the preparation require further work, or whether there is preparation adequacy or
34 preparation clearance regarding the worked target zone T. In particular, the
35 occlusion map may inform the practitioner whether the preparation is adequate
36 for the type of crown that he/she was intending to use, or what type of crown may
37 be used, if any, with the preparation in its present condition. For example, a PFM
38 crown typically requires greater occlusion between the preparation and opposed
39 tooth (due the requirement for greater material thickness) than an all-ceramic
40 crown, which in turn needs more clearance than a metal crown.

1 [\[0131\]](#) Optionally, the system 50 may be configured for automatically advising
2 whether, for a given desired type of prosthesis (for example ceramic, PFM, metal
3 and so on) the preparation is adequate, or conversely, given the current state of
4 the preparation, what is the optimal type of prosthesis that is best suited for it, or
5 if in fact the preparation is still unsuitable for receiving any prosthesis in its
6 current state. This feature allows the practitioner to check whether the preparation
7 is of the type that he/she wants. Further, the system 50 may be adapted to provide
8 the practitioner with indications on how to further work the preparation so that it
9 is optimally suited to the type of prosthesis that it is desired to be used therewith.
10 For example, the contour map and/or a graphical representation of the target zone
11 T may be annotated, for example by suitably coloring corresponding areas
12 therein, to indicate the corresponding areas of the preparation where more
13 material needs to be removed, for example, fo as to accommodate a particular
14 type of prosthesis.

15 [\[0132\]](#) Modification of the stump 82 typically requires a material removing
16 operation, and after doing so, the intra oral cavity may be re-scanned to provide
17 a second numerical entity. The second numerical entity, in particular the portions
18 thereof -relating to the -stump -82, -may -then -be analysed -as before -to determine
19 whether the geometry of the stump 82 is acceptable according to the
20 predetermined rules, and without reference to the original entity. -Alternatively,
21 such a second numerical entity may be compared with the original entity, and
22 any deviations between the two may be highlighted in display 54 in order to
23 facilitate the next cycle of modification to the stump 82.

24 [\[0133\]](#) Alternatively, the processor 52 may simply display the numerical entity
25 and the highlighted stump 82 on display 54, and this may at times represent
26 sufficient feedback for enabling the user to inspect the image thus created and to
27 determine in a subjective manner whether the stump 82 is suitable or not.

28 [\[0134\]](#) Optionally, the numerical entity may be transmitted to a remote location
29 such as for example a dental lab 26, to be analysed there by a computer (not
30 shown), or by a skilled technician or another user. The computer or skilled
31 technician may then communicate the results of the analysis to the original user
32 via the communication network 24 to provide feedback data to the original user
33 regarding the stump 82.

34 [\[0135\]](#) In a third embodiment, the method 10 is adapted for providing the user
35 with feed back data regarding the insertion path with respect to a preparation or
36 preparations that is/are being created at a dental site for receiving a prosthesis
37 such as a crown or bridge.

38 [\[0136\]](#) Taking the relatively simpler case of a crown first, the method 10
39 comprises the first step of providing a numerical entity of the intraoral cavity,
40 including in particular the part of the cavity comprising the preparation.

1 Optionally, and preferably, the numerical entity also comprises 3D data of the
2 teeth A, B adjacent to the preparation 80. -The 3D numerical entity may be
3 provided in a similar manner to that described herein, mutatis mutandis.

4 [0137] In the next step, it is desired to determine whether the preparation is
5 suitable to receive a crown prosthesis. - One aspect of such a determination is to
6 advise the user whether the preparation 80 provides an adequate insertion path
7 for the crown. -In this connection, the processor 52 first identifies from the entity
8 W the external surface 125 corresponding to the part of the preparation onto
9 which -the crown is to be mounted (~~Fig.~~ FIG. 4), and suitable algorithms for this
10 purpose may be created, possibly as described above for the second embodiment,
11 mutatis mutandis. Then, a virtual model 100 of the crown is either created by the
12 processor 52, or input thereto by the user or a third party such as service center
13 or dental clinic 26, for example. -Alternatively, this process may be commenced
14 with a virtual model of the coping 160. - The crown model 100 must be sized such
15 as to fit between the adjacent teeth A, B, and thus be in abutting contact therewith
16 when properly mounted onto the preparation 80. The crown model 100 may be a
17 full 3D model, comprising an external 3D surface, or may simply comprise key
18 dimensional parameters, such as for example the mesiodistal width of the tooth
19 between the adjacent teeth A, B. -The crown model 100 also comprises a full 3D
20 representation of the internal 3D surface 125, which ~~is typically~~ may be
21 substantially complementary to the external surface 120 of the preparation,
22 optionally taking into account an adhesive layer thickness that is to be introduced
23 between the preparation and the said internal surface. The processor 52 then
24 calculates the insertion path for the internal surface 120 of the virtual crown 100,
25 and then checks whether this path is also suitable for the external surface 140 of
26 the virtual crown 100. Alternatively, the processor 52 calculates the insertion
27 path for the external surface 140 of the virtual crown 100, and then checks
28 whether this path is also suitable for the internal surface 120 of the virtual crown
29 100. - Ideally, the insertion path of the virtual crown 100 as a whole should enable
30 the same to be maneuvered into position with respect to the preparation without
31 colliding with or unduly interfering with other dental surfaces at or in the vicinity
32 of the preparation.

33 [0138] For example, referring to ~~Fig~~ FIG. 6, the geometry of the preparation 82
34 approximates a right frustro-conical cone, and the central axis 101 thereof is more
35 or less perpendicular to the occlusal plane OP. -In this example, the insertion path
36 IP₁ of the internal surface constrains the external surface 140 to path IP₂, which
37 enables the external surface of the virtual crown 100 to be guided to the mounted
38 position on the preparation without interfering or colliding with other parts of the
39 dentition. In the Example illustrated in ~~Fig~~ FIG. 7, the geometry of the preparation
40 is approximately that of a slanting frustro-convex cone, wherein the central axis
41 101 thereof is at a minimum angle α to the occlusal plane. In this example, the
42 insertion path ~~IP₁~~ IP₁' of the internal surface constrains the external surface to

1 path ~~IP₂'~~IP₂', which would result in the external surface 140 of the virtual crown
2 100 colliding with adjacent tooth B, and it would be impossible to fit a real crown
3 corresponding to the virtual crown 100 with such a preparation geometry.
4 Similarly, in the example illustrated in ~~Fig~~FIG. 8, the insertion path IP₂"_" of the
5 external surface constrains the internal surface to path IP₁"_" which would result
6 in an undercut part 105 of the virtual crown 100 colliding with the stump 82, and
7 it would be impossible to fit a real crown corresponding to the virtual crown 100
8 with such a preparation geometry. Optionally, the overhanging portion 88 and/or
9 undercut part 105 may be highlighted by suitably coloring the corresponding
10 zone in a graphical representation of the target zone T.

11 [0139] Optionally, and particularly when the geometry of the preparation is
12 similar to that shown in ~~Fig~~FIG. 8, another type of plan may be considered in
13 place of or in conjunction with a material removal plan. -Having a slanting
14 frusto-conical profile for the preparation typically requires material to be
15 removed until a substantial part of the overhanging portion 88 of the stump 82 is
16 removed. Such a procedure may result in over-weakening of the stump 82.
17 Instead, and according to the invention, it is possible to create an internal surface
18 of the virtual crown 100 that is not fully correlated to the external surface 125 of
19 the stump 82, but only partially correlated thereto, along areas thereof that are
20 non-overlapping in the direction of the insertion path, e.g., in which there is no
21 undercuts. -However, regarding the overlapping areas of the stump 82, i.e., the
22 part of the stump overshadowed by the overhanging portion 88 in the direction
23 of the insertion path, it is instead possible to create a portion of the internal
24 surface 120 of the crown 100 corresponding thereto that is designed not to
25 interfere or in any way collide with the overlapping areas of the stump 82 when
26 the same is installed via the appropriate insertion path. -The overlapping areas or
27 zones refer to portions of the crown 100 which would need to be removed to
28 prevent collision of the internal surface 120 of the crown 100 with the stump 82.
29 However, this would leave a substantial cavity between the part of the preparation
30 and the corresponding part of the internal surface of the crown. This cavity is
31 preferably filled by manufacturing an auxiliary prosthesis 121 having the shape
32 of this cavity, and then bonding the auxiliary prosthesis to the stump 82, as
33 illustrated in ~~Fig~~FIG. 9.- Alternatively, suitable cement or filler material may be
34 bonded to the overlapping areas, and these areas then subjected to a material
35 removal operation to provide the desired result. -Particularly in such a case, but
36 also for the previous case in which an auxiliary prosthesis for the cavity is bonded
37 in place, the modified stump may be scanned to check the new geometry of the
38 modified preparation.

39 [0140] The insertion paths for prostheses are preferably substantially rectilinear,
40 to ease the user's task in duplicating the path when maneuvering the real crown
41 onto the preparation. However, it is also possible to calculate insertion paths in
42 which there is one or more change in the direction thereof, and/or in which the

1 crown (i.e., first the virtual crown, and then the real crown) can be rotated about
2 one or more of three orthogonal axes.

3 [\[0141\]](#) In some cases, there may be a plurality of possible insertion paths for the
4 internal surface, or particularly for the external surface, and the processor 52 can
5 attempt to match such paths.

6 [\[0142\]](#) When more than one matching pair of internal and external insertion paths
7 match, the various alternatives may be presented to the user by means of display
8 54.— Additionally or alternatively, the processor 52 may determine which
9 matching pair is optimal, based on rules, or may present the different options in
10 ascending or descending order of preference, according to any predetermined
11 criteria, such as for example requiring a minimum number of direction or
12 rotational changes in the path.

13 [\[0143\]](#) Preferably, display 54 displays an image of the dental site 200, together
14 with the predicted insertion path of the internal surface and that of the external
15 surface constrained thereby, or vice versa, and the processor 52 also provides the
16 necessary input to the display 54 to highlight any part of the adjacent teeth A, B
17 and/or preparation 80 that interfere with the particular insertion path.
18 Alternatively, or additionally, when a situation such as those illustrated in ~~Figs.~~
19 [FIGS. 7, 8](#) arises, the processor 52 may generate a suitable warning signal, audio
20 and/or visual, warning the user that the insertion path for the current preparation
21 geometry is not suitable, and that remedial action is required.

22 ~~h~~[\[0144\]](#) [In](#) particular, the processor may be programmed to determine possible
23 plans for removing additional dental material from the preparation 80 to enable
24 a suitable insertion path to be provided. —This may be accomplished in a number
25 of ways.— For example, the processor may determine a particular suitable path for
26 the external surface 140 of the virtual crown 100, for example the simplest and
27 most —direct path, and then identify the zones of the preparation which would
28 need to be removed to prevent collision of the internal surface of the crown
29 therewith, herein referred to as the ~~“overlapping zones”~~. However, since the
30 internal surface of the crown is a function of the external geometry of the
31 preparation, this procedure is preferably accomplished in a reiterative manner.
32 That is, once the processor 52 identifies the overlapping zones, and removes, in
33 a virtual manner, a small part of the overlapping zone. —The amount of removal
34 may be preset by the user, and any increment is possible. —Preferably, such an
35 amount may be correlated to the minimum removal of material that is normally
36 possible in an analogous real life situation. —The processor 52 then adjusts the
37 geometry of the internal surface of the virtual crown 100 to take into account the
38 new preparation geometry, and examines the insertion path of the inner surface
39 with respect to the new preparation geometry. —If there is still interference
40 between the internal surface and the preparation, more material is removed in the
41 virtual sense, the geometry of the internal surface 120 adjusted, and the new

1 internal surface insertion path re-examined for collision. -Additional cycles may
2 be performed until the external surface 125 of the preparation is suitably modified
3 to be compatible with the insertion path.

4 [0145] In some cases, the result of such a virtual procedure may not be acceptable
5 for a real crown, for example too much material needs to be removed, and this
6 would provide a much weakened stump 82, according to pre-known rules.

7 [0146] Accordingly, the virtual procedure may be repeated, each time starting
8 with a different insertion path for the external surface 140, until a reasonable
9 preparation geometry is arrived at that is compatible with the external insertion
10 path and that is also reasonable according to such rules.

11 [0147] Additionally or alternatively, other virtual procedures for modifying the
12 geometry of the preparation may be accomplished. -For example, such a
13 procedure may involve a combination of reducing the overhanging portion, and
14 adding an auxiliary prosthesis 121.

15 [0148] However, it may be possible, that, given the condition of the preparation
16 and the topology of the adjacent dental surfaces, no reasonable modified
17 preparation geometry can be found. -Such an outcome is also feed back data that
18 is presented to the user.

19 [0149] Thus, the geometry of such a preparation is optionally, and preferably,
20 analysed according to such rules, and a suitable warning provided to the user
21 when the geometry of preparation is inherently unsuitable. -The warning may be
22 audio/and or visual, and may be simple, such as a bip or series of bips, or a
23 flashing light or lights, or may be complex for example an audio or a visual
24 message, created by the processor 52, actually describing the reason for the
25 warning. For example, such a warning could comprise an audio and/or visual
26 message stating "Warning! -The stump geometry is defective!". Where such
27 warnings are audio, the display 54 preferably comprises optional ear phone or
28 headphones that enable the user to hear the message, but not the patient, since
29 such a message may cause unnecessary alarm or anxiety to the patient. Such
30 earphones or headphones may be operatively connected to the processor 52 via
31 suitable cables, or via remote link such as an infrared transmitter/receiver system,
32 or may be integrated into display 54, for example. -A similar analysis and
33 warning, where necessary, may be provided at the beginning of the exercise, and
34 thus alert the user that the original preparation is unsuitable, preferably listing the
35 reasons. -In either case, where the present or virtually modified preparation is
36 inherently unsuitable, the processor 52 may be programmed to provide
37 recommendations, such as to remove the preparation completely, and to replace
38 it with a pivot core or post.

1 [0150] On the other hand, if the processor 52 determines one or more material
2 removal plans for the preparation 80 which theoretically yield a reasonable
3 preparation geometry compatible with a possible insertion path, the different
4 plans may be displayed to the user, who can then choose one plan. -Preferably,
5 each plan comprises displaying the overlapping areas of the preparation that
6 require to be modified, and the nature of the insertion path that is required for
7 maneuvering the prosthesis into place. -Both factors need to be weighed by the
8 user before deciding how to proceed. -The aforementioned overlapping areas can
9 be displayed over an image of the dentition (provided from the 3D entity W), and
10 preferably such an image can be manipulated, for example on a screen, to enable
11 the user to fully study the plan.

12 [0151] Once a preparation modification plan is chosen, the user can modify the
13 real preparation area in the intraoral cavity as closely as possible to the
14 overlapping areas marked in the virtual model (3D numerical entity). -At any
15 point in the material removal procedure, the user may re-scan the intraoral cavity
16 to check on the progress. -For this purpose, the processor 52 may be further
17 programmed to effectively overlay the new numerical entity over the original
18 entity, in particular to highlight the differences in geometry between the areas in
19 which actual material removal has occurred and the overlapping areas which
20 were earmarked by the procedure for material removal. -Further, the processor
21 52 may be further programmed to detect with respect to these entities where
22 material still needs to be removed, and where too much material has been
23 removed. -This may be displayed in display 54 on an image of the intraoral cavity,
24 and the under-modified areas may be displayed in one color, say green, and then
25 over modified areas may be displayed in a different color, say red. Preferably,
26 should the presence of over-modified areas be detected, i.e., areas where too
27 much material has been removed, the processor 52 recalculates the insertion path
28 and advises the user whether the original modification plan is still possible, or
29 whether the excess material removal requires a modification of the plan. -Such a
30 modification in the plan may be determined in a similar manner to the original
31 plan, as described above, mutatis mutandis. Of course, it is also possible that the
32 over modified areas have now rendered the preparation unsuitable according to
33 the aforementioned rules, and the preparation must be replaced with an artificial
34 pivot, core or post.

35 [0152] The methodology described above for an insertion path has been
36 described with respect to a crown that is directly bonded onto a preparation, such
37 as for example a metallic crown. -For other types of crowns (for example ceramic
38 crowns) that require a coping, the method is modified to take account of the
39 coping geometry. -Thus, the external surface 125 of the stump is displaced
40 outwardly to create a virtual representation of a constant thickness coping.
41 Alternatively, any other suitable means may be used to define the coping external
42 surface. -The internal surface 120 of the crown is then defined with respect to the

1 external surface of the coping, and is typically complementary thereto, optionally
2 taking into account a thin layer of adhesive.

3 [0153] The above method may also be adapted for the purpose of providing a
4 suitable insertion path for the coping itself, mutatis mutandis.

5 [0154] The methodology described above for the insertion path of a crown may
6 be used, mutatis mutandis, for any dental restoration or dental prosthesis. -In the
7 case of a bridge, in particular, preparations have to be created in the abutment
8 teeth on either side of the missing tooth, and the geometries of both preparations
9 need to be considered simultaneously in relation to the insertion path of the bridge
10 as a unit. -Thus, referring to ~~Fig~~FIG. 10, the preparation geometries illustrated
11 allow the bridge 150 to be mounted via an insertion path 151, while the
12 preparation geometries illustrated in ~~Fig~~FIG. 11 do not provide a common
13 insertion path for the bridge ~~150~~150'. Thus, in order for the insertion path for
14 the bridge 150 to be suitable, the individual insertion paths for the two
15 preparations must be parallel, and moreover, such an insertion path must be such
16 as to avoid collision of the bridge with the adjacent teeth ~~A'A'~~ and ~~B'-B'~~. In the
17 analysis and design of modification plans for such cases, the processor 52 may
18 provide one or more plans for the modification of one or both of the preparations,
19 substantially as described above for a crown, mutatis mutandis. -While the cases
20 illustrated in ~~Figs~~FIGS. 10 and 11 relate to a 3-unit bridge, the foregoing relates,
21 mutatis mutandis, to a multiple unit bridge as well.

22 [0155] The ~~Fig~~FIG. 12 illustrates a method ~~10'10'~~ for providing feedback data
23 useful in at least one prosthodontic procedure associated with the intra oral
24 cavity, in accordance with a second aspect of the invention. -In the second aspect
25 of the invention, the method is concerned with ensuring that numerical entity W
26 sufficiently defines the area of interest of the intraoral cavity. -The method ~~10'10'~~
27 comprises the following basic steps:

28 [0156] Step ~~11':11'~~ providing at least one numerical entity representative of the
29 three-dimensional surface geometry of at least part of the intra-oral cavity from
30 which dental material has been removed.

31 [0157] Step ~~12':12'~~ manipulating said entity to determine sufficiency of
32 definition of said numerical entity in step ~~11'11'~~ with respect to a first said
33 procedure, and providing sufficiency data representative of said sufficiency.

34 [0158] Step ~~13':13'~~ determining at least one relationship between said
35 sufficiency data and said first procedure.

36 [0159] Step ~~14':14'~~ generating feedback data representative of said at least one
37 relationship.

1 [0160] Preferably, steps 11' to 14' are carried out in a relatively short space
2 of time, more preferably in real time or close thereto.

3 [0161] For all embodiments, the first step 11' of the method according to the
4 present invention relates to providing at least one numerical entity that is
5 representative of the three-dimensional surface. This step is carried in a similar
6 manner to step 11 of FIG. 1, as described above, mutatis mutandis.

7 [0162] Thus in step 11', scanner 32 of system 50 (FIG. 2) scans the area
8 of interest of the intraoral cavity and a numerical entity corresponding to the
9 surface scanned is created by processor 52 and optionally displayed by display
10 54. As with the first aspect of the invention, the data from the scanner may be
11 transmitted to a dental clinic 23, service centre 26, or consultancy centre 27, inter
12 alia, for creation of the numerical entity, which is then transmitted to the
13 processor 52.

14 [0163] In step 12', the processor 52 (or indeed another computer in the
15 aforesaid dental clinic 23, service centre 26, or consultancy centre 27, inter alia)
16 analyses the numerical entity to determine the sufficiency of definition of the
17 numerical entity. The numerical entity may be obtained in a single scan, or
18 alternatively, the numerical entity is originally created by taking multiple scans
19 of the target area, and stitching the numerical entities thus obtained together. In
20 any case, the processor 52 first checks whether the numerical entity lacks surface
21 data in any particular part thereof. Such a lack of data may be due to the user not
22 passing the scanner over the full zone to be scanned, for example, or by taking
23 multiple scan in which there is insufficient overlap, for example.

24 [0164] When multiple scan are employed, then, in step 11', the scanner 31
25 may be used for obtaining high resolution numerical sub-entities representative
26 of the surface topography within the intra-oral cavity. Accordingly, different
27 zones of the intraoral cavity are sequentially scanned with scanner 31 to provide
28 the corresponding sub entities. Some of these zones typically partially overlap
29 with all the other zones, while other zones may only overlap with one or two
30 other zones, and thus theoretically the corresponding sub-entities should have a
31 portion of their data identical to one another within the overlap zone. However,
32 since the scanner itself moves in orientation and position from scan to scan, the
33 coordinates relating to these overlap zones will usually vary between adjacent
34 scans, even though they relate to the same spatial feature. Nevertheless, by
35 identifying the overlap zone within the entities, the spatial relationship between
36 the entities may be established, and the various entities stitched together or
37 combined to form a global numerical entity that comprises the full geometry and
38 color representation of the target zone. The larger the overlap zone, the greater
39 the accuracy with which the different zones may be synchronized or stitched
40 together spatially. Where the sub entities include color data of the intraoral cavity
41 200, the actual stitching technique may applied to data points corresponding to

1 the hard tissues therein, which have a different color to the soft tissues such as
2 gums, for example as described in the aforesaid co-pending application entitled
3 "METHOD FOR PROVIDING DATA ASSOCIATED WITH THE
4 INTRAORAL CAVITY".

5 [0165] The zones that are scanned should preferably together fully span the target
6 zone T of interest, however it sometimes happens that a part of the target zone is
7 missed out, and thus after the stitching procedure is completed, the global
8 numerical entity thus formed still lacks surface data in some areas. -According to
9 the invention, such areas are identified in steps 12'12' and 13'13' by the processor
10 52 which determines that the density of data points in some parts of the entity is
11 below a predetermined value, indicative of a lack of data thereat, for example.

12 [0166] Additionally or alternatively, having provided to the processor 52 the type
13 of procedure for which the numerical entity is required, the processor can analyse
14 the numerical entity in a different manner to determine whether it is sufficiently
15 defined for this purpose. For example, having found quantitatively there is
16 sufficient data, it is now necessary to determine if qualitatively the data is
17 sufficient.

18 [0167] For example, if the numerical entity is to be used in the context of a crown
19 prosthesis, for example as described above for the first aspect of the invention, it
20 is important for the finish line to be well defined. - Sometimes, parts of the finish
21 line may be defined on a dental surface that is close to orthogonal with respect to
22 the occlusal plane. If a confocal-type scanner is used at 31 for providing the
23 surface data for this part of finish line, it is possible for the accuracy of definition
24 of the finish line to be diminished the closer to parallel the output face of the
25 scanner is with respect to the occlusal plane. -Greater accuracy could be obtained
26 in the scanner is turned to face the aforesaid dental surface close to face-on rather
27 than close to edge-on. Accordingly, the processor 52 may determine whether the
28 definition of the finish line is sufficiently good, and this -may be done by
29 comparing the orientation of the scanner 32 with respect to the aforesaid dental
30 surface, according to preset criteria, for example. -Thus, in step 13',13', the
31 processor 52 determines whether data is missing, or whether the accuracy of the
32 data of the numerical entity is insufficient.

33 [0168] In step 14',14', feedback data is generated to alert the user as to how to
34 correct for the insufficiency of definition. -For example, in the case where some
35 surface areas of the entity are missing, the processor 52 first identifies the missing
36 areas for the user, and then may compute the best angle and position for the
37 scanner 31 to scan the intraoral cavity such as to provide the missing surface data.
38 This information may be provided by display 54, for example by providing a
39 graphical image of the entity, with the deficient areas marked hereon, and then
40 arrows or markers with respect thereto showing the desired position of the
41 scanner 31. -Of course, it may be that more than one scan is required to make up

1 for the missing data, and the processor provides the required feedback data to
2 deal with each scan.

3 [0169] Similarly, in the case where some surface areas of the entity require better
4 definition, the processor 52 may compute the best angle and position for the
5 scanner 31 to scan the intraoral cavity such as to provide better definition of those
6 areas. - This information may also be provided by display 54, for example by
7 providing a graphical image of the entity, and then arrows or markers with respect
8 thereto showing the desired position of the scanner 31. - As before, more than one
9 scan may be required to provide the higher accuracy data, and the processor
10 provides the required feedback data to deal with each scan. - Other parts requiring
11 special definition may include, for example, undercut zones of the preparation.

12 [0170] Furthermore, the processor may be programmed to alert the user when the
13 entity is sufficiently well defined for the purpose for which it is needed. - In such
14 a case, the feedback data is designed to alert the user that the scan is complete,
15 and may comprise a distinct visual or audio signal, similar but distinguishable
16 from other audio/visual signals provided by display 54, as described herein,
17 mutatis mutandis.

18 [0171] It should be noted that the method ~~10~~ 10' according to the second aspect
19 of the invention may be carried out in step 11 (~~Fig. 1~~ FIG. 1) of the first aspect of
20 the invention, such as to ensure that the entity provided in step 11 is sufficient
21 for steps ~~12~~ 12 to 14 thereof.

22 [0172] Thus, in the second aspect of the invention, the feedback data may
23 essentially be used to facilitate the acquisition of data that may be used to
24 construct the numerical entity for subsequent use, for example according to the
25 first aspect of the invention.

26 [0173] According to the first and second aspects of the invention, the entity
27 obtained by scanning via scanner 31 is displayed in real time via display 54, and
28 when the scanning is complete and acceptable, feedback data is provided alerting
29 the user to this fact.

30 [0174] Further, the present invention, according to the first and second aspects
31 thereof, may be used solely to obtain verification that a particular preparation is
32 in a suitable condition for implanting a prosthesis.

33 [0175] Further, the analysis of the scanned data, whether locally or at a remote
34 site such as for example the service centers 23, dental labs 26, and so on, typically
35 via suitable algorithms, may also use the following parameters: the type of
36 restoration required; patient parameters—age, sex, origin, dental condition
37 (implants in the scanned area, root canals, soft tissue condition, and so on),
38 budget for the procedure, and so on.

1 [0176] In the third aspect of the invention, the feedback data is essentially used
2 in an interactive manner together with a material removing process to facilitate
3 the performance of a procedure with respect to the intraoral cavity.

4 [0177] For example, the process for removing dental material to create the
5 preparation may be effected in a number of stages, at the end of each material
6 removing stage the preparation area being scanned and displayed in real time to
7 guide the dental practitioner as to how to proceed to the next stage, such as to
8 provide an optimal preparation geometry. -In particular, when the prosthesis is a
9 bridge, the system guides the practitioner to provide the one of the preparation
10 zones, and then based on this geometry calculates an optimal geometry for the
11 second preparation zone required for the bridge, and correspondingly guides the
12 practitioner accordingly. -At each material removing stage, the processor 52 re-
13 -evaluates the full picture, and may suggest that the first preparation be modified
14 instead of or in addition to the second preparation.

15 [0178] At least the first aspect of the invention may be used with respect to a
16 positive model of a dentition, in a similar manner to that described above for a
17 real dentition, mutatis mutandis.

18 [0179] While the method of the invention has been described, based on a
19 representation of surface information, the three dimensional entities in the oral
20 cavity, such as for example the teeth gums and so on, and also the 3D entities
21 that are created by the system 50, including the preparation 10, for example, may
22 be described instead by solid representations or any other topographical or
23 geometrical representations.

24 [0180] According to the invention feedback data useful in prosthodontic
25 procedures associated with the intra oral cavity is provided. First, a 3D numerical
26 model of the target zone in the intra oral cavity is provided, and this is
27 manipulated so as to extract particular data that may be useful in a particular
28 procedure, for example data relating to the finish line or to the shape and size of
29 a preparation. The relationship between this data and the procedure is then
30 determined, for example the clearance between the preparation and the intended
31 crown. Feedback data, indicative of this relationship, is then generated, for
32 example whether the preparation geometry is adequate for the particular type of
33 prosthesis.

34 [0181] In the method claims that follow, alphabetic characters and Roman
35 numerals used to designate claim steps are provided for convenience only and do
36 not imply any particular order of performing the steps.

37 [0182] Finally, it should be noted that the word "comprising" as used
38 throughout the appended claims is to be interpreted to mean "including but not
39 limited to".

| 1 [\[0183\]](#) While there has been shown and disclosed exemplary embodiments in
2 accordance with the invention, it will be appreciated that many changes may be
3 made therein without departing from the spirit of the invention.

1 **CLAIMS:**

2 1. — A method for providing feedback data useful in at least one prosthodontic
3 procedure associated with the intra oral cavity, comprising:

4 (a) — providing at least one numerical entity representative of the
5 three-dimensional surface geometry of at least part of the intra-oral cavity;

6 (b) — manipulating said entity to provide desired data of a type useful
7 in at least a first said procedure;

8 (c) — determining at least one relationship between said desired data
9 and said first procedure; and

10 (d) — generating feedback data representative of said at least one
11 relationship.

12 2. — Method according to claim 1, wherein dental material has been
13 previously removed from said part of the intra-oral cavity by means of a second
14 procedure.

15 3. — Method according to claim 1, wherein step (c) comprises testing an
16 adequacy of said desired data for performing said first procedure according to at
17 least one predetermined parameter.

18 4. — Method according to claim 3, wherein step (d) comprises generating
19 feedback data representative of said adequacy.

20 5. — Method according to claim 3, wherein said first procedure comprises
21 mounting at least one dental prosthesis with respect to a dental preparation
22 comprised in said intraoral cavity and provided prior to step (a).

23 6. — Method according to claim 5, wherein said desired data relates to the
24 geometry of a finish line associated with said dental preparation.

25 7. — Method according to claim 6, wherein step (c) comprises determining
26 whether or not the said finish line geometry is suitable for receiving a prosthesis
27 according to predetermined parameters.

28 8. — Method according to claim 7, wherein said feedback data in step (d)
29 comprises a suitable message advising whether or not said finish line geometry
30 is suitable, according to said determination in step (c).

31 9. — Method according to claim 7, wherein in step (c) it is determined that the
32 said finish line geometry is not suitable for receiving a prosthesis according to
33 predetermined parameters, and further comprises the step:

- 1 (e) — providing suggested changes to said finish line geometry such as
2 to provide a new finish line geometry that is suitable for receiving a prosthesis
3 according to predetermined parameters.
- 4 10. — Method according to claim 9, wherein said suggested changes are
5 calculated according to predetermined rules.
- 6 11. — Method according to claim 9, wherein said suggested changes are
7 displayed on a two-dimensional representation of said dental preparation,
8 wherein said new finish line geometry is superimposed over said representation.
- 9 12. — Method according to claim 11, wherein a location of said existing finish
10 line geometry is highlighted with respect to said new finish line geometry.
- 11 13. — Method according to claim 9, further comprising repeating steps (a) to
12 (d) after further material has been removed from the preparation to conform a
13 finish line thereof to said new finish line geometry.
- 14 14. — Method according to claim 9, further comprising repeating steps (a) to (d)
15 concurrently with each step of a material removal operation, said material
16 removal operation being adapted to conform a finish line of said preparation to
17 said new finish line geometry, wherein step (e) is performed at each step of said
18 material removal operation.
- 19 15. — Method according to claim 5, wherein said desired data relates to an
20 insertion path geometry for said prosthesis with respect to said dental preparation
21 and surrounding dental tissues.
- 22 16. — Method according to claim 15, wherein step (c) comprises determining
23 whether or not the said insertion path geometry is suitable for enabling said
24 prosthesis to be mounted with respect to said dental preparation.
- 25 17. — Method according to claim 16, wherein said feedback data comprises a
26 suitable message advising whether or not said insertion path geometry is suitable,
27 according to said determination in step (c).
- 28 18. — Method according to claim 16, wherein in step (c-) it is determined that
29 the said insertion path geometry is not suitable for receiving a prosthesis
30 according to predetermined parameters, and further comprises the step:
- 31 (f) providing suggested changes to said dental preparation such as to
32 provide a new insertion path geometry that is suitable for receiving a prosthesis
33 according to predetermined parameters.
- 34 19. — Method according to claim 18, wherein said suggested changes are
35 determined on the basis of identifying overlapping areas between the prosthesis

1 and the preparation, and providing guidance as to corresponding changes
2 required in at least one of said prosthesis and said preparation.

3 20.—Method according to claim 18, wherein ~~—~~said suggested changes are
4 displayed on a two-dimensional representation of said dental preparation,
5 wherein said new insertion path geometry is superimposed over said
6 representation.

7 21.—Method according to claim 18, further comprising repeating steps (a) to
8 (d) after further material has been removed from the preparation to conform said
9 preparation to said new insertion path geometry.

10 22.—Method according to claim 18, further comprising repeating steps (a) to
11 (d) concurrently with each step of a material removal operation, said material
12 removal operation being adapted to said preparation to said new insertion path
13 geometry, wherein step (e) is evaluated at each step of said material removal
14 operation.

15 23.—Method according to claim 15, wherein said prosthesis is any one of a
16 crown or bridge.

17 24.—Method according to claim 5, wherein said desired data relates to at least
18 one predetermined dimension between said dental preparation and said
19 prosthesis.

20 25.—Method according to claim 24, wherein step (c) comprises determining
21 whether or not the said at least one dimension is suitable for enabling a prosthesis
22 to be received according to predetermined parameters.

23 26.—Method according to claim 25 wherein said at least one dimension relates
24 to a characteristic thickness of said prosthesis.

25 27.—Method ~~—~~according to claim 25, wherein said prosthesis comprises a
26 ceramic cap that is mountable over a metal coping bonded to said preparation.

27 28.—Method according to claim 25, wherein said prosthesis comprises a
28 porcelain fused to metal (PFM) cap.

29 29.—Method according to claim 25, wherein said feedback data comprises a
30 suitable message advising whether or not said at least one dimension is suitable,
31 according to said determination in step (c).

32 30.—Method according to claim 25, wherein in step (c) it is determined that
33 the said at least one dimension is not suitable for receiving a prosthesis according
34 to predetermined parameters, and further comprises the step:

- 1 (e) ~~providing~~ providing suggested changes to preparation geometry such as to
2 provide a dimension that is suitable for receiving a prosthesis according to
3 predetermined parameters.
- 4 31. ~~Method~~ Method according to claim 30, wherein said suggested changes are
5 determined taking into consideration the type of prosthesis to be implanted at
6 said preparation.
- 7 32. ~~Method~~ Method according to claim 30, wherein said suggested changes are
8 displayed on a two-dimensional representation of said dental preparation,
9 wherein said changes to preparation geometry are superimposed over said
10 representation.
- 11 33. ~~Method~~ Method according to claim 30, further comprising repeating steps (a) to
12 (d) after further material has been removed from the preparation to conform said
13 preparation to said new preparation geometry.
- 14 34. ~~Method~~ Method according to claim 30, further comprising repeating steps (a) to
15 (d) concurrently with each step of a material removal operation, said material
16 removal operation being adapted to conform said preparation to said new
17 preparation geometry, wherein step (e) is evaluated at each step of said material
18 removal operation.
- 19 35. ~~Method~~ Method according to claim 1, wherein step (a) is performed by scanning
20 said at least part of said intra oral cavity using a suitable 3D surface scanner.
- 21 36. ~~Method~~ Method according to claim 35, wherein in step (c) said relationship is
22 insufficiently determined due to incomplete definition of numerical entity
23 provided by step (a).
- 24 37. ~~Method~~ Method according to claim 36, further comprising the step of
25 determining the location of at least one area of said intra oral cavity where 3D
26 definition thereof is required for enabling step (c) to be performed.
- 27 38. ~~Method~~ Method according to claim 37, wherein said determination of the location
28 of said at least one area is performed by suitable algorithms.
- 29 39. ~~Method~~ Method according to claim 37, wherein said at least one area is displayed
30 on a two-dimensional representation of said dental preparation, wherein said at
31 least one area is superimposed over said representation.
- 32 40. ~~Method~~ Method according to claim 5 wherein said prosthesis comprises any one
33 of an inlay onlay, crown, bridge or restoration.
- 34 41. ~~Method~~ Method according to claim 1, wherein step (b-) comprises simulating said
35 procedure first with respect to said numerical entity to provide said desired data.

- 1 42. ~~Method~~ according to claim 1, wherein step (a) comprises the steps of:
- 2 (i) ~~scanning~~ a part of said intra-oral cavity to provide a 3D numerical
3 entity thereof;
- 4 (ii) ~~determining~~ whether a definition of said 3D numerical entity is
5 sufficient for enabling step (c) to be performed;
- 6 (iii) ~~if~~ said definition is insufficient, advising a user to continue
7 scanning a different part of said intra-oral cavity, and repeating step (ii) until said
8 definition is sufficient, wherein step (v) is performed;
- 9 (iv) ~~if~~ said definition is sufficient in step (ii), proceeding with step (v);
- 10 (v) ~~advising~~ a user that said definition is sufficient~~;~~ and proceeding
11 with steps (b) to (d).
- 12 43. ~~Method~~ according to claim 1, wherein in step (a), said numerical entity
13 further comprises color data of said part of the intra oral cavity.
- 14 44. ~~Method~~ according to claim 43, wherein step (b) comprises differentiating
15 parts of said entity according to whether the said color associated therewith is
16 correlated with soft tissues or hard tissues of the intra oral cavity.
- 17 45. ~~Method~~ as claimed in claim 1, wherein step (a) is performed in one
18 location, and at least one of steps (b) to (d) are performed in at least one different
19 location.
- 20 46. ~~Method~~ according to claim 1, wherein step (d) is provided substantially
21 in real-time with respect to step (a).
- 22 47. ~~Method~~ of providing feedback data useful in at least one prosthodontic
23 procedure associated with the intra oral cavity, comprising:
- 24 (i) ~~providing~~ at least one numerical entity representative of the
25 three-dimensional surface geometry of at least part of the intra-oral cavity that
26 has been previously modified by means of a first part of said procedure;
- 27 (ii) ~~manipulating~~ said entity to provide desired data useful in at least
28 a second part of said procedure;
- 29 (iii) ~~testing~~ adequacy of said desired data for performing said second
30 part of said procedure; and
- 31 (iv) generating feedback data representative of said adequacy.

- 1 48.—Method according to claim 47, wherein said first part of said procedure
2 comprises a dental material removal operation in said intra-oral cavity.
- 3 49.—Method according to claim 47, wherein step (ii) comprises manipulating
4 said entity to determine sufficiency of definition of said numerical entity in step
5 (i) with respect to said first said procedure, and providing sufficiency data
6 representative of said sufficiency, and wherein step (iii) comprises determining
7 at least one relationship between said sufficiency data and said first procedure.
- 8 50.—Method according to claim 47, wherein said desired data relates to a
9 measure of surface data definition of said entity.
- 10 51.—System for providing feedback data useful in at least one prosthodontic
11 procedure associated with the intra oral cavity comprising:
- 12 —(A) —scanner means for— providing at least one numerical entity
13 representative of the three-dimensional surface geometry of at least part of the
14 intra-oral cavity;
- 15 —(B) —microprocessor means adapted for manipulating said entity to
16 provide desired data of a type useful in at least a first said procedure, and for
17 determining at least one relationship between said desired data and said first
18 procedure; and
- 19 —(C)— output means for outputting feedback data representative of said at
20 least one relationship generated by said microprocessor means.
- 21 52.—System according to claim 51, wherein said scanner comprises a confocal
22 scanner.
- 23 53.—System according to ~~claim~~claim 52, wherein said scanner comprises a
24 capability for providing color data as well as geometrical data of a surface.
- 25 54.—System according to claim 51, wherein said output means comprises a
26 visual and/or audio display means.
- 27 55.—System according to claim 51, wherein said microprocessor means is
28 adapted for operation according to a method as defined in any one of claims 1 to
29 50.

