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(54) Title: MODELING AND MANUFACTURING ORTHODONTIC APPLIANCES

(57) Abstract: Disclosed is a method for generating a virtual orthodontic element for use in manufacturing an orthodontic appliance for a patient, the method comprising, -obtaining a patient data set for said patient, the patient data set comprises a virtual 3D teeth model, where said virtual 3D teeth model comprises a virtual upper jaw and a virtual lower jaw resembling the upper jaw and lower jaw, respectively, of the patient's mouth; - arranging the virtual upper jaw and the virtual lower jaw in an initial relative configuration in a virtual articulator which is able to simulate the articulation between the virtual upper jaw and the virtual lower jaw based at least on motion relative to at least one axis representing the terminal hinge axis of the patient; -designing the virtual orthodontic element based on at least a part of the virtual 3D teeth model and the arrangement of the 3D teeth model in the virtual articulator.



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Modeling and manufacturing orthodontic appliances

This invention generally relates to the generation of a virtual model of an orthodontic appliance, from which virtual model the orthodontic appliance can be manufactured.

Disclosed is a method for generating a virtual orthodontic element for use in manufacturing an orthodontic appliance for a patient, the method comprising,

- obtaining a patient data set for said patient, the patient data set comprises a virtual 3D teeth model, where said virtual 3D teeth model comprises a virtual upper jaw and a virtual lower jaw resembling the upper jaw and lower jaw, respectively, of the patient's mouth;
- arranging the virtual upper jaw and the virtual lower jaw in an initial relative configuration in a virtual articulator which is able to simulate the articulation between the virtual upper jaw and the virtual lower jaw based at least on motion relative to at least one axis representing the terminal hinge axis of the patient;
- designing the virtual orthodontic element based on at least a part of the virtual 3D teeth model and the arrangement of the 3D teeth model in the virtual articulator.

Designing the virtual orthodontic appliance, or at least a part thereof i.e. the virtual orthodontic element, in a virtual articulator as disclosed herein provides the orthodontist with a tool that is very powerful and flexible when designing an orthodontic.

The techniques and practices used by orthodontics vary greatly. Thus, in order to provide a virtual environment, e.g. a CAD program, wherein the orthodontic can design orthodontic appliances or elements it is important that high flexibility in designing is provided. However, common for mostly all treatments and appliances within orthodontic that the appliance seeks to

correct a malocclusion or maintain a specific occlusion. Thus, the ability to analyze the occlusion of a patient is extremely valuable to the orthodontist.

5 Thus, by providing a method as disclosed the orthodontist is able to simulate the effect of the designed orthodontic element in a virtual articulator and based on the occlusion he may determine whether the designed orthodontic element will provide the desired effect or should be modified or re-designed.

10 The ability to do this analysis virtually is very powerful since it allows the orthodontist or dental technician to easily modify or re-design an orthodontic element compared to common manual techniques where a re-design may result in the need to create new gypsum models, scrap prototypes of the orthodontic appliance etc.

15 In particular within orthodontics where the occlusion need to be verified for the entire jaw, and not only for a single crown or restoration, such simulation both saves time and money and in many cases leads to a better result since the orthodontist may try different solutions which would not be able if the work was done manually.

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The virtual articulator serves to simulate articulation of the upper and lower jaw similar to that of commonly known physical articulators. Physical articulators come in many different models and the settings and freedom of movement varies greatly. Common for most articulators is that they seek to simulate the relative movement between the upper and lower jaw. Orthodontics or dental technician will use this to be able to simulate the occlusion of the patient and based on this determine a treatment plan and based on this design or prescribe an appliance or device in order to bring the teeth or jaws into another more optimal occlusion.

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In general it can be said that the virtual articulator, as a minimum, simulate the articulation between the virtual upper and lower jaw based on the motion relative to at least one axis representing the terminal hinge axis of the patient. The terminal hinge axis is the axis of rotation of the mandible when
5 the mandibular condyles are in their most superior position in the glenoid fossa. It should of course be understood that the at least one axis in the virtual articulator which represents the terminal hinge axis does not necessarily replicate the terminal hinge axis exactly, as this depends on the method used to determine the terminal hinge axis.

10

The motion relative to this axis depends upon the specific articulator's freedom of movement. Thus, the motion may be a rotation, a lateral or transverse motion or a combination thereof. Other types or parameters may also be applied as is well known within physical articulators, such as the
15 Bennett angle, Bennett movement, condylar guidance angle, incisal guidance or the intercondylar guidance.

In one embodiment the step of designing the virtual orthodontic element comprises designing an intermediate part of the virtual orthodontic element in
20 the virtual articulator. By designing at least an intermediate part of the virtual orthodontic element in the virtual articulator the orthodontist may evaluate the result continuously thus confirming even minor changes almost instantly.

By an intermediate part of the virtual orthodontic element it should be
25 understood that this may be a part which is designed in a sub-step and has to be modified in a further step before resulting in the actual virtual orthodontic element. Thus, the method of designing a virtual orthodontic element may comprise several sub-steps in which a separate intermediate part is treated in each step.

30

For example in one sub-step the intermediate part may be a library file that is chosen and have a preset shape. In another sub-step the library file is modified and simulated while placed in the virtual articulator creating a second intermediate part. Finally, the virtual orthodontic element may be designed by adding the second intermediate part to a virtual of a standard appliance, e.g. representing a night guard, retainer or similar.

The virtual orthodontic element may represent the final orthodontic appliance as manufactured. However, it may also be a part of an orthodontic appliance. This may for example be an orthodontic appliance where a part is made in hand or is pre-manufactured, such as the rod in an Herbst appliance and the part fitting the teeth is virtually designed as the orthodontic element.

Accordingly, the virtual orthodontic element can in one embodiment represent the orthodontic appliance to be manufactured.

In another embodiment the virtual orthodontic element represents at least a part of the orthodontic appliance to be manufactured.

In yet another embodiment the virtual orthodontic element may represent a negative of the orthodontic appliance to be manufactured. This can for example be the case where the orthodontic appliance is manufactured by thermoforming the appliance on a dental model, or the dental model is used to otherwise produce the orthodontic appliance.

Thus, in the following the term virtual orthodontic appliance should be read broadly in the sense that the virtual orthodontic appliance may be a virtual orthodontic element, which when manufactured forms a part of a complete physical orthodontic appliance.

By designing the virtual orthodontic element in the virtual articulator it is possible to take into consideration a number of situations where the possibility of simultaneous design and articulation is of particular advantage.

- 5 For example, in one embodiment the step of designing the virtual orthodontic element comprises that the virtual upper and lower jaw is arranged in a modified relative configuration in the virtual articulator and that the virtual orthodontic element is at least partly designed in the modified relative configuration.

10

This can for example be that a nightguard is to be designed. By providing the jaws in an open relationship with respect to each other an optimal fit based on the open relationship can be obtained for the nightguard.

- 15 In another embodiment the step of designing the virtual orthodontic element comprises

- obtaining a dynamic occlusion surface from a dynamic occlusion simulation of the teeth,

- arrange the virtual upper and lower jaw in a modified relative configuration in the virtual articulator,

20

- design an intermediate part of the virtual orthodontic element in the modified relative configuration, and

- designing the virtual orthodontic element by applying the dynamic occlusion surface to the intermediate part of the virtual orthodontic element.

25

This further allows the designer to take into account the dynamic occlusion of the patient and in the end provide an even further optimized orthodontic appliance.

- 30 By observing movement in the virtual articulator the orthodontics may modify the virtual orthodontic element based on such movement. A virtual

environment may even suggest modifications if certain types of movements occur.

Thus, for example, the step of designing the virtual orthodontic element may
5 comprise arranging an intermediate part of the virtual orthodontic element on
the virtual 3D model within the virtual articulator and modifying the
intermediate part of the virtual orthodontic element based on the movement
of virtual upper jaw and virtual lower jaw in the virtual articulator.

10 In particular, the orthodontics is interested in identifying collisions between
element, and if relevant modify the orthodontic appliance based on such
collision. Thus, in one embodiment thereof, the intermediate part of the virtual
orthodontic element is modified based on collision on the intermediate part
during movement of virtual upper jaw and virtual lower jaw in the virtual
15 articulator.

Such collision may for example be between the intermediate part of the
orthodontic element and an opposing virtual element, such as an opposing
jaw or an opposing virtual orthodontic element.

20 To allow the orthodontist to easily identify the collisions, they may visually
illustrated as collision paths on the virtual orthodontic element. Such paths
can tell the orthodontist whether the virtual orthodontic element or appliance
will provide the desired effect.

25 In particular with respect to the virtual element such information may be
relevant in order to decide whether the virtual orthodontic element should be
modified. Thus, the step of designing the virtual orthodontic element may
comprise arranging an intermediate part of the virtual orthodontic element on
30 the virtual 3D model within the virtual articulator and visually illustrate
collisions on the intermediate part as collision paths.

Thus, based on the collision paths the virtual orthodontic element may be modified.

- 5 Such modification can for example be done by virtually adding or virtually removing material from the intermediate part of virtual orthodontic element along at least a part of the contact paths.

10 In some cases it may be desirable to design the virtual orthodontic appliance in a virtual articulator setup wherein the virtual lower and upper jaw are arranged in a target configuration that the orthodontics sees as the final and resulting configuration resulting from the treatment.

15 Thus, in one embodiment the method comprises the additional step of arranging the virtual lower and upper jaw in a target relative configuration in the virtual articulator.

20 For example the step of designing the virtual orthodontic element may comprise designing at least an intermediate part of the virtual orthodontic element based on the difference between the initial relative configuration and the target relative configuration.

25 In another embodiment the step of designing the virtual orthodontic element may also or additionally comprise designing at least an intermediate part of the virtual orthodontic element based on the target relative configuration.

30 Even further, the orthodontist may want to perform the treatment in steps. In such case the step of designing the virtual orthodontic element may comprise designing at least an intermediate part of the virtual orthodontic element based on a sequence of intermediate relative configurations of the virtual lower and upper jaw in the virtual articulator.

One advantage of the virtual articulator is that virtual models may be considered as solids or transparent. For example, when designing an virtual orthodontic element it may in one case be interesting to view the articulation
5 between opposing jaws where the teeth models ignored the model of the orthodontic element. In other case it is desirable to include the orthodontic element in the articulation. In particular in cases where the virtual orthodontic appliance is made up of several virtual orthodontic elements it may be of interest to see how the different elements influence the articulation and thus
10 the occlusion and how they in different combinations influence each other.

Thus, in one embodiment the movement of the virtual articulator is constrained by the surfaces of the 3D teeth model and the virtual orthodontic element.
15

In some embodiment the constraints by the surfaces prevents surfaces of the 3D teeth model and the virtual orthodontic element to intersect.

In some embodiment the virtual orthodontic element may be at least partly
20 designed based on a library component.

This can for example be a digital data file, such as a STL-file.

The library component may define a standard component which is applied to
25 orthodontic element after production in order to finalize the orthodontic appliance. Such components may for example be a Herbst rod, an attachment, a bracket or a drive, e.g. comprising springs or screws in order to adjust parts relative to each other.

30 Similar as described above the movement of the virtual articulator may be constrained by the surfaces of the 3D teeth model, the virtual orthodontic

element and the library component, in order to simulate the different part in the virtual articulator

5 The constraints by the surfaces may for example prevent surfaces of the 3D teeth model, the virtual orthodontic element and the library component to intersect.

10 Beside the articulation it is also relevant for the orthodontist to consider tooth arrangement in order to achieve the correct occlusion. Thus, in order to give a more complete picture to the orthodontist the tooth arrangement of the 3D teeth model may in some embodiments be changed in the virtual articulator.

15 In particular, it may be of interest to the orthodontist to observe how the tooth arrangement is changed based on the virtual orthodontic element.

In many cases the orthodontist will work in an iterative process in order to achieve the optimal orthodontic appliance. Thus, the step of designing the virtual orthodontic element may further comprise

- 20
- designing an intermediate part of the virtual orthodontic element based on the initial relative configuration,
 - adjust the virtual articulator to fit the intermediate part of the virtual orthodontic element,
 - design the virtual orthodontic element based on the adjusted virtual articulator.

25

In the virtual environment the virtual orthodontic element may be designed in a number of ways.

30 In one embodiment the virtual orthodontic element can be designed as a bar wherein the step of designing the virtual orthodontic element comprises

- generating a bar spline,

- generating a bar profile,
- generating a bar element having a profile defined by the bar profile and an extent defined by the bar spline.

5 The bar profile will typically be bound to the bar spline, to ensure that the bar is designed correctly.

Bars are often used as spacers or similar, in order to arrange the jaws in a slightly open or offset position. Bar can for example be advantageously
10 when designing nightguards, anti-snoring devices etc. In such cases it may be advantageous that the bar spline is arranged in a virtual plane arranged in the virtual articulator. The virtual plane can be set by the orthodontist based on the articulation and by using this as a base to design the virtual orthodontic element a correct bite can be achieved.

15

The virtual plane can for example be an occlusal plane representing the occlusal plane of the patient.

In another embodiment it may be desirable that the bar surface follows the
20 contour of the teeth whereon it is arranged. In such case the bar spline follows the contour of at least a part of the teeth surface of the 3D teeth model.

Another way to design the virtual orthodontic appliance may be by designing
25 it according to a shell principle.

In such an embodiment the step of designing the virtual orthodontic element comprises,

- generating a first boundary curve for the virtual orthodontic appliance,
- 30 - generating a first tooth contacting surface of the virtual orthodontic appliance, where said first tooth contacting surface at least partly is shaped

according to teeth in the first section of the virtual 3D teeth model and is bounded by said first boundary curve,

- generating an outer shell surface, and

- generating a first connecting surface configured for connecting the first
5 boundary curve and the outer shell surface.

Shells are particular advantageous when an orthodontic appliance is desired that is similar to that of the teeth and thus may be designed to be difficult to see.

10

In one embodiment the first tooth contacting surface at least partly comprises a first occlusion guiding segment of the virtual orthodontic appliance, where the first occlusion guiding segment is configured to provide that an orthodontic appliance manufactured from the virtual orthodontic appliance is
15 capable of guiding the patient's upper and lower jaw towards a target geometrical relationship during occlusion or of maintaining the patient's upper and lower jaw in a target geometrical relationship

20 Disclosed is a method for generating at least a portion of a virtual orthodontic appliance for manufacturing an orthodontic appliance for a patient, the method comprising:

a): providing a patient data set for said patient, the patient data set
25 comprising a virtual 3D teeth model, where the virtual 3D teeth model comprises a virtual upper jaw and a virtual lower jaw resembling the upper jaw and lower jaw, respectively, of the patient's mouth;

b): defining or generating a first boundary curve for a first section of the
30 virtual 3D teeth model;

c): generating a first tooth contacting surface of the virtual orthodontic appliance, where said first tooth contacting surface at least partly fits the teeth in the first section of the virtual 3D teeth model and is bounded by said first boundary curve;

5

d): generating a first occlusion guiding surface of the virtual orthodontic appliance, which first occlusion guiding surface is configured to define a target geometrical relationship between the upper and lower jaw, where the target geometrical relationship is configured to realize a target effect of the
10 orthodontic appliance; and

e): generating a first connecting surface configured for connecting the first boundary curve and the first occlusion guiding surface.

15 This disclosed method, and the embodiments relating thereof as disclosed in the following, may advantageously also be combined with the method as described above. Thus, for example, the first occluding guiding surface may be generated based on the arrangement of the 3D teeth model in the virtual articulator.

20

In the context of the present invention, the phrase "virtual orthodontic appliance for manufacturing an orthodontic appliance" refers to the case where a physical orthodontic appliance can be manufactured according to the virtual orthodontic appliance, such that e.g. the shape of one at least a
25 portion of the manufactured orthodontic appliance is described by the virtual orthodontic appliance.

The phrase "first" is used in relation to the boundary curve, the tooth facing surface and the connection surface of the first part of the orthodontic
30 appliance in order to distinguish the features of the first part from that of a second part.

In the context of the present invention, the phrase “tooth contacting surface” refers to a portion of a virtual orthodontic appliance which faces one or more teeth of the virtual 3D teeth model, when the virtual orthodontic appliance is arranged anatomically correct relative to the virtual 3D teeth model. The tooth contacting surface of the manufactured orthodontic appliance may face one or more of the teeth when the orthodontic appliance is arranged anatomically correct in the patient’s mouth. Depending on which target effect a particular orthodontic appliance is intended to have on the teeth, the tooth contacting surface may be in physical contact with one or more teeth of the set of teeth.

In the context of the present invention, the phrase “the tooth contacting surface at least partly fits the teeth” refers to the case where the tooth contacting surface of the orthodontic appliance at least over an area is substantially aligned with the surface of one or more teeth of the virtual 3D teeth model. For the manufactured orthodontic appliance, this corresponds to the situation where the tooth contacting surface of the orthodontic appliance is in physical contact with and/or surrounds the teeth when the orthodontic appliance is arranged at the patient’s teeth.

The tooth contacting surface may be said to fit the teeth both when there is physical contact between the orthodontic appliance and the teeth over the entire section and when there is physical contact over one area of the section and a gap between the orthodontic appliance and the teeth over another area.

In the context of the present invention, the phrase “virtual orthodontic appliance” refers to a virtual model of the orthodontic appliance and the phrases “virtual orthodontic appliance” and “virtual model of the orthodontic appliance” may be used interchangeably.

The virtual upper jaw and the virtual lower jaw may resemble at least part of the upper and lower jaw, respectively, of the patient's mouth. The virtual upper jaw and the virtual lower jaw may resemble substantially the entire upper and lower jaw, respectively, of the patient's mouth.

5

In some embodiments, the method comprises obtaining a target configuration of the set of teeth. This target configuration be obtained using CAD based software used for manipulating and validating computer representations of the virtual orthodontic appliance.

10

In some embodiments, the first occlusion guiding segment comprises a first occlusion guiding surface. In some embodiments, the second occlusion guiding segment comprises a second occlusion guiding surface.

15

In some embodiments, the first occlusion guiding segment comprises a first occlusion guiding unit, such as the telescope part of a Herbst appliance. In some embodiments, the second occlusion guiding segment comprises a second occlusion guiding unit.

20

In some embodiments, the second part of the virtual orthodontic appliance is taken into account when selecting the first occlusion guiding segment. This may be the case when the virtual orthodontic appliance is designed to provide that the first occlusion guiding segment of a manufactured orthodontic appliance contacts the second part of the manufactured orthodontic appliance during occlusion.

25

In some embodiments, the virtual orthodontic appliance is configured to provide that a segment of an orthodontic appliance manufactured from the virtual orthodontic appliance corresponding to the first occlusion guiding segment contacts a segment corresponding to the second occlusion guiding segment during occlusion.

30

In some embodiments, the virtual orthodontic appliance is configured to provide that a surface of an orthodontic appliance manufactured from the virtual orthodontic appliance corresponding to the first occlusion guiding surface contacts a surface corresponding to the second occlusion guiding surface during occlusion.

In some embodiments, the virtual orthodontic appliance comprises a first part configured for being positioned at the first section of the virtual 3D teeth model, and the first boundary curve, the first tooth contacting surface, the first occlusion guiding surface, and the first connecting surface are comprised in said first part.

In the context of the present invention, a part of the virtual orthodontic appliance is configured for being positioned at a section of the virtual 3D teeth model when the corresponding part of the manufactured orthodontic appliance can be positioned at the corresponding section of the patient's teeth.

The boundary curve may define the lower boundary of the virtual orthodontic appliance of the orthodontic appliance on both the lingual surface and labial/buccal surface of 3D teeth model.

The first boundary curve may be lower at some places than at others or it may have a substantially constant distance from the occlusal surface of the teeth at which it is positioned. This may also be the case for the second boundary curve.

In the context of the present invention, the phrase "lower" is only used to describe the relative orientation of different elements and does not present a limitation on which element is closer to the ground than the other parts. The

lower part of a tooth may be the root of the tooth, with the cusp of the tooth being referred to as the upper part.

5 In some embodiments, the boundary curve may be generated automatically by algorithm based analysis of the virtual 3D teeth model. For some orthodontic appliances, the boundary curve or curves may coincide with the margin line and algorithms known to the skilled person may be used to generate the boundary curve. The boundary curve may also be substantially parallel to the margin line with a well-defined offset between the two.

10

The boundary curve may be defined by an operator using e.g. a pointer tool, such as a mouse, to mark positions on the curve relative to a graphical displayed virtual model of the teeth.

15 In some embodiments, the virtual 3D teeth model comprises a root structure of the teeth and/or the jaw bone and/or soft tissue, such as lips, tongue, buccal tissue or the gingiva.

20 The virtual 3D teeth model may comprise a modified set of teeth. The modified set of teeth may be modified e.g. to improve the aesthetic appearance of the patients set of teeth and/or to correct for an occlusal problem. The generating of the virtual model of the orthodontic appliance may be adapted to take into account this modified set of teeth, such that the manufactured orthodontic appliance may act on the patient's set of teeth in
25 such a manner that the set of teeth is changed towards the teeth arrangement according to the modified set of teeth.

In some embodiments, the virtual 3D teeth model is formed from a 3D representation of an observed set of teeth.

30

In some embodiments, the 3D representation is obtained by a face bow analysis, an occlusal force registration and/or by scanning the observed set of teeth, such as scanning by means of extraoral or intraoral scanning of the teeth, or by scanning an impression of the teeth, or by scanning a physical
5 model of the teeth.

The scanning may be performed by means a scanning technique selected from the group of laser light scanning, white light scanning, probe-scanning, X-ray scanning, CT scanning, a Cone Beam CT, magnetic resonance based
10 imaging, biomagnetic imaging, Diaphanography, Digital Radiography, Endoscopy, Ultra sound, Radio Fluoroscopy, Radiographic Imaging, Thermography, or X-Ray Angiography.

In some embodiments, the 3D representation of the set of teeth comprises a
15 point cloud presenting the surface of the set of teeth, from which point cloud the virtual 3D teeth model is formed for example by triangulation.

In some embodiments, the upper and lower jaws are aligned in said virtual
3D teeth model.

20 In the context of the present invention, the phrase "the lower and the upper jaw are aligned" may refer to the situation where the upper and lower sections of the virtual 3D teeth model are arranged anatomical correct relative to each other, such that the virtual 3D teeth model shows an anatomical correct arrangement of the set of teeth.

25 The upper and lower sections of the virtual 3D teeth model may be arranged in a static occlusion such that the virtual 3D teeth model shows the teeth in a static occlusion, and the occlusion guiding surface(s) of the part(s) of the virtual orthodontic appliance may be derived for a static occlusion of the set of teeth.

30

In some embodiments, the alignment of the lower and the upper sections of the virtual 3D teeth model is such that teeth in the upper and/or the lower jaw of the virtual 3D teeth model are displaced from the occlusal plane of the virtual 3D teeth model.

- 5 The displacement may provide an offset of the adjoining surfaces of the teeth in the opposing sections of the 3D model. The adjoining surfaces of opposing mandibular and maxillary molar teeth may thus be offset from each other during the displacing of the upper part and/or the lower part of the virtual 3D teeth model.

10

The off-set may provide space for the orthodontic appliance. The offset may be uniform in the occlusal plane, i.e. the offset provides a uniform displacement over the occlusal plane of the virtual 3D teeth model.

- 15 In some cases the offset is determined first and then the shape of the orthodontic appliance is derived based on the offset, the shape being such that the teeth do not extend out of the boundaries provided by said offset.

20 The virtual 3D teeth model may thus relate to the situation where the set of teeth is arranged with some distance between the mandibular teeth and the maxillary teeth.

This may correspond to the situation where the mouth of the patient is slightly opened, such as where the distance between the mandibular teeth and the maxillary teeth is comparable to the interocclusal distance of the patient. In
25 the context of the present invention the phrase "the interocclusal distance" may refer to the distance between the occluding surfaces of the maxillary and mandibular teeth with the mandible in physiologic rest position.

30 The distance between the mandibular teeth and the maxillary teeth provided by said offset may be such that the distance between the occluding surfaces of the posterior maxillary and mandibular teeth of the patient is in the range

of about 0.5 mm to about 10 mm, such as in the range of about 1 mm to about 7 mm, in the range of about 2 mm to about 5 mm. The distance may be such that the distance between the occluding surfaces of the anterior maxillary and mandibular teeth of the patient is in the range of about 0.5 mm to about 10 mm, such as in the range of about 1 mm to about 7 mm, such as in the range of about 2 mm to about 5 mm.

In the context of the present invention, the occlusal plane may be defined as a plane passing through the occlusal or biting surfaces of the teeth representing the mean of the curvature of the occlusal surface. It may be defined at the plane stretched between three specific teeth. Furthermore, the occlusal plane may be defined as an imaginary surface that is related physiologically to the cranium and that theoretically touches the incisal edges of the incisors and tips of the occluding surfaces of the posterior teeth. Furthermore, the occlusal plane may be defined as a line drawn between points representing one half of the incisal overbite, vertical overlap, in front and one half of the cusp height of the last molars in back. The occlusal plane may on a physical, mechanical articulator be marked with a rubber band placed at specific points relative to the teeth on the model of the teeth, such that the rubber band indicates a plane.

The occlusal plane may be a flat plane, but it is understood that the occlusal plane can have any shape etc. Thus the occlusal plane can be flat or undulating following the different heights of the different teeth.

In some embodiments, the method comprises a segmentation of the virtual 3D teeth model allowing for an individual movement of the teeth or groups of teeth in said virtual 3D teeth model.

The individual movement may be such that each tooth can be arranged correctly in the set of teeth, to provide e.g. an improved aesthetic appearance of the set of teeth.

In some embodiments, the method comprises defining or generating a second boundary curve for a second section of the virtual 3D teeth model and generating a second tooth contacting surface, where said second tooth contacting surface fits the teeth in the second section and is bounded by said second boundary curve. In this case, a portion of the contacting surface in the manufactured orthodontic appliance can contact the teeth when the orthodontic appliance is arranged at the patient's teeth.

In some embodiments, the second boundary curve and the second tooth contacting surface are comprised in the first part of the orthodontic appliance.

The orthodontic appliance may consist of the first part. In some embodiments, the orthodontic appliance is a coherent one-piece unit. Such a coherent one-piece unit may comprise a first tooth contacting surface configured to fit the teeth of the first section and a second tooth contacting surface configured to fit the teeth of the second section.

In some embodiments, the virtual orthodontic appliance comprises a second part configured for being positioned at a second section of the virtual 3D teeth model. In such embodiments the method may comprise:

- defining or generating a second boundary curve for the second section of the virtual 3D teeth model;
- generating a second tooth contacting surface of the second part of the virtual orthodontic appliance, where said second tooth contacting surface fits the teeth in the second section of the virtual 3D teeth model and is bounded by said second boundary curve;
- generating a second occlusion guiding surface of the second part of the virtual orthodontic appliance, where the second occlusion guiding surface is comprised in or comprises a second occlusal surface of the second part of the virtual orthodontic appliance; and

- generating a second connecting surface of the second part of the virtual orthodontic appliance, where said second connecting surface is configured for connecting the second boundary curve and the second occlusion guiding surface;
- 5 where said first and second occlusion guiding surfaces are configured such that they together define the target geometrical relationship between the upper and lower jaw.
- 10 In some embodiments, the method comprises generating a second occlusion guiding surface, which is configured to define a target geometrical relationship, also referred to as a target relative configuration, between the upper and lower jaw, where the target geometrical relationship is configured to realize a target effect of the orthodontic appliance, and generating a
- 15 second connecting surface configured for connecting the second boundary curve and the second occlusion guiding surface.

The second boundary curve, the second tooth contacting surface, the second occlusion guiding surface, and the second connecting surface may be

20 comprised in said second part or the orthodontic appliance.

The first and second occlusion guiding surface may together define the target geometrical relationship between the upper and lower jaw.

25 The orthodontic appliance manufactured from the virtual orthodontic appliance may comprise parts equivalent to the parts of the virtual orthodontic appliance, i.e. the manufactured orthodontic appliance may comprise a first part configured for being arranged in relation to a first section of the set of teeth of the patient, and a second part configured for being

30 arranged in relation to a second section of the set of teeth of the patient. The features of the virtual orthodontic appliance may have equivalent features in

the orthodontic appliance manufactured from the virtual orthodontic appliance, such that e.g. the form of the tooth contacting surface of one part of the manufactured virtual orthodontic appliance and its position relative to the other elements of the orthodontic appliance may be determined from the
5 form and position in the virtual orthodontic appliance.

The various elements of the invention may be applied both in relation to generating an orthodontic appliance and in relation to modifying an existing model of an orthodontic appliance.
10

When the manufactured orthodontic appliance is positioned correctly in the patient's mouth, the first and the second parts of the orthodontic appliance may have a physical influence on each other during occlusion.

15 In some embodiments, the target geometrical relationship relates to a range of relative positions of the first and second parts, such as a number of relative positions during a relative movement of these parts, or a specific position in this range. The range of relative positions of the first and second parts may be analyzed in a virtual dynamical articulator.

20

The virtual orthodontic appliance may comprise three or more parts.

In some embodiments, the first occlusion guiding surface is arranged on a lingual and/or a buccal/labial side of teeth in the virtual 3D teeth model.

25 In some embodiments, the second occlusion guiding surface is arranged on a lingual and/or a buccal/labial side of teeth in the virtual 3D teeth model.

The first occlusion guiding surface may be comprised in a first occlusal surface of the virtual orthodontic appliance.

30

The first occlusion guiding surface may comprise a first occlusal surface of the virtual orthodontic appliance.

5 The second occlusion guiding surface may be comprised in a second occlusal surface of the virtual orthodontic appliance.

The second occlusion guiding surface may comprise a second occlusal surface of the virtual orthodontic appliance.

10 In some embodiments, the virtual orthodontic appliance is configured such that the first occlusion guiding surface is intended to contact the second section of the set of teeth during occlusion, and the generating of the first occlusion guiding surface takes into account said second section of the set of teeth, i.e. the virtual orthodontic appliance may be such that the first
15 occlusion guiding surface of the manufactured orthodontic appliance is configured for being in physical contact with the second section of the patient's set of teeth during occlusion.

When such a physical contact is provided during occlusion, the orthodontic appliance may apply a force to the patient's set of teeth.

20 The generating of the second occlusion guiding surface may take into account said first section of the set of teeth

In some embodiments, the virtual orthodontic appliance is configured such that the first occlusion guiding surface is intended to contact an occlusal
25 surface of teeth in said second section during occlusion, i.e. the virtual orthodontic appliance may be such that the first occlusion guiding surface of the manufactured orthodontic appliance is configured for being in physical contact with an occlusal surface of teeth in said second section of the patient's set of teeth during occlusion.

30 When such a physical contact is provided during occlusion, the orthodontic appliance may apply a force to the patient's set of teeth.

In some embodiments, the virtual orthodontic appliance is configured such that the first occlusion guiding surface is intended to contact the second part of the virtual orthodontic appliance during occlusion, and the generating of the first occlusion guiding surface takes into account said second part of the virtual orthodontic appliance. The generating of the second occlusion guiding surface may take into account said first part of the virtual orthodontic appliance.

The virtual orthodontic appliance may be such that the first occlusion guiding surface of the manufactured orthodontic appliance is configured for being in physical contact with the second part of the manufactured orthodontic appliance during occlusion.

When such a physical contact is provided during occlusion, the orthodontic appliance may apply a force to the patient's set of teeth.

The generating of the second occlusion guiding surface may take into account said first part of the virtual orthodontic appliance.

In some embodiments, the virtual orthodontic appliance is configured such that the first occlusion guiding surface is intended to contact the second occlusion guiding surface during occlusion. That is, the virtual orthodontic appliance may be configured such that its first and second parts are in contact during the occlusion.

The virtual orthodontic appliance may be such that the first occlusion guiding surface of the manufactured orthodontic appliance is configured for being in physical contact with the second occlusion guiding surface of the manufactured orthodontic appliance during occlusion.

When such a physical contact is provided during occlusion, the orthodontic appliance may apply a force to the patient's set of teeth.

Taking into account said second section of the set of teeth may comprise taking into account the shape and/or the position of the teeth in the second section, such as their shape and position in an occlusal plane of the patient.

- 5 Taking into account said second part of the orthodontic appliance may comprise taking into account the shape and/or the position of the second part of the orthodontic appliance, such as the shape and position in an occlusal plane of the patient.
- 10 The taking into account the shape of one surface when deriving the shape of an adjoining surface may comprise aligning at least a portion of the one surface with the adjoining surface and defining one or more features on the one surface, where the features may be shaped according to the target effect of the orthodontic appliance. The aligning may comprise replacing the portion
- 15 of the one surface with the adjoining surface. The aligning and the forming of the feature may be realized using known computer implemented algorithms. In some embodiments, the virtual orthodontic appliance is configured to provide that the manufactured orthodontic appliance is such that the relative motion of the first and second sections is at least partly constrained by the
- 20 orthodontic appliance during protrusion and/or retrusion and/or occlusion.

In some embodiments, the virtual orthodontic appliance is configured such that adjoining surfaces of the first and second parts of the virtual orthodontic appliance defines the target geometrical relationship between the upper and

25 lower jaw, i.e. the virtual model is such that the first and second parts of an orthodontic appliance manufactured from the virtual model together defines the target geometrical relationship.

In the context of the present invention, the phrase "adjoining surfaces" may relate to surfaces that are in contact when the set of teeth is in occlusion.

In the context of the present invention, the phrase “the set of teeth is in occlusion” may be used both in relation to the situation where the occlusal surfaces of the teeth are in direct contact or the situation where orthodontic appliance is arranged at the teeth and the opposing parts of the orthodontic
5 appliance are in contact.

In some embodiments, the method comprises providing a virtual dynamical articulator comprising the virtual 3D teeth model, and performing a virtual dynamical articulation, where the virtual orthodontic appliance is arranged in
10 relation to the virtual 3D teeth model during the virtual dynamical articulation and where the effect of the orthodontic appliance on the patient, such as the effect on the patient’s teeth, is estimated from the virtual dynamical articulation.

15 In some embodiments, the target geometrical relationship is such that the manufactured orthodontic appliance provides that the relative movement of the upper and lower jaw of the set of teeth is at least partially constrained. The virtual orthodontic appliance may be such that adjoining surfaces of the first and second parts of the manufactured orthodontic appliance provide that
20 the relative movement of the upper and lower jaw of the set of teeth is at least partially constrained.

The target geometrical relationship between the upper and lower jaw may comprise that the relative movement of the upper and lower jaw of the set of
25 teeth is least partially constrained in the occlusal plane.

In some embodiments, the target geometrical relationship between the upper and lower jaw comprises that the relative movement of the upper and lower jaw of the set of teeth is least partially constrained in a direction
30 perpendicular to the occlusal plane.

In some embodiments, the target geometrical relationship comprises that the alignment of the virtual 3D teeth model is such that the virtual upper and the virtual lower jaw are displaced from the occlusal plane of the virtual 3D teeth model such that an offset between the virtual upper jaw and the virtual lower jaw is provided. In the patient's mouth this corresponds to displacing the upper jaw and/or the lower jaw from the occlusal plane.

In some embodiments, the first occlusal guiding surface defines a first guiding structure in the occlusal surface of the first part of the virtual orthodontic appliance

In some embodiments, the second occlusal guiding surface defines a second guiding structure in an occlusal surface of the second part of the virtual orthodontic appliance.

The interaction of the first and second guiding structures may define the target geometrical relationship. The target geometrical relationship may relate to a guided relative motion of the upper and lower jaw of the patient during occlusion.

In the context of the present invention, the phrases "guided relationship" and "guided relative motion" may refer to the case where the first and second sections of the set of teeth are connected and only are partially mobile relative to each other. The guided relationship and guided relative motion may be such that the sections of the set of teeth are capable of moving more freely in one direction than another. The guided relationship and guided relative motion may be such that the first and second sections only are capable of moving a certain distance along a given direction. The guided relationship and guided relative motion may be such that the parts are capable of moving less than a when the orthodontic appliance is not arranged on the teeth.

The first and second guiding structures may be configured to mate, such that the occlusion and/or articulation of the set of teeth is at least partly constrained.

5

In some embodiments, the first and second guiding structures are configured to mate, such that the target geometrical relationship is obtained during occlusion.

- 10 In some embodiments, the method comprises providing a virtual dynamical articulator comprising the virtual 3D teeth model, and performing a virtual dynamical articulation of the set of teeth.

The interaction of the maxillary and mandibular teeth of a patient may be visualized using a computer-implemented virtual dynamical articulation, which may be referred to as a virtual dynamical articulator, or just virtual articulator. The virtual dynamical articulator may provide a graphical display that simulates the operation of the patient's jaw or the operation of a conventional mechanical articulator attached to a physical model of the patient's teeth. The virtual dynamical articulator may orient upper and lower arches of the 3D model in the same manner that the patient's physical arches will be oriented in the patient's mouth. The articulator may then move the arch models through a range of motions that simulate common motions of the human jaw.

The virtual dynamical articulator may comprise a digital model of a mechanical articulator, for example, from a computer-aided design (CAD) file or image data gathered during a laser scan of the mechanical articulator. Other implementations may include a digital model of human jaws created, for example, from 2D or 3D x-ray data, CT scan data, or mechanical measurements of the jaws, or from a combination of these types of data. The virtual dynamical articulator may be created from image data or mechanical

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measurements of the patient's head and simulate the jaws of the patient whose teeth are being treated.

Animation instructions may define the movements that the virtual dynamical articulator simulates. Like a mechanical articulator, the animation instructions are derived from a variety of sources. The animation instructions associated with the simulation of a mechanical articulator may require little more than a mathematical description of the motion of a mechanical hinge. A virtual dynamical articulator simulating the human jaw, on the other hand, may require a more complex set of instructions, based on human anatomical data.

One method of building this set of instructions is the derivation of mathematical equations describing the common motions of an ideal human jaw. Another method is through the use of a commercially available jaw-tracking system, which contacts a person's face and provides digital information describing the motion of the lower jaw. X-ray and CT scan data also provide information indicating how the teeth and jaws relate to each other and to the rest of the person's head. Jaw-tracking systems and x-ray and CT scan data are useful in developing an articulator that simulates a particular patient's anatomy. As the virtual dynamical articulator simulates the motion of a patient's teeth, it may detect a trace of any collisions between the maxillary and mandibular teeth, and determine whether and how the patient's teeth will collide during the normal course of oral motion.

In some embodiments, the method comprises providing a virtual dynamical articulator comprising the virtual 3D teeth model, and performing a virtual dynamical articulation.

25

The virtual orthodontic appliance may be arranged in relation to the virtual 3D teeth model during the virtual dynamical articulation

The virtual dynamical articulation may provide information relating to the occlusal forces/biomechanical forces experienced by the patient when the orthodontic appliance is used.

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In some embodiments the virtual dynamical articulator is configured to provide a predefined motion which may comprise movement in one or more of the directions:

- 5 - protrusion;
 - retrusion;
 - laterotrusion to the right;
 - laterotrusion to the left;
 - mediotrusion to the right;
 - 10 - mediotrusion to the left;
 - latero-re surtrusion to the right;
 - latero-re surtrusion to the left.
- 15 In some embodiments, the method comprises
- f): defining the target effect of the orthodontic appliance;
 - g): evaluating from a result of said performed virtual dynamical articulation the effect obtained by the orthodontic appliance during articulation and/or occlusion;
 - 20 h): comparing the obtained effect with the target effect;
 - i): adjusting the virtual orthodontic appliance if the comparison shows that the obtained effect differs from the target effect by more than an effect threshold value;
 - j): optionally repeating g) to i) until the obtained effect differs from the target
 - 25 effect by less than said effect threshold value.

In some embodiments, the effect of the orthodontic appliance on the patient, such as the effect on the patient's teeth, is estimated from the virtual dynamical articulation.

- 5 In some embodiments, the effect relates to an orthodontic effect and/or a biomechanical effect.

In some embodiments, the occlusal forces exerted on teeth in the set of teeth during occlusion are estimated from the virtual dynamical articulation.

10

The virtual dynamical articulation may comprise a dynamical occlusion.

In some embodiments, the first and/or the second occlusion guiding segment is generated from a result of the dynamical virtual occlusion.

- 15 The first and/or the second occlusion guiding surface may be generated from a result of the dynamical virtual occlusion.

- 20 In some embodiments, the second section of the virtual 3D teeth model is taken into account when selecting the first occlusion guiding segment. This may be the case when the virtual orthodontic appliance is designed to provide that the first occlusion guiding segment of a manufactured orthodontic appliance contacts the teeth according to the second section of the virtual 3D teeth model during occlusion.

- 25 In some embodiments, the target effect can be reached by providing a target force to the patient's teeth during e.g. occlusion, where the target force is realized due to having the manufactured orthodontic appliance arranged in relation to the patient's teeth.

- 30 In some embodiments, the obtained effect is described by a measure of the forces obtained on the patient's teeth during occlusion when the orthodontic

appliance manufactured from the present form of the virtual model is arranged in relation to the patient's teeth. A measure of the obtained forces applied to the teeth during the occlusion and hence the obtained effect can be estimated from the virtual dynamical articulation.

5

In some embodiments, the comparison between the target force and the obtained force is provided in the form of a two-dimensional mapping of the difference over the tooth contacting surfaces. The iterative process of step j above may then be stopped when the difference is below the effect threshold value.

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The effect threshold value may be represented by a maximum local value such that there is a limitation to how much the obtained force may differ from the target force at any part of the first and/or second tooth contacting surface.

15

The effect threshold value may be represented as an integrated value measured over the first and/or second tooth contacting surface.

The effect threshold value may relate to a measure of the contact distribution over one or more surfaces of the teeth, such as the occlusal surfaces of the teeth, during occlusion if the orthodontic appliance is manufactured from the present form of the virtual model. The effect threshold value may comprise a two-dimensional mapping of the contact distribution over the occlusal surfaces of all teeth in the first section of the virtual 3D teeth model or over selected teeth.

25

The effect threshold value may be defined by a single value or an interval of values.

In some embodiments, the method comprises obtaining a trace showing any collisions between the adjoining occlusal surfaces of opposing sections of the

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set of teeth during the virtual articulation, and where the first and/or second occlusion guiding surfaces are selected from this trace.

5 In some embodiments, the method comprises obtaining a trace showing any collisions between the adjoining occlusal surfaces of opposing sections of the set of teeth during the virtual dynamical articulation, and the first and/or second occlusion guiding surfaces may be generated from this trace.

10 In some embodiments, the virtual dynamical articulation provides a trace showing any collisions between adjoining surfaces of the virtual orthodontic appliance during the virtual dynamical articulation.

The first and/or second occlusion guiding segment may be selected from said trace. The first and/or second occlusion guiding surfaces may be generated from said trace.

15

In some embodiments, the virtual dynamical articulation provides a trace showing any collisions between the first occlusion guiding surface and an adjoining surface of the second section of the set of teeth during the virtual dynamical articulation. The first occlusion guiding segment may be selected from said trace. The first occlusion guiding surface may be generated from said trace.

25 In some embodiments, the virtual dynamical articulation provides a trace showing any collisions between the first and second occlusion guiding surfaces of the virtual orthodontic appliance during the virtual dynamical articulation, and the first and second occlusion guiding surfaces may be generated from said trace.

30 In some embodiments, the generating of the first and/or second occlusion guiding surfaces from said trace may comprise a process, wherein a trace is

obtained using one version of the virtual orthodontic appliance and the result of that trace is used to modify this version to obtain a new version of the virtual orthodontic appliance. The process may be used one or more times, such as in an iterative process.

5

In some embodiments, a post-treatment trace is compared to a pre-treatment trace such that the effect of a treatment can be compared with an expected effect of the treatment based on the orthodontic appliance used in the treatment.

10

In some embodiments, the method comprises:

- i. determining a target virtual dynamical articulation;
- ii. performing said virtual dynamical articulation with the virtual model positioned anatomically correct at the 3D model, and
- 15 iii. adjusting the virtual model of the orthodontic appliance based on a result of the virtual dynamical articulation,

where ii) and iii) are performed as an iterative process until the virtual model is such that the target virtual dynamical articulation is obtained.

- 20 The target virtual dynamical articulation may be derived from the target effect of the orthodontic appliance.

The method may comprise using a virtual dynamical articulator for simulating occlusion of teeth.

25

In some embodiments, the method may comprise:

- providing a virtual dynamical articulator comprising a virtual 3D teeth model comprising the upper jaw, defined as the virtual upper jaw, and a virtual 3D
30 teeth model comprising the lower jaw, defined as the virtual lower jaw,

resembling the upper jaw and lower jaw, respectively, of the patient's mouth;
and

- providing movement of the virtual upper jaw and the virtual lower jaw
5 relative to each other for simulating dynamic occlusion, whereby collisions
between teeth in the virtual upper and virtual lower jaw occur.

The teeth in the virtual upper jaw and virtual lower jaw may be blocked from
10 penetrating each other's virtual surfaces in the collisions.

The virtual dynamical articulator can be used for treatment planning in
orthodontics simulating a dynamic occlusion of the teeth in the orthodontic
cases.

15

The orthodontic appliance manufactured from said virtual orthodontic
appliance may be configured to be part of an orthodontic treatment and the
method may comprise an orthodontic treatment planning which the virtual
model may be generated as a part of.

20

In some embodiments, treatment planning in orthodontics comprises
segmenting teeth, moving teeth, and/or simulating motion of jaws and teeth.

Thus when using a virtual dynamical articulator in treatment planning, teeth
segmentation may be performed virtually, teeth movement may be performed
25 virtually, motion simulation may be performed virtually etc.

Treatment planning may comprise providing the existing dental situation for a
patient, and providing a desired final dental situation after orthodontic
treatment, and then using the method of virtual dynamical articulation for
testing and simulating whether the final dental situation is suitable.

30

When using the method of virtual dynamical articulation in relation to an orthodontic treatment, preferably no teeth parts should be cut away, but a tooth colliding with another tooth may be moved, rotated, turned, etc. in a directions so that undesired collision is avoided in the real bite of the patient.

5 When the orthodontic appliance is used by the patient, collisions between the teeth and or between the orthodontic appliance and the teeth may be provided. The location and force applied to the teeth during these collisions may be such that a malocclusion treatment based on functional orthodontics is obtained.

10

In some embodiments, collisions between teeth and/or the orthodontic appliance are hence introduced or controlled by the orthodontic appliance.

In some embodiments, the method aims at reducing collisions present for a
15 pre-treatment set of teeth of the patient. The orthodontic appliance manufactured from the generated virtual model may then be such that a change in the arrangement of the teeth is such that said collisions are reduced. The reduction may be provided by an orthodontic appliance which when used by the patient provides collisions that provide the required change
20 of the set of teeth such that the original collisions of the set of teeth are reduced/ the problems relating to the original collisions are mitigated.

In some embodiments, the method comprises registering the trace of collisions, and based on this the orthodontic treatment, e.g. movement of the different teeth, is planned.

25

In some embodiments, the method comprises assigning a weight to one or more teeth.

In some embodiments, the weight assigned to a tooth determines how
30 susceptible the tooth is to movement.

In some embodiments, a high weight signifies that the tooth must not be moved, a low weight signifies that it is under all circumstances allowed to move the tooth, and a medium weight signifies that it is allowed to move the tooth if suitable for the treatment.

- 5 It may be an advantage to assign different weights to the teeth to control and guide the treatment, e.g. movement, since some teeth may have a function or a position already which is important for e.g. the functionality of the bite, and these teeth should maybe by no means be moved. Whereas other teeth have no important function or position, and it may therefore be insignificant
- 10 for the functionality or visual aesthetics if those teeth are moved. The middle group may comprise a number of different weights over a range, and if two teeth are colliding undesirably during simulating, then for example the tooth with the lowest weight is the one which should be moved.

- 15 In some embodiments two or more teeth are locked together, whereby the two or more teeth are configured to move as an entity.
It may be an advantage that teeth can be locked together, since it may be desired that for example the front teeth are not moved relative to each other.

- 20 In some embodiments the treatment planning and the occlusion simulation is performed in an iterative manner, whereby each time a change is made in the treatment plan, the occlusion is simulated.

- 25 In some embodiments constraints of movement of one or more teeth are implemented.

In some embodiments modeling of orthodontic appliances is configured to be performed.

- 30 In some embodiments the patient's occlusion with the modeled appliances is configured to be simulated.

In some embodiments the modeling of the appliances are performed in an iterative manner, whereby for each change in the appliances, the occlusion is simulated.

5

In some embodiments appliances for the upper jaw and appliances for the lower jaw are modeled in parallel.

10 In some embodiments occlusion of the present set of teeth is simulated, and the one or more designed appliances is/are optionally included in the simulation.

In some embodiments the one or more designed appliances are modified based on the occlusion simulation.

15

In some embodiments the one or more appliances are modified with respect to position and/or anatomy.

20 In some embodiments the virtual dynamical articulator is configured to maintain the upper and lower models in an open position.

It may be an advantage that the teeth models in the virtual dynamical articulator can be held in an open position because for some orthodontic cases appliances should be designed which keeps the upper and lower jaw in an open position with a distance to each other such that the bite can be remodelled. When keeping the models in an open position in the virtual
25 dynamical articulator these appliances for providing a distance between the teeth can be designed. Thus appliance which raised and opens the bite can be designed using the virtual dynamical articulator.

30 In some embodiments the teeth in the virtual dynamical articulator are color coded for indicating contact between teeth.

In some embodiments the time-wise sequence of events in the occlusion simulation is registered.

- 5 In some embodiments an occlusal compass is generated based on the virtual dynamical articulation.

In some embodiments the occlusal contact forces in one or more parts on the teeth is registered.

10

In some embodiments the occlusal contact forces over time in one or more parts of the teeth are registered.

- 15 In some embodiments the occlusal contact forces are registered by means of an electronic sensor for measuring the occlusal contact forces.

In some embodiments the registered occlusal contact forces are transferred to the virtual dynamical articulator.

- 20 It may be an advantage to use an electronic sensor for measuring the occlusal contact forces, e.g. a T-Scan III (R) from Tekscan, since hereby the occlusal contact forces can be determined in the mouth of the patient and transferred electronically to the virtual dynamical articulator for use in the simulation of dynamic occlusion. The virtual dynamical articulation and simulation of the patient's bite may be enhanced using the occlusal contact
25 force measurement.

In some embodiments the force of occlusion is simulated.

The simulation may be performed in the software, using e.g. the virtual dynamical articulator.

30

In some embodiments the registered and/or simulated force of occlusion is visualized.

5 In some embodiments a biophysical model of the functionality of the jaws and the force of the occlusion is generated.

In some embodiments data from a force measurement is recorded by means of an electronic component in the patient's mouth.

10 In some embodiments the data from the force measurement is transferred into and overlaid in the virtual dynamical articulator.

15 In some embodiments a CT scan of the patient's mouth is generated, and a virtual 3D model of the patient's mouth is automatically generated based on the scan, and occlusion is configured to be simulated based on the 3D CT model.

20 In some embodiments the positions and/or sizes of the jaw muscles are derived from the CT scan, and based on the muscles the strength of the occlusion is configured to be simulated.

In some embodiments a CT scan of at least part of the patient's skull is transferred into the virtual dynamical articulator.

25 In some embodiments constraints to the simulation of the occlusion are derived from the CT scan.

In some embodiments one or more tooth roots are visible on the CT scan, and the position of the tooth roots are used to simulate movement of teeth.

30

In some embodiments a 2D image of the patient is transferred into the virtual dynamical articulator.

5 In some embodiments a weight assigned to a tooth determines its functionality importance in guiding the occlusion of the patient.

In some embodiments a high weight signifies that the tooth is important for guiding the occlusion.

10 In some embodiments a low weight signifies that the tooth is not important for guiding the occlusion.

In some embodiments a medium weight signifies that tooth's importance for guiding the occlusion is medium.

15

In some embodiments the central teeth and/or the canines is/are assigned a high weight.

It may be an advantage to assign a high weight to the centrals and/or to the canines in the upper and/or lower jaw, since these teeth often are the most important teeth for guiding the occlusion, since they are the longest teeth. Thus if these teeth are important for guiding the occlusion, they should preferably not be moved, shortened, removed, restored etc, since this could influence the occlusion negatively.

20

25 In some embodiments one or more contact criteria for occlusion is defined and used in simulation of occlusion.

In some embodiments the one or more contact criteria comprises:

- specific teeth must be in contact with each other;

30

- a maximum number of teeth must be in contact;

- a maximum area of the teeth surfaces must be in contact;

- specific teeth must not be in contact;
 - a maximum number of contact points must be obtained;
 - contact points must be evenly spatially distributed over the surface of teeth;
and/or
- 5 - the contact points between teeth must not be disclosed more than a certain distance during certain dynamic occlusion movements.

The contact criteria may be used to estimate, correct, and/or improve the virtual dynamical articulator model, e.g. the geometrical and/or physiological
10 model of the virtual dynamical articulator.

Parameters of the virtual dynamical articulator model may be automatically optimized, adjusted, corrected, defined, determined etc. by simulating the movement of the jaws in the articulator, and the simulation may be based on
15 the virtual dynamical articulator model.

For example the operator may often wish to optimize the condyle inclination, since this an important parameter for many cases.

By improving the occlusion by means of parameters and contact criteria, the quality of the occlusion will be improved in relation to the patient's real,
20 physiologic occlusion.

For example if there are mistakes or faults in the data of the patient's occlusion taken from the mechanical articulator, the facebow etc., then the occlusion can be corrected using parameters and contact criteria.
25

Disclosed is also an orthodontic appliance for use in an orthodontic treatment planning, where the appliance is designed according to the present method.

In some embodiments, the target effect of the orthodontic appliance is to
30 provide that the patient's teeth are arranged according to a target arrangement of the teeth.

In some embodiments, the target configuration of the set of teeth relates to a relative teeth arrangement of the teeth in the upper jaw and/or to a relative arrangement of the teeth in the lower upper jaw.

5

In some embodiments, the target effect of the orthodontic appliance is to provide that the patient's teeth are arranged according to a target articulation.

10 In some embodiments, the method comprises a treatment plan configured for adjusting the occlusion of the set of teeth from an observed occlusion towards a target occlusion and/or for adjusting the arrangement of the set of teeth from an observed arrangement towards a target arrangement and/or for adjusting the articulation of the set of teeth from an observed articulation towards a target articulation.

15

The method may comprise selecting a tooth treatment pattern from a library of predetermined tooth treatment patterns and generating a malocclusion treatment plan implementing the selected tooth treatment pattern. A series of successive tooth arrangements may be generated such that the arrangement
20 of teeth progress from a first tooth arrangement to a second tooth arrangement when the malocclusion treatment plan is applied to the set of teeth of a patient. The generating of the malocclusion treatment plan may comprise determining one or more tooth paths based on the selected tooth treatment pattern

25 The treatment plan may comprise a number of steps, where each step of the treatment plan may require a specific orthodontic appliance. The specific orthodontic appliance of one step in the treatment plan may adjust the tooth arrangement from one arrangement to another.

The method may comprise calculating the number of steps and accordingly
30 the number of orthodontic appliances required for the treatment plan.

In some embodiments, the treatment plan comprises providing some constraints to one or more teeth in the set of teeth. These constraints may relate to the absolute or relative arrangement of the one or more teeth in the set of teeth. These constraints may relate to the absolute or relative
5 arrangement of the one or more teeth in the mouth of the patient.

The method may thus comprise a marking of one or more teeth which should be maintained in a fixed position in relation to the remaining teeth or in relation to the mouth during an orthodontic treatment.

For a treatment plan comprising a number of steps, some constraints may be
10 applied to some steps while other constraints may be applied to other steps of the treatment plan.

In some embodiments, the method comprises deriving the number of steps and accordingly the number of orthodontic appliances required for the treatment plan.

15 In some embodiments, each step of the treatment plan requires a specific orthodontic appliance. Each specific orthodontic appliance may be manufactured from a virtual orthodontic appliance generated with the method according to the present invention.

20 For a number of said treatment steps, a trace obtained by a virtual dynamical articulation before the step may be compared to a trace obtained by a virtual dynamical articulation after the step.

In some embodiments, the first part of the virtual orthodontic appliance is in
25 contact with teeth of the first section of the virtual 3D teeth model over at least a portion of the tooth contacting surface of the first part.

In some embodiments, a gap is provided between the first part of the virtual
30 orthodontic appliance and the teeth of the first section of the virtual 3D teeth model over at least a portion of the tooth contacting surface of the first part.

The first tooth contacting surface may be configured such that contact is established over a specific area of one or more teeth in the first section.

5 The contact between the first part of the virtual orthodontic appliance and the first section of the virtual 3D teeth model may be distributed uniformly or non-uniformly over first tooth contacting surface.

10 The generated virtual orthodontic appliance may be designed such that the orthodontic appliance manufactured from the virtual model realizes a target effect.

In some embodiments, the target effect of the orthodontic appliance is to correct for a malocclusion of the set of teeth, and the target geometrical relationship between the upper and lower jaw may be configured to correct for this malocclusion.

15 In some embodiments, the effect of the orthodontic appliance is to modify a biomechanical situation of the patient, such as Temporomandibular joint disorder or a muscular situation in e.g. the patients neck linked to the patient's mastication, and the target geometrical relationship between the
20 upper and lower jaw may be configured to modify this biomechanical situation.

In some embodiments, the effect of the orthodontic appliance is to provide a protection of the set of teeth, such as where the orthodontic appliance
25 comprises a mouthguard.

The orthodontic appliance may comprise a teeth protection device.

30 In the context of the present invention, the phrase "orthodontic appliance" may also covers mouth guards, i.e. devices that not necessary provides an orthodontic treatment. In principle, the phrase may cover any intraoral device which is designed to be positioned at the teeth to provide a target effect.

In some embodiments, the orthodontic appliance is configured for an orthodontic treatment. The orthodontic treatment may be selected from the group of malocclusion treatment, a treatment of a dentofacial deformity, a treatment of a Temporomandibular joint disorder or modification of a biomechanical situation of the patient.

In some embodiments, the patient data set comprises a diagnosis relating to a dental problem of the set of teeth of the patient, and the target effect of the orthodontic appliance relates to this diagnosis.

In some embodiments, a diagnosis for the patient is derived from said patient data set, and the target effect of the orthodontic appliance relates to this diagnosis.

The diagnosis may be selected from the group of a malocclusion, a dentofacial deformity, Temporomandibular joint disorder, a muscular situation, or snoring.

The patient data set may comprise one or more of the result of a virtual dynamical articulation of the set of teeth, the set of teeth arranged in a static occlusion, the occlusion of the set of teeth, disclusion of the set of teeth, a digital representation of the masticatory system of the patient, a static articulation/occlusion of the set of teeth, an analysis of the bite force and/or timing of the contact between the different contacting surfaces of the set of teeth during an occlusion, the result of an Electromyography, the result of activation/stimulation of the muscles in e.g. the neck or jaw region of the patient, an analysis of the biomechanical forces active during occlusion, the arrangement and motion of soft tissue such as the tongue, the lips and the buccal tissue.

In some embodiments, a target arrangement of the set of teeth is determined from the virtual 3D teeth model provided in said patient data set.

The target arrangement may also be determined using rules or by selecting from a library of "ideal" tooth configurations

5

In the context of the present invention the phrase "X determined from Y" may refer to the case wherein determining X takes into account Y. Other parameters may still influence X.

10 The set of teeth may comprise some or all of the patient's teeth.

In some embodiments, the virtual orthodontic appliance is such that the manufactured orthodontic appliance is for applications within functional orthodontics and the effect of the orthodontic appliance may be obtained
15 utilizing biomechanical forces of the patient, i.e. where the orthodontic appliance utilizes the muscle action of the patient to produce orthodontic or orthopaedic forces. The relative motion of the upper and lower jaw may contribute to the orthodontic treatment. Such appliances are also known as dentofacial orthopaedic appliances.

20 The first and/or the second part of the virtual orthodontic appliance may be such that a manufactured orthodontic appliance will exert a force or a pressure on at least one section of the set of teeth during occlusion/a bite.

25 In some embodiments, a functional orthodontic appliance comprises a removable functional appliance.

The removable functional appliance may be selected from the group of an Andresen Appliance, a Bionator, a Biobloc, a Clark Twin Block, a Bass Dynamax, or a Medium Opening Activator

30 In some embodiments, a functional orthodontic appliance comprises a fixed functional appliance.

The fixed functional appliance may be selected from the group of a Herbst orthodontic appliance or a Fixed Twin Block orthodontic appliance.

5 The effect of a malocclusion on other parts of the patient muscular-skeletal system may be evaluated and corrected for in a malocclusion treatment

The orthodontic appliance may be a removable appliance or a fixed appliance.

10 In some embodiment the orthodontic appliance is selected from the group of braces, brackets, splints, retainers, arch-wires, aligners, andr shells.

In some embodiments, the orthodontic appliance is configured for applications within active orthodontics such that the orthodontic appliance is
15 configured to apply force/pressure to the teeth to change the relationship of the teeth. The active orthodontic appliance may be selected from the group of bite-appliance, a Herbst appliance, an Expansion and Labial Segment Alignment Appliance (ELSAA), a Pin and Tube Appliance, a Ribbon Arch Appliance, a Begg Lightwire Appliance, an Edgewise Appliance, a Pre-
20 adjusted Edgewise Appliance, a Self-ligating Edgewise Appliance, a Bi Helix, a Tri Helix, a Quad Helix, a Rapid Maxillary Expansion Appliance (RME) or a pin stripe appliance.

In some embodiments, the orthodontic appliance is configured for
25 applications within passive orthodontics.

The passive orthodontic appliance may be selected from the group of a Space Maintainer or a retainer, such as a Hawley Retainer, a Begg Retainer a Vacuum Formed "Essix" Retainer, or a Bonded "Twistflex" Retainer

30 An Andresen Appliance may be configured to reduce an overbite of a patient, making the molars over-erupt.

A Bionators may initially look like a sort of combined upper and lower Hawley retainer, but do not fasten to the teeth and is not used for post-brace removal treatment. Bionators are held in the mouth within the space that the teeth surround when biting. They are used to expand the palate of the mouth and
5 create space for incoming teeth. A Hawley retainer may comprise a metal wire that surrounds the teeth and keeps them in place

A Biobloc may be an appliance used to posture forward the lower jaw.

A Clark Twin Block orthodontic appliance may incorporates the use of upper and lower bite blocks to position the mandible forward for skeletal Class II
10 correction.

A Bass Dynamax orthodontic appliance may be similar in principle to the Clark Twin Block. It is based around a prefabricated modular spring, built into a maxillary (upper) occlusal splint. Two integral vertical springs make contact with a fixed lingual arch or removable lower appliance to posture the
15 mandible (lower jaw) forward for skeletal Class II correction. A lingual arch may be an orthodontic device which connects two molars in the upper or lower dental arch

A Medium Opening Activator is a modified version of the Andresen appliance.

A Herbst Appliance may correct overbites by holding the lower jaw in a protrusive position. It is similar to the Twin Block Appliance except that it is fixed in place and hence non-removable. This appliance is most commonly used in non-compliant patients. The Herbst appliance is very effective in
20 correcting large overbites due to small lower jaws in patients that are growing.
25

In some embodiments, the orthodontic appliance comprises a Twin Block appliance. This appliance may be made up of two separate appliances that work together as one. The upper plate of the appliance may comprise an
30 optional expansion screw to widen the upper arch of the patient, if needed, as well as pads to cover the molars. The lower plate may comprise pads to

cover the lower bicuspid. These upper and the lower plate may interlock at an angle such that they move the patient's lower jaw forward and lock it into the ideal position when the patient bite together. This new position, while temporary, will eventually become the permanent corrected position.

5

In some embodiments, the virtual orthodontic appliance is configured to provide that the manufactured orthodontic appliance retains teeth in their position.

10 In some embodiments, the virtual orthodontic appliance is configured to provide that the manufactured orthodontic appliance hinders the patient from grinding his teeth

The orthodontic appliance may comprise a surgical wafer.

15

In some embodiments, the virtual orthodontic appliance is configured to provide that the manufactured orthodontic appliance hinder the patient from snoring in his sleep.

The orthodontic appliance may comprise an anti-snoring device.

20 In some embodiments, the virtual orthodontic appliance is configured to provide that the manufactured orthodontic appliance be comfortable to wear for the patient.

25 In some embodiments, the virtual model of the orthodontic appliance comprises a connecting structure arranged between the first and second parts, such that the first and second parts of a manufactured orthodontic appliance are physically connected by said connecting structure.

30 In some embodiments, the first and or occlusion guiding segment comprises a connecting structure arranged to connect the first and second parts of the orthodontic appliance, such that the first and second parts of an orthodontic

appliance manufactured from the virtual orthodontic appliance are physically connected by said connecting structure.

5 In some embodiments, the virtual orthodontic appliance is configured such that a relative movement of the first and second parts of the manufactured orthodontic appliance is allowed.

The connecting structure may be configured for guiding the relative motion of the first and second parts of the orthodontic appliance.

10 The connecting structure may comprise a spring, a guiding rod or a piston.

In some embodiments, the method comprises generating at least one surface of the virtual orthodontic appliance by subtracting the first section of the virtual 3D teeth model from a predefined 2D profile of the appliance cross section, where the predefined 2D profile is selected from a library.

15 The at least one surface may be a facial/buccal, a lingual and/or an occlusal surface of the virtual orthodontic appliance.

In some embodiments, the method comprises generating the virtual orthodontic appliance from a 2D profile. The 2D profile may depict the cross sectional form of at least one surface of the virtual orthodontic appliance, such as the tooth contacting surface and/or the occlusion guiding surface.

25 In the context of the present invention, the phrase "cross section form" may refer to the profile of the virtual orthodontic appliance in a plane perpendicular to the occlusal plane of the set of teeth and to the dental arch of the section of the set of teeth at which the virtual orthodontic appliance is positioned.

30 In some embodiments, the 2D profile changes along the arc of the set of teeth. A change in the 2D profile cross section of the virtual orthodontic

appliance may be related to a change in a guiding structure on an occlusal guiding surface of the virtual orthodontic appliance. The change of the guiding structure may be such that a displacement force provided to e.g. the upper part of the set of teeth changes along the dental arc of the set of teeth.

- 5 The orthodontic appliance may provide a displacement force which is smaller or larger in the left side than in the right side of the set of teeth, or vice versa.

In some embodiments, the 2D profile is substantially maintained along the arc of the set of teeth.

10

In some embodiments, the 2D profile is a predefined 2D profile selected from a library.

The predefined 2D profile may be bar-shaped along the arc of the set of teeth.

15

The method may comprise modifying the predefined 2D profile along at least a portion of the arc. An operator may e.g. adjust the height, width and/or shape of the cross sectional of the 2D profile.

- 20 In some embodiments, the 2D profile is visualized with control points, where the position of the control points in the 2D plane can be adjusted by the operator.

- 25 In some embodiments, the method comprises obtaining a 2D profile describing at least an outer shape of the appliance cross section, and where the first tooth contacting surface is generated by subtracting a corresponding cross section of the first section of the virtual 3D teeth model from the 2D profile.

- 30 In some embodiments, the generating of the first part of the virtual orthodontic appliance comprises subtracting the first section from the predefined 2D profile or the modified 2D profile.

In some embodiments, the method comprises removing undercuts. The undercuts may appear at the lower portion of the teeth where the cross section of the tooth is smaller than at the occlusal plane.

5

In some embodiments, the properties of the material(s) used for manufacturing the orthodontic appliance are taken into account when generating the virtual orthodontic appliance.

The material properties may be included in the generation of the virtual
10 orthodontic appliance.

Using a flexible material at the tooth contacting surface of the manufactured orthodontic appliance may allow for some undercut at the lower part of the teeth. This may allow for instance retainers to be more securely fixed to the
15 patient's teeth.

The first and second sections may correspond to opposite sections of the virtual 3D teeth model

20 In some embodiments, the first section of the 3D model corresponds to a right section of the set of teeth, and the second section corresponds to a left section of the set of teeth, or vice versa.

The opposing first and second sections of the virtual 3D teeth model may be arranged opposite to each other relative to the sagittal plane of the patient.

25 For example, when using the universal tooth designation system, the first section may comprise teeth 14-16 and the second section may comprise teeth 1-3.

In some embodiments, the first section of the 3D model comprises at least
30 section of the upper jaw of the set of teeth, and the second section comprises at least section of the lower jaw of the set of teeth, or vice versa.

The opposing sections of the 3D model may be arranged opposite to each other relative to the occlusal plane of the patient.

For example, when using the universal tooth designation system, the first section may comprise teeth 14-16 and the second section may comprise
5 teeth 17-19.

The generating of the first and/or second occlusion guiding surface may thus take into account at least one tooth in the lower jaw (a mandibular tooth) and at least one tooth in the upper jaw (a maxillary tooth).

10 In some embodiments, all the mandibular and/or all the maxillary teeth of the virtual 3D teeth model are used when generating the first and/or second occlusion guiding surface.

In some embodiments, only part of the mandibular and/or part of the maxillary teeth of the virtual 3D teeth model is taken into account when
15 generating the first and/or second occlusion guiding surface.

In some embodiments, the first section of the 3D model corresponds to an anterior section of the set of teeth, and the second section corresponds to a posterior section of the set of teeth, or vice versa.

20

In some embodiments the method comprises defining a target contact distribution between a part of the virtual orthodontic appliance and a section of the virtual 3D teeth model.

25 When the orthodontic appliance manufactured from the virtual orthodontic appliance is arranged at the patient's teeth, the portion(s) of the orthodontic appliance corresponding to the target contact distribution contacts the patient's teeth.

30 The effect threshold value may relate to a measure of the contact distribution over one or more surfaces of the teeth, such as the occlusal surfaces of the

teeth, during occlusion if the orthodontic appliance is manufactured from the present form of the virtual model. The effect threshold value may comprise a two-dimensional mapping of the contact distribution over the occlusal surfaces of all teeth in the first section of the virtual 3D teeth model or over
5 selected teeth.

The virtual orthodontic appliance may be adjusted if a result of e.g. a virtual dynamical articulation shows that a present contact distribution differs from the target contact distribution by more than a contact threshold value.

10 The target contact distribution may relate to the contact between said first part of the virtual orthodontic appliance and said first section of the virtual 3D teeth model, such as between the first tooth contacting surface and a surface of the teeth in the first section.

15 In some embodiments, the target contact distribution is between the first occlusion guiding surface and the occlusal surface of teeth in the second section of the virtual 3D teeth model, or vice versa.

In some embodiments, the target contact distribution is between the first and
20 second occlusion guiding surfaces.

In some embodiments, the target geometrical relationship comprises a fixed occlusion, such as for a fully constrained relationship between the upper and lower jaw of the set of teeth.
25

A fully or a guided relationship may relate to the relative movement of the first and second sections of the set of teeth in one or more relative directions.

A fully or a guided relationship may be provided by the shape of the
30 orthodontic appliance manufactured from the virtual appliance, where said

shape constrains the relative movement of the first and second sections of the set of teeth at least in one relative direction.

5 In some embodiments, the method comprises identifying a target occlusion of the set of teeth, and where said virtual orthodontic appliance may be for manufacturing an orthodontic appliance configured for providing the target occlusion.

10 In some embodiments, the method comprises identifying a target arrangement of the teeth in the set of teeth, and said virtual application may be for manufacturing an orthodontic appliance configured for providing the target arrangement.

15 In some embodiments, the method comprises identifying a target articulation of the set of teeth and where said virtual application may be for manufacturing an orthodontic appliance configured for providing the target articulation.

20 In some embodiments, the method comprises virtually rearranging individual teeth and/or groups of teeth in the virtual 3D teeth model.

25 In some embodiments, the virtual orthodontic appliance is adjusted by an additive process or a subtractive process where material virtually is added or removed from the virtual orthodontic appliance, such as virtually added to a modified surface or virtually removed from the modified surface of the first and/or second part of the virtual orthodontic appliance

30 In some embodiments, the modified surface is selected from the group of the first occlusion guiding surface, the second occlusion guiding surface, the first tooth contacting surface, the second tooth contacting surface, the occlusal surface of the first part, the occlusal surface of the second part, a surface of

the virtual orthodontic appliance facing the sagittal plane of the virtual 3D teeth model, a surface of the virtual orthodontic appliance facing the anterior/posterior plane of the virtual 3D teeth model.

- 5 In some embodiments, the tongue and/or buccal and labial tissues of the patient are taken into account when generating the first and/or the second occlusion guiding surface.

The pressure provided on the set of teeth by the tongue and by the buccal and labial tissues may affect the occlusion and could preferably be taken into
10 account. The tongue may provide an outwards directed pressure while the buccal and labial tissues may provide an inwards directed pressure on the teeth. The shape of the orthodontic appliance may e.g. compensate for these pressures. The 3D model may comprise the tongue and/or the buccal and labial tissues.

15

An initial virtual orthodontic appliance may be provided by selecting among predefined virtual orthodontic appliances from a library. The library may comprise a STL file format or a number of predefined profiles.

- 20 The method may comprise a Boolean operation for combining a number of functionalities and/or features from a library.

The method may comprise combining a number of operations on the first and/or second part of the virtual orthodontic appliance.

25

In some embodiments, the method comprises applying rules in the generation of the first and/or the second occlusion guiding surface.

- In some embodiments, the method comprises applying rules in the
30 generation of the first and/or the second occlusion guiding segment.

The rules may relate to medical, biological, biomechanical orthodontic, physical and/or orthodontic parameters.

5 The method may comprise modifying the orthodontic appliance manually with tools supplied by computer software.

The method may comprise generating the orthodontic appliance manually with a freeform tool supplied by computer software.

10 In some embodiments, the first and/or the second occlusion guiding surface is generated from an occlusal compass.

15 In some embodiments an occlusal compass is generated by real dynamic occlusion in the patient's mouth and subsequently transferred to the virtual dynamical articulator.

In some embodiments the occlusal compass indicates movements in the following directions:

- protrusion;
- 20 - retrusion;
- laterotrusion to the right;
- laterotrusion to the left;
- mediotrusion to the right;
- mediotrusion to the left;
- 25 - latero-re surtrusion to the right;
- latero-re surtrusion to the left.

In some embodiments the occlusal compass indicates the different movement directions with different colors on the teeth.

An occlusal compass for a cusp is a three-dimensional pattern, which is a summation of a cusp's movement in all three planes of motion. The occlusal compass has elevations and depressions, and for any given cusp it may vary from that of any other cusp as a function of its relationship to the mandibular rotation centers. It may thus be an advantage to use occlusal compasses, since there is not one type of occlusal morphology suitable for every patient.

In some embodiments, b), c) and d) are performed in one step.

In some embodiments, a minimal thickness of the virtual orthodontic appliance is ensured to provide that the orthodontic appliance is sufficiently robust.

The minimal thickness may be such that the thinnest point of the walls of the manufactured orthodontic appliance is more than about 0.5 mm, such as more than about 1 mm, such as more than about 1.5 mm, such as more than about 2 mm, such as more than about 2.5 mm, such as more than about 3 mm, such as more than about 4 mm, such as more than about .5 mm.

In some embodiments, the method comprises visualizing the result of the orthodontic treatment, such as visualizing the post-orthodontic result, such as the result of the mal-occlusion treatment. The visualization may comprise the trace or a 3D image of the set of teeth or the collision points on the teeth.

In some embodiments, the effect of the orthodontic appliance on the patient is estimated from a distribution of collision points measured using the virtual dynamical articulation. The collision points may e.g. appear at collisions between the parts of the virtual orthodontic appliance and a section of the virtual 3D teeth model.

In some embodiments, the method comprises adjusting the virtual orthodontic appliance based on the estimated effect of the orthodontic appliance.

In some embodiments, the method comprises repeating the estimation of the obtained effect and the adjusting of the virtual orthodontic appliance until the distribution of the collisions points is accepted.

5

In some embodiments, the virtual 3D teeth model is modified using CAD computer code.

The virtual orthodontic appliance may be for manufacturing a coherent
10 orthodontic appliance where the first and second parts are permanently in
physical contact at least when the orthodontic appliance is positioned in the
patient's mouth. The orthodontic appliance may consist of one solid or
coherent part, such that the manufactured orthodontic appliance is in one
15 piece. The manufactured orthodontic appliance may comprise different
materials attached to each other thus forming a solid one-piece orthodontic
appliance. The attachment of the different materials to each other may be
permanent or releasable.

In some embodiments, the manufactured orthodontic appliance comprises
20 two parts, where the first part of the orthodontic appliance may be configured
to be positioned at the lower part of said set of teeth, such as at the teeth of
the lower jaw, and the second part of the orthodontic appliance may be
configured to be positioned at the upper part of said set of teeth, such as at
the teeth of the upper jaw.

25

Disclosed is a method for generating at least a portion of a virtual orthodontic
appliance for manufacturing an orthodontic appliance for a patient's set of
teeth, the method comprising:

30 a): obtaining a patient data set for said patient, the patient data set
comprising a virtual 3D teeth model, where the virtual 3D teeth model

comprises a virtual upper jaw and a virtual lower jaw resembling at least part of the patient's upper jaw and lower jaw, respectively, with a first section of the virtual 3D teeth model corresponding to a section of the patient's set of teeth at which a first part of the manufactured orthodontic appliance is to be arranged;

b): generating a first boundary curve for the virtual orthodontic appliance;

c): generating a first tooth contacting surface of the virtual orthodontic appliance, where said first tooth contacting surface at least partly is shaped according to teeth in the first section of the virtual 3D teeth model and is bounded by said first boundary curve;

d): generating or selecting a first occlusion guiding segment of the virtual orthodontic appliance, where the first occlusion guiding segment is configured to provide that an orthodontic appliance manufactured from the virtual orthodontic appliance is capable of guiding the patient's upper and lower jaw towards a target geometrical relationship during occlusion or of maintaining the patient's upper and lower jaw in a target geometrical relationship; and

e): generating a first connecting surface configured for connecting the first boundary curve and the first occlusion guiding segment.

In some embodiments, the first tooth contacting surface at least partly is shaped according to teeth in the first section of the virtual 3D teeth model, such that a portion of the contacting surface in the manufactured orthodontic appliance will contact the teeth when the orthodontic appliance is arranged at the patient's teeth.

In some embodiments, the first tooth contacting surface is bounded by said first boundary curve. The first tooth contacting surface may be formed first and the boundary curve defined next, or *vice versa*.

- 5 Disclosed is a method for generating at least a portion of a virtual orthodontic appliance for manufacturing an orthodontic appliance for a patient, where the virtual orthodontic appliance comprises a first part configured for being positioned at a first section of a virtual 3D teeth model of the patient's teeth, the method comprising:
- 10 a): providing a patient data set for said patient, the patient data set comprising said virtual 3D teeth model, where said virtual 3D teeth model comprises a virtual upper jaw and a virtual lower jaw resembling the upper jaw and lower jaw, respectively, of the patient's mouth;
- b): defining or generating a first boundary curve for a first section of the
15 virtual 3D teeth model;
- c): generating a first tooth contacting surface of the first part of the virtual orthodontic appliance, where said first tooth contacting surface at least partly fits the teeth in the first section of the virtual 3D teeth model and is bounded by said first boundary curve;
- 20 d): generating a first occlusion guiding surface of the first part of the virtual orthodontic appliance, where the first occlusion guiding surface is comprised in or comprises a first occlusal surface of the first part of the virtual orthodontic appliance; and
- e): generating a first connecting surface of the first part of the virtual
25 orthodontic appliance where said first connecting surface is configured for connecting the first boundary curve and the first occlusion guiding surface;
- where the first occlusion guiding surface is configured to define a target geometrical relationship between the upper and lower jaw during occlusion,

where the target geometrical relationship is configured to realize a target effect of the orthodontic appliance.

Disclosed is a computer program product comprising program code means
5 for causing a data processing system to perform the method of any one of the preceding claims, when said program code means are executed on the data processing system.

The computer program product may comprise a computer-readable medium
10 having stored thereon the program code means.

Disclosed is a nontransitory computer readable medium storing thereon a computer program, where said computer program is configured for causing computer-assisted data processing to perform the method of any one of the
15 preceding claims, when said program code means are executed on the data processing system.

The computer program product may comprise a computer-readable medium having stored thereon the program code means.
20

Disclosed is a method for manufacturing at least a portion of an orthodontic appliance for a patient, where the method comprises:

a): providing virtual orthodontic appliance, where the virtual orthodontic
25 appliance is generated using the method according to any of claims 1-82;
and

b): manufacturing the orthodontic appliance or the portion of the orthodontic appliance from said virtual model.
30

The orthodontic appliance may be manufacturing from the virtual orthodontic appliance using different techniques. The techniques may comprise wax and casting, 3D printing, milling, shaping metal parts such as cables and plates. The techniques may be performed alone or in combination.

5

The manufacturing of the orthodontic appliance may comprise a two-material process where different portions of the orthodontic appliance are manufactured in different materials.

10 Disclosed is a method for generating at least a portion of a virtual orthodontic appliance for manufacturing an orthodontic appliance for a patient, where the virtual orthodontic appliance comprises a first part configured for being positioned at a first section of a virtual 3D teeth model of the patient's teeth, the method comprising:

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providing said virtual 3D teeth model, where said virtual 3D teeth model comprises a virtual upper jaw and a virtual lower jaw resembling the upper jaw and lower jaw, respectively, of the patient's mouth;

- I. providing an initial shape of the virtual orthodontic appliance;
- 20 II. determining a target virtual dynamical articulation for the set of teeth;
- III. performing a virtual dynamical articulation with the virtual orthodontic appliance positioned anatomically correct at the 3D model, and
- IV. adjusting the virtual orthodontic appliance based on a result of the virtual dynamical articulation,

25 where III) and IV) are performed as an iterative process until the shape of the virtual orthodontic appliance is change from the initial shape to a final shape where the target virtual dynamical articulation is obtained when the orthodontic appliance is arranged at the patients teeth.

It should be understood that the methods disclosed above and the embodiments thereof can be combined with each other in order to achieve the advantages of the different embodiments.

5 **Embodiments**

1. A method for generating at least a portion of a virtual orthodontic appliance for manufacturing an orthodontic appliance for a patient's set of teeth, the method comprising:

10

a): obtaining a patient data set for said patient, the patient data set comprising a virtual 3D teeth model, where the virtual 3D teeth model comprises a virtual upper jaw and a virtual lower jaw resembling at least part of the patient's upper jaw and lower jaw, respectively, with a first section of the virtual 3D teeth model corresponding to a section of the patient's set of teeth at which a first part of the manufactured orthodontic appliance is to be arranged;

15

b): generating a first boundary curve for the virtual orthodontic appliance;

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c): generating a first tooth contacting surface of the virtual orthodontic appliance, where said first tooth contacting surface at least partly is shaped according to teeth in the first section of the virtual 3D teeth model and is bounded by said first boundary curve;

25

d): generating or selecting a first occlusion guiding segment of the virtual orthodontic appliance, where the first occlusion guiding segment is configured to provide that an orthodontic appliance manufactured from the virtual orthodontic appliance is capable of guiding the patient's upper and lower jaw towards a target geometrical relationship during occlusion or of

30

maintaining the patient's upper and lower jaw in a target geometrical relationship; and

e): generating a first connecting surface configured for connecting the first
5 boundary curve and the first occlusion guiding segment.

2. The method according to any of the previous embodiments, where the first
10 boundary curve is generated in relation to the first section of the virtual 3D
teeth model.

3. The method according to any of the previous embodiments, where the
15 target geometrical relationship is configured to realize a target effect of the
manufactured orthodontic appliance.

4. The method according to any of the previous embodiments, wherein the
first occlusion guiding segment comprises a first occlusion guiding surface.

5. The method according to any of the previous embodiments, wherein the
20 first occlusion guiding segment comprises a first occlusion guiding unit, such
as the telescope part of a Herbst appliance.

6. The method according to any of the previous embodiments, wherein the
25 virtual 3D teeth model relates to teeth and/or root structure of the teeth
and/or the upper jaw bone and/or the lower jaw bone and/or soft tissue, such
as lips, tongue, buccal tissue or the gingiva.

7. The method according to any of the previous embodiments, wherein the
method comprises obtaining a target configuration of the set of teeth.

30

8. The method according to any of the previous embodiments, wherein the virtual 3D teeth model relates to a modified set of teeth.

5 9. The method according to any of the previous embodiments, wherein the modified set of teeth is according to a target configuration of the set of teeth.

10. The method according to any of the previous embodiments, wherein the target configuration of the set of teeth relates to a target relative jaw arrangement of the upper and lower upper jaw in occlusion.

10

11. The method according to any of the previous embodiments, wherein the target configuration of the set of teeth relates to a relative teeth arrangement of the teeth in the upper jaw and/or to a relative arrangement of the teeth in the lower upper jaw.

15

12. The method according to any of the previous embodiments, wherein said virtual 3D teeth model is formed from a 3D representation of an observed set of teeth.

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13. The method according to any of the preceding embodiments, wherein the 3D representation is obtained by a face bow analysis, an occlusal force registration, a scanning the observed set of teeth, such as scanning by means of extra-oral or intraoral scanning of the teeth or by scanning an impression of the teeth or by scanning a physical model of the teeth.

25

14. The method according to any of the previous embodiments, wherein the scanning is performed by means of laser light scanning, white light scanning, probe-scanning, X-ray scanning, CT scanning, a Cone Beam CT, and/or magnetic resonance based imaging.

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15. The method according to any of the previous embodiments, wherein the method comprises generating a second boundary curve for a second section of the virtual 3D teeth model; generating a second tooth contacting surface, where said second tooth contacting surface is shaped according to the teeth
5 in the second section and is bounded by said second boundary curve.

16. The method according to any of the previous embodiments, wherein the virtual orthodontic appliance comprises a second part, and wherein the method comprises:

- 10 • generating a second boundary curve for the virtual orthodontic appliance in relation to a second section of the virtual 3D teeth model;
- generating a second tooth contacting surface of the second part of the virtual orthodontic appliance, where said second tooth contacting surface at least partly is shaped according to the teeth in the second
15 section of the virtual 3D teeth model and is bounded by said second boundary curve;
- generating or selecting a second occlusion guiding segment of the second part of the virtual orthodontic appliance,; and
- generating a second connecting surface of the second part of the
20 virtual orthodontic appliance, where said second connecting surface is configured for connecting the second boundary curve and the second occlusion guiding segment;

where said first and second occlusion guiding segments are configured to provide that an orthodontic appliance manufactured from the virtual
25 orthodontic appliance is capable of guiding the patient's upper and lower jaw towards the target geometrical relationship between the upper and lower jaw during occlusion or of maintaining the patient's upper and lower jaw in the target geometrical relationship.

17. The method according to any of the previous embodiments, wherein a second section of the virtual 3D teeth model corresponds to a section of the patient's set of teeth at section a second part of the manufactured orthodontic appliance is to be arranged

18. The method according to any of the previous embodiments, where the second boundary curve is generated in relation to the second section of the virtual 3D teeth model.

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19. The method according to any of the previous embodiments, wherein the second occlusion guiding segment comprises a second occlusion guiding surface.

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20. The method according to any of the previous embodiments, wherein the second occlusion guiding segment comprises a second occlusion guiding unit.

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21. The method according to any of the previous embodiments, wherein the first and/or second occlusion guiding surface is arranged on a lingual and/or a labial side of teeth in the virtual 3D teeth model.

25

22. The method according to any of the previous embodiments, wherein the first occlusion guiding surface is comprised in or comprises a first occlusal surface of the virtual orthodontic appliance.

30

23. The method according to any of the previous embodiments, wherein the second occlusion guiding surface is comprised in or comprises a second occlusal surface of the virtual orthodontic appliance.

24. The method according to any of the previous embodiments, wherein the second section of the virtual 3D teeth model is taken into account when selecting the first occlusion guiding segment.

5 25. The method according to any of the previous embodiments, wherein the virtual orthodontic appliance is configured to provide that a surface of an orthodontic appliance manufactured from the virtual orthodontic appliance corresponding to the first occlusion guiding surface contacts an occlusal surface of teeth in said second section during occlusion.

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26. The method according to any of the previous embodiments, wherein the second part of the virtual orthodontic appliance is taken into account when selecting the first occlusion guiding segment.

15 27. The method according to any of the previous embodiments, wherein the virtual orthodontic appliance is configured to provide that a surface of an orthodontic appliance manufactured from the virtual orthodontic appliance corresponding to the first occlusion guiding surface contacts the second part of the manufactured orthodontic appliance during occlusion,

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28. The method according to any of the previous embodiments, wherein the virtual orthodontic appliance is configured to provide that a segment of an orthodontic appliance manufactured from the virtual orthodontic appliance corresponding to the first occlusion guiding segment contacts a segment
25 corresponding to the second occlusion guiding segment during occlusion.

29. The method according to any of the previous embodiments, wherein the virtual orthodontic appliance is configured to provide that a surface of an orthodontic appliance manufactured from the virtual orthodontic appliance
30 corresponding to the first occlusion guiding surface contacts a surface corresponding to the second occlusion guiding surface during occlusion.

30. The method according to any of the previous embodiments, wherein the virtual orthodontic appliance is configured such that the first occlusion guiding surface is intended to contact the second occlusion guiding surface during occlusion.

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31. The method according to any of the previous embodiments, wherein the relative motion of the first and second sections of the patient's teeth are at least partly constrained during protrusion and/or retrusion and/or occlusion.

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32. The method according to any of the previous embodiments, wherein the virtual orthodontic appliance is configured to provide that adjoining surfaces of the first and second parts of the virtual orthodontic appliance defines the target geometrical relationship between the upper and lower jaw in occlusion.

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33. The method according to any of the previous embodiments, wherein the target geometrical relationship is such that the manufactured orthodontic appliance provides that the relative movement of the upper and lower jaw of the patient's set of teeth is at least partially constrained.

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34. The method according to any of the previous embodiments, wherein the target geometrical relationship is such that the relative movement of the upper and lower jaw of the patient's set of teeth is least partially constrained in the occlusal plane.

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35. The method according to any of the previous embodiments, wherein the target geometrical relationship is such that the relative movement of the upper and lower jaw of the patient's set of teeth is least partially constrained in a direction perpendicular to the occlusal plane.

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36. The method according to any of the previous embodiments, wherein the target geometrical relationship is such that the upper and lower jaw are displaced from the patient's occlusal plane and an offset between the upper and lower jaw is provided.

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37. The method according to any of the previous embodiments, wherein the first occlusal guiding surface defines a first guiding structure in the occlusal surface of the first part of an orthodontic appliance manufactured from the virtual orthodontic appliance.

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38. The method according to any of the previous embodiments, wherein the second occlusal guiding surface defines a second guiding structure in an occlusal surface of the second part of an orthodontic appliance manufactured from the virtual orthodontic appliance.

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39. The method according to any of the previous embodiments, wherein the first and second guiding structures are such that in a orthodontic appliance manufactured from the virtual orthodontic appliance the corresponding surfaces are configured to mate, and where the interaction of the first and second guiding structures provides that the target geometrical relationship is obtained during occlusion.

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40. The method according to any of the previous embodiments, wherein the first and second guiding structures are such that in a orthodontic appliance manufactured from the virtual orthodontic appliance the corresponding surfaces are configured to mate, such that the occlusion and/or articulation of the patient's set of teeth is at least partly constrained.

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41. The method according to any of the previous embodiments, wherein the method comprises providing a virtual dynamical articulator comprising the virtual 3D teeth model and performing a virtual dynamical articulation.

30

42. The method according to any of the previous embodiments, wherein the virtual orthodontic appliance is arranged in relation to the virtual 3D teeth model during the virtual dynamical articulation.

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43. The method according to any of the previous embodiments, wherein the method comprises

10 f): defining the target effect of the orthodontic appliance;

g): estimating from a result of said performed virtual dynamical articulation the effect obtained by the orthodontic appliance during articulation and/or occlusion;

15

h): comparing the estimated obtained effect with the target effect;

i): adjusting the virtual orthodontic appliance if the comparison shows that the obtained effect differs from the target effect by more than an effect threshold value;

20

j): optionally repeating g) to i) until the obtained effect differs from the target effect by less than said effect threshold value.

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44. The method according to any of the previous embodiments, wherein the effect of the orthodontic appliance on the patient is estimated from the virtual dynamical articulation.

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45. The method according to any of the previous embodiments, wherein the effect of the orthodontic appliance on the patient is estimated from a

distribution of collision points measured using the virtual dynamical articulation.

46. The method according to any of the previous embodiments, wherein
5 method comprises adjusting the virtual orthodontic appliance based on the estimated effect of the orthodontic appliance.

47. The method according to any of the previous embodiments, wherein
10 method comprises repeating the estimation of the obtained effect and the adjusting of the virtual orthodontic appliance until the distribution of the collisions points is accepted.

48. The method according to any of the previous embodiments, wherein the
15 effect of the orthodontic appliance relates to an orthodontic effect and/or a biomechanical effect.

49. The method according to any of the previous embodiments, wherein the
20 occlusal forces exerted on teeth in the patient's set of teeth during occlusion are estimated from the virtual dynamical articulation.

50. The method according to any of the previous embodiments, wherein said
virtual dynamical articulation comprises a dynamical occlusion.

51. The method according to any of the previous embodiments, wherein the
25 first and/or the second occlusion guiding surface is generated from a result of the dynamical virtual occlusion.

52. The method according to any of the previous embodiments, where the
30 method comprises obtaining a trace showing any collisions between the adjoining occlusal surfaces of opposing sections of the set of teeth during the

virtual articulation, and where the first and/or second occlusion guiding surfaces are generated from this trace.

53. The method according to any of the previous embodiments, where the
5 virtual dynamical articulation provides a trace showing any collisions between adjoining surfaces of the virtual orthodontic appliance during the virtual dynamical articulation, and where the first and/or second occlusion guiding surfaces are generated from said trace.

10 54. The method according to any of the previous embodiments, where the virtual dynamical articulation provides a trace showing any collisions between the first occlusion guiding surface and an adjoining surface of the second section of the virtual 3D teeth model during the virtual dynamical articulation, and where the first occlusion guiding surface is generated from said trace or
15 modified based on said trace.

55. The method according to any of the previous embodiments, where the virtual dynamical articulation provides a trace showing any collisions between
20 the first and second occlusion guiding surfaces of the virtual orthodontic appliance during the virtual dynamical articulation, and where the first and second occlusion guiding surfaces are generated from said trace or modified based on said trace.

56. The method according to any of the previous embodiments, wherein a
25 post-treatment trace is compared to a pre-treatment trace such that the effect of a treatment can be compared with an expected effect of the treatment based on the orthodontic appliance used in the treatment.

57. The method according to any of the previous embodiments, wherein the
30 first tooth contacting surface is shaped such that the first part of an orthodontic appliance manufactured from the virtual orthodontic appliance

contacts teeth of the corresponding section of the patient's teeth over at least a portion of the surface of the teeth.

58. The method according to any of the previous embodiments, wherein the first tooth contacting surface is shaped such that a gap is provided between the first part of an orthodontic appliance manufactured from the virtual orthodontic appliance and the teeth of the corresponding section of the patient's teeth over at least a portion of the surface of the teeth.

59. The method according to any of the previous embodiments, wherein the virtual orthodontic appliance is configured to provide that the first tooth contacting surface is such that contact is established between an orthodontic appliance manufactured from the virtual orthodontic appliance and the patient's teeth over a specific area of one or more teeth in the first section of the patient's teeth.

60. The method according to any of the previous embodiments, wherein the virtual orthodontic appliance is configured to provide that the contact between a first part of an orthodontic appliance manufactured from the virtual orthodontic appliance and the first section of the patient's teeth is distributed uniformly or non-uniformly over first tooth contacting surface.

61. The method according to any of the previous embodiments, wherein the target effect of the orthodontic appliance is to correct for a malocclusion of the set of teeth.

62. The method according to any of the previous embodiments, wherein the target effect of the orthodontic appliance is to modify a biomechanical situation of the patient, such as Temporomandibular joint disorder or a muscular situation in e.g. the patients neck linked to the patient's mastication.

63. The method according to any of the previous embodiments, wherein the target effect of the orthodontic appliance is to provide a protection of the set of teeth, such as where the orthodontic appliance comprises a mouthguard.

5 64. The method according to any of the previous embodiments, wherein said patient data set comprises a diagnosis relating to a dental problem of the set of teeth of the patient, and the target effect of the orthodontic appliance relates to this diagnosis.

10 65. The method according to any of the previous embodiments, wherein a diagnosis for the patient is derived from said patient data set, and the target effect of the orthodontic appliance relates to this diagnosis.

15 66. The method according to any of the previous embodiments, wherein the diagnosis is selected from the group of a malocclusion, a dentofacial deformity, Temporomandibular joint disorder, a muscular situation, or snoring.

20 67. The method according to any of the previous embodiments, wherein the patient data set comprises one or more of the result of a virtual articulation of the set of teeth, a digital representation of the set of teeth arranged in a static occlusion, the occlusion of the set of teeth, disclusion of the set of teeth, a digital representation of the masticatory system of the patient, a static articulation/occlusion of the set of teeth, an analysis of the bite force and/or
25 timing of the contact between the different contacting surfaces of the set of teeth during an occlusion, the result of an Electromyography, the result of activation/stimulation of the muscles in e.g. the neck or jaw region of the patient, an analysis of the biomechanical forces active during occlusion, the arrangement and motion of soft tissue such as the tongue, the lips and the
30 buccal tissue.

68. The method according to any of the previous embodiments, wherein a target arrangement of the set of teeth is determined from the virtual 3D teeth model provided in said patient data set.

5 69. The method according to any of the previous embodiments, where the virtual upper and lower jaws are aligned in said virtual 3D teeth model.

70. The method according to any of the previous embodiments, wherein an orthodontic appliance manufactured from the virtual orthodontic appliance is
10 such that the manufactured orthodontic appliance is configured for applications within functional orthodontics and the effect of the orthodontic appliance is obtained utilizing biomechanical forces of the patient.

71. The method according to any of the previous embodiments, wherein the
15 first and/or the second part of the virtual orthodontic appliance is such that a orthodontic appliance manufactured from the virtual orthodontic appliance will exert a pressure on at least one section of the set of teeth during occlusion.

72. The method according to any of the previous embodiments, wherein the
20 virtual model of the orthodontic appliance comprises a connecting structure arranged to connect the first and second parts, such that the first and second parts of an orthodontic appliance manufactured from the virtual orthodontic appliance are physically connected by said connecting structure.

25 73. The method according to any of the previous embodiments, wherein the first and or occlusion guiding segment comprises a connecting structure arranged to connect the first and second parts of the orthodontic appliance, such that the first and second parts of an orthodontic appliance manufactured from the virtual orthodontic appliance are physically connected by said
30 connecting structure.

74. The method according to any of the previous embodiments, wherein the connecting structure is configured for guiding a relative motion of the first and second parts of the orthodontic appliance, such that orthodontic appliance manufactured from the virtual orthodontic appliance is capable of guiding the patient's upper and lower jaw towards the target geometrical relationship.

75. The method according to any of the previous embodiments, wherein said connecting structure comprises a spring, a guiding rod or a piston.

76. The method according to any of the previous embodiments, wherein the method comprises generating the virtual orthodontic appliance from a 2D profile of the appliance cross section.

77. The method according to any of the previous embodiments, wherein generating the first part of the virtual orthodontic appliance comprises subtracting the first section from the predefined 2D profile or the modified 2D profile.

78. The method according to any of the previous embodiments, wherein the method comprises obtaining a 2D profile describing at least an outer shape of the appliance cross section, and where the first tooth contacting surface is generated by subtracting a corresponding cross section of the first section of the virtual 3D teeth model from the 2D profile.

79. The method according to any of the previous embodiments, wherein the 2D profile changes along the arc of the set of teeth or wherein the 2D profile is substantially maintained along the arc of the set of teeth.

80. The method according to any of the previous embodiments, wherein the 2D profile is a predefined 2D profile selected from a library.

81. The method according to any of the previous embodiments, wherein the method comprises modifying the predefined 2D profile along at least a portion of the arc.

5 82. The method according to any of the previous embodiments, wherein the predefined 2D profile is bar-shaped along the arc of the set of teeth.

83. The method according to any of the previous embodiments, wherein the method comprises removing undercuts.

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84. The method according to any of the previous embodiments, wherein the properties of the material(s) used for manufacturing the orthodontic appliance are taken into account when generating the virtual orthodontic appliance.

15 85. The method according to any of the previous embodiments, wherein the target geometrical relationship comprises a fixed occlusion, such as for a fully constrained relationship between the upper and lower jaw of the set of teeth.

20 86. The method according to any of the previous embodiments, where the method comprises identifying a target occlusion of the set of teeth, and where said virtual orthodontic appliance is for manufacturing an orthodontic appliance configured for guiding the upper and lower jaw to the target occlusion or for maintaining the upper and lower jaw in the target occlusion.

25 87. The method according to any of the previous embodiments, wherein the method comprises identifying a target arrangement of the teeth in the set of teeth, and where said virtual application is for manufacturing an orthodontic appliance configured for providing the target arrangement or for maintaining the target occlusion.

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88. The method according to any of the previous embodiments, wherein the method comprises identifying a target articulation of the set of teeth and where said virtual application is for manufacturing an orthodontic appliance configured for guiding the upper and lower jaw to the target articulation.

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89. The method according to any of the previous embodiments, wherein the method comprises virtually rearranging individual teeth and/or groups of teeth in the virtual 3D teeth model.

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90. The method according to any of the previous embodiments, wherein the virtual orthodontic appliance is adjusted by an additive process or a subtractive process where material virtually is added or removed from the virtual orthodontic appliance, such as virtually added to a surface or virtually removed from a surface of the first and/or second part of the virtual orthodontic appliance

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91. The method according to any of the previous embodiments, wherein the surface is selected from the group of the first occlusion guiding surface, the second occlusion guiding surface, the first tooth contacting surface, the second tooth contacting surface, the occlusal surface of the first part, the occlusal surface of the second part, a surface of the virtual orthodontic appliance facing the sagittal plane of the virtual 3D teeth model, a surface of the virtual orthodontic appliance facing the anterior/posterior plane of the virtual 3D teeth model.

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25

92. The method according to any of the previous embodiments, wherein the tongue and/or buccal and labial tissues of the patient are taken into account when generating the first and/or the second occlusion guiding surface.

93. The method according to any of the previous embodiments, wherein the tongue and/or buccal and labial tissues of the patient are taken into account when selecting the first and/or the second occlusion guiding segment.

5 94. The method according to any of the previous embodiments, where an initial virtual orthodontic appliance is provided by selecting among predefined virtual orthodontic appliances from a library.

10 95. The method according to any of the previous embodiments, where the method comprises a Boolean operation for combining a number of functionalities or feature from a library.

15 96. The method according to any of the previous embodiments, wherein the method comprises combining a number of operations on the first and/or second part of the virtual orthodontic appliance.

20 97. The method according to any of the previous embodiments, wherein the method comprises applying rules in the generation of the first and/or the second occlusion guiding segment.

98. The method according to any of the previous embodiments, wherein the method comprises applying rules in the generation of the first and/or the second occlusion guiding surface.

25 99. The method according to any of the previous embodiments, wherein said rules relate to medical, biological, biomechanical orthodontic, physical and/or orthodontic parameters.

30 100. The method according to any of the previous embodiments, wherein the first and/or the second occlusion guiding segment is generated from an occlusal compass

101. The method according to any of the previous embodiments, wherein the first and/or the second occlusion guiding surface is generated from an occlusal compass.

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102. The method according to any of the previous embodiments, wherein b), c) and d) are performed in one step.

103. The method according to any of the previous embodiments, wherein the virtual orthodontic appliance is configured to have a thickness which nowhere is less than a minimum thickness to ensure that an orthodontic appliance manufactured from the virtual orthodontic appliance is sufficiently robust.

104. The method according to any of the previous embodiments, wherein the target geometrical relationship relates to a range of relative positions of the first and second parts during a relative movement of these parts, or a specific position in this range.

105. A computer program product comprising program code means for causing a data processing system to perform the method of any one of the preceding embodiments, when said program code means are executed on the data processing system.

106. A computer program product according to embodiment 105, comprising a computer-readable medium having stored thereon the program code means.

107. A non-transitory computer readable medium storing thereon a computer program, where said computer program is configured for causing computer-assisted data processing to perform the method of any one of the preceding

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embodiments, when said program code means are executed on the data processing system.

5 108. A computer program product according to embodiment 107, comprising a computer-readable medium having stored there on the program code means.

109. A method for manufacturing at least a portion of an orthodontic appliance for a patient, where the method comprises:

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a): providing virtual orthodontic appliance, where the virtual orthodontic appliance is generated using the method according to any of embodiments 1-104; and

15

b): manufacturing the orthodontic appliance or the portion of the orthodontic appliance from said virtual model.

110. The method according to embodiment 110, wherein the manufacturing 20 comprises milling or 3D printing the orthodontic appliance from the virtual orthodontic appliance.

111. The method according to embodiment 109 or 110, wherein the manufacturing of the orthodontic appliance comprises a two-material process 25 where different portions of the orthodontic appliance are manufactured in different materials.

Brief description of the drawings

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The above and/or additional objects, features and advantages of the present invention, will be further elucidated by the following illustrative and non-limiting detailed description of embodiments of the present invention, with reference to the appended drawings, wherein:

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Fig. 1 shows a flow chart of one embodiment of the method for generating a virtual model of an orthodontic appliance.

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Fig. 2 shows a cross section representation of a virtual orthodontic appliance comprising an occlusion guiding surface.

Fig. 3 shows a cross section representation of an orthodontic appliance with a guiding structure in the first and second occlusion guiding surfaces.

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Fig. 4 shows an example of a flow chart of a method for performing a virtual dynamical articulation.

Fig. 5 shows an example of movements of the jaws for simulating occlusion.

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Fig. 6 shows an example of a collision between a tooth in the upper jaw and the opposing tooth in the lower jaw.

Fig. 7 shows a schematic example of movement along the occlusal axis.

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Fig. 8 shows an example of a virtual occlusal plane.

Fig. 9 shows a first example of a virtual occlusal plane and a virtual model before they are adjusted relative to each other's positions.

30

Fig. 10 shows a second example of a virtual occlusal plane and a virtual model while they are adjusted relative to each other's positions.

Fig. 11 shows an example of a virtual occlusal plane and a virtual model after they are adjusted relative to each other's positions.

5 Fig. 12 shows an example of a virtual dynamical articulator.

Fig. 13 shows an example of a flow chart of an virtual dynamical articulation procedure.

10 Fig. 14 shows an example of a movement of the virtual upper jaw and the virtual lower jaw relative to each other.

Fig. 15 shows an example of an occlusal compass.

15 Fig. 16 shows an example of playing a recording of the jaw movements.

Fig. 17 shows an example of modeling a restoration to compensate for collisions with the opposite teeth.

20 Fig. 18 shows an example of how the use of an orthodontic appliance may provide that occlusal forces are applied to a tooth during occlusion.

Fig. 19 shows a boundary line defined at teeth in a virtual 3D teeth model.

25 Fig. 20 shows the use of a predefined bar-like structure to form the virtual orthodontic appliance.

Fig. 21 shows examples of the traces of movement.

30 Fig. 22 shows an example of virtual simulation of orthodontic treatment planning.

Fig. 23 shows an example of virtual simulation of dental displacement.

Fig. 24 shows an example of an orthodontic appliance for displacing teeth.

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FIG. 25 shows virtual dynamical articulator with the virtual 3D teeth model positioned at the virtual orthodontic appliance.

FIG. 26 illustrates the basic principles of providing a bar design.

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FIG. 27 illustrates the basic principles of providing a shell design.

FIG. 28 shows how using the shell design together with the virtual articulator facilitates designing a virtual orthodontic element.

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FIG. 29 shows how using the bar design together with the virtual articulator facilitates designing a virtual orthodontic element.

FIG. 30 shows using attachments in designing the virtual orthodontic element.

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FIG. 31 shows how using a combination of bar designs facilitates designing a virtual orthodontic element.

25 In the following description, reference is made to the accompanying figures, which show by way of illustration how the invention may be practiced.

Fig. 1 shows an example of a flow chart with steps of the method 10 for generating a virtual model of an orthodontic appliance from which virtual model an orthodontic appliance can be manufactured.

30

Initially in step 11, a patient data set for said patient is obtained, the patient data set comprising a virtual 3D teeth model and the pre-treatment articulation of the set of teeth. This may involve a 3D scanning of the set of teeth, such as an intraoral scanning or a scanning of an impression of the
5 teeth.

The pre-treatment articulation may be obtained by use of a virtual dynamical articulator and/or by measuring the articulation of the patient using e.g. sensors attached to the patient.

In step 12, a target articulation and/or a target arrangement of the set of teeth
10 is defined. The target articulation and/or a target teeth arrangement may be described by a number of parameters relating to the desired post-treatment articulation and/or teeth arrangement of the patient. The parameters may relate to e.g. the occlusion of the set of teeth the relative motion of the upper and lower jaw during occlusion and/or to a repositioning of one or more teeth
15 in the set of teeth.

From the defined target articulation and/or target teeth arrangement, an initial shape of the virtual orthodontic appliance is derived in step 13. The shape of the orthodontic appliance may be configured to provide that the upper and
20 lower jaws adhere to a target geometrical relationship, where the target geometrical relationship is configured to realize the target effect of the orthodontic appliance. The change in articulation and/or a change in the occlusion of the patient can be by a functional, a passive or an active orthodontic treatment. In some embodiments, the shape of a first part of the
25 orthodontic appliance is derived by generating a number of surfaces of the orthodontic appliance. A first boundary curve, a first tooth contacting surface, a first occlusion guiding surface, and a first connecting surface are generated for the first part of the virtual orthodontic appliance. The first tooth contacting surface is bounded by said first boundary curve. The first occlusion guiding
30 surface is comprised in or comprises a first occlusal surface of the first part of the virtual orthodontic appliance and the first connecting surface is configured

for connecting the first boundary curve and the first occlusion guiding surface.

5 In step 14, the virtual orthodontic appliance with the shape derived in step 13 is arranged in relation to the virtual 3D teeth model and the occlusion and/or articulation of the patient with the orthodontic appliance on is evaluated in a virtual dynamical articulator. The evaluation can include an estimation of the occlusal forces experienced when the patient is using the orthodontic
10 appliance. The evaluation can also provide a measure of the distribution over the surface of the teeth of force exerted by the orthodontic appliance of the teeth.

15 In step 15, the expected effect of a treatment using an orthodontic appliance manufactured from the virtual orthodontic appliance is estimated based on the estimation made in step 14.

In step 16 is determined whether the expected effect estimated in step 15 is
20 sufficiently close to the target articulation and/or target teeth arrangement as defined in step 12. If the estimated expected effect of the treatment is not satisfactory, the procedure of steps 13 to 16 may be repeated until a satisfactory result is obtained. The decision may be made by an operator or by the computer program used to implement the method.

25

For a malocclusion treatment, the orthodontic appliance may be configured for exerting a force to the set of teeth.

The force may propagate into the mandibular bone and/or the maxillary bone of the patient and provide a force to e.g. the TM-joint. Based on the identified
30 malocclusion, a target contact distribution target may be derived, where a target contact distribution illustrates a preferred distribution of the contact

between e.g. the first part of the virtual orthodontic appliance and the occlusal surface of teeth in the second section and/or the teeth in the first section in order to correct for the malocclusion.

5 The malocclusion may for instance relate to a correction of the position of teeth where e.g. the mandibular teeth are displaced to one side relative to the maxillary. The contact between the orthodontic appliance and the teeth should preferably correct for this displacement and the target contact distribution is preferably such that e.g. the mandibular part of the set of teeth is shifted towards the left side during a treatment. This shift may result in a
10 displacement of teeth relative to the jaw corresponding bone, or in a displacement of one jaw bone relative to the other.

The target contact distribution may be determined from the present arrangement of the set of teeth and from the desired post-treatment arrangement of the teeth.

15 The change obtained during a malocclusion treatment may concern the relative arrangement of the teeth in the patient's upper or lower jaw.

20 The change obtained during a malocclusion treatment may concern the relative arrangement of the upper and lower jaw, such that e.g. the relative motion of the mandibular bone and the maxillary bone during an articulation is changed during the treatment.

25 Deriving the shape of the orthodontic appliance may comprise modeling the target contact distribution between the manufactured orthodontic appliance and the patient's teeth.

In a malocclusion treatment, the pre-treatment occlusion and/or pre-treatment arrangement of the set of teeth may be observed using a number of techniques, as described elsewhere herein.

A desired post-treatment occlusion and/or post-treatment arrangement of the set of teeth may also be determined, for instance by selecting among templates in a library or by software assisted modeling.

5 The manufactured orthodontic appliance is configured to exert a force or pressure on the patient's set of teeth, such that a change of teeth arrangement during the treatment is provided by the orthodontic appliance manufactured from the virtual model.

The force exerted by a specific orthodontic appliance may be customized for the patient's set of teeth and the target effect of the treatment.

10 When generating the virtual orthodontic appliance, the desired post-treatment arrangement is taken into consideration and the forces which must be applied to the set of teeth in order to change from the pre-treatment configuration to the post-treatment configuration can be derived.

15 An initial virtual orthodontic appliance may be selected from a library comprising a number of pre-defined virtual orthodontic appliances adapted for e.g. different malocclusion treatments. One pre-defined virtual orthodontic appliance may e.g. be adapted to correct for a TMJ disorder.

20 The method may comprise manually adjusting the selected predefined virtual orthodontic appliances to personalize it to the needs of the patient and the current state of the patient's set of teeth.

25 Some steps in defining the virtual orthodontic appliances may be at least partly manual using e.g. a computer-implemented tool for generating the different surfaces of the virtual orthodontic appliance. Such a computer-implemented tool may also be used for the personalization of a predefined virtual orthodontic appliance.

30 The virtual orthodontic appliances may be generated from a desired occlusion or teeth arrangement using e.g. a computer-implemented algorithm.

For example, if the manufactured orthodontic appliance must provide that the occlusal force acting on the set of teeth has a maximum at the molar teeth, the virtual orthodontic appliance may be adapted such that the manufactured
5 orthodontic appliance will be thicker at the molar teeth compared to parts of the orthodontic appliance arranged at the other teeth.

The method described in Figure 1 may be utilized for generating a virtual orthodontic appliance configured for functional orthodontics, where the effect
10 of the orthodontic appliance is to change the articulation and/or the teeth arrangement of the patient using the forces exerted on the set of teeth when the patient uses his or hers teeth.

In cases where the orthodontic appliance is for a passive or an active treatment, the evaluation performed in step 15 may instead focus on the level
15 of discomfort experienced by the patient when wearing the orthodontic appliance.

The shape of the virtual orthodontic appliance may be derived from a set of 3D coordinates describing the surface of the orthodontic appliance. The 3D
20 coordinates may then be triangulated using a standard triangulation algorithm to form the shape of the virtual orthodontic appliance.

Fig. 2 shows a cross sectional representation of a virtual orthodontic appliance comprising an occlusion guiding surface.

25 The boundary curve is defined by a number of points marked on e.g. the virtual 3D teeth model. The points may be defined automatically by computer algorithms or manually by an operator. The manual process may include identifying the points on the patient's teeth before scanning the teeth to provide a virtual 3D teeth model or on a formed virtual 3D teeth model. The
30 points may be connected by a spline which then describes the boundary curve. Typically the boundary curve has a portion 291 running on the lingual

side of the teeth 22 and a portion 292 running on the buccal/labial side of the teeth.

The tooth contacting surface 251 may in part be defined by an offset from the surface of the tooth 22 in the virtual 3D teeth model. The relevant portion(s)
5 of the offset surface is then shaped such that contact to the virtual 3D teeth is provided at the contact portion(s) described by the target contact distribution. The reverse approach may also be applied, such that the tooth contacting surface 251 is formed by modifying a copy of the tooth part 22 of the virtual 3D teeth model and then offsetting the portions complementary to the contact
10 portions described by the target contact distribution.

The connecting surface 25 extends from the boundary curve to the occlusion guiding surface 27 which here is illustrated as a narrow bar arranged at an occlusal surface of the virtual orthodontic appliance. The tooth contacting surface 251 is aligned with the tooth 22 at contact portion 28 at which contact
15 portion the orthodontic can apply a force to the tooth.

Fig. 3 shows a schematic of an orthodontic appliance 30 comprising a first, upper section 32 and a second, lower section 34 of the virtual model of the patient's set of teeth, where a guiding structure 37, 38 is provided on the first
20 and second occlusion guiding surfaces 35, 36 of the first and second parts 31, 33 of the orthodontic appliance 30. The upper 31 and lower 33 parts of the virtual orthodontic appliance are arranged in relation to the first 32 and second 34 section of the set of teeth, respectively.

The first occlusion guiding surface 35 comprises guiding structure 37 in the
25 form of a protrusion, while a guiding structure 38 of the second occlusion guiding surface 36 is in the form of an indentation.

When the patient bites the motion of the set of teeth in occlusion is guided by the guiding structures 37, 38 of the first and second occlusion guiding
30 surfaces 35, 36. In Fig. 3, the protrusion 37 fits into the indentation 38 directly when the patient bites. The indentation and the protrusion are formed such

that during occlusion, the upper and lower parts of the patient's set of teeth are guided towards a preferred occlusion. In many applications, the indentation and the protrusion may be arranged such that the fit is obtained by a slight displacement of the lower and/or upper part of the set of teeth, such that the biting of the patient provides a force to the set of teeth. Over time, the guiding may then correct for e.g. a malocclusion or a Temporomandibular joint disorder.

Fig. 4 shows an example of a flow chart showing the steps of the computer-implemented method of using a virtual dynamical articulator for simulating occlusion of teeth.

In step 101 the virtual dynamical articulator comprising a virtual three-dimensional model of the upper jaw and a virtual three-dimensional model of the lower jaw resembling the upper jaw and lower jaw, respectively, of the patient's mouth is provided.

In step 102 movement of the virtual upper jaw and the virtual lower jaw relative to each other is provided for simulating dynamic occlusion, whereby collisions between teeth in the virtual upper and virtual lower jaw occur;

In step 103 the teeth in the virtual upper jaw and virtual lower jaw are provided to be blocked from penetrating each other's virtual surfaces in the collisions.

Fig. 5 shows examples virtual dynamical articulators.

Fig. 5a) shows a virtual upper jaw 204 with teeth 206 and a virtual lower jaw 205 with teeth 206. Six teeth 207 in the upper jaw 204 have been restored.

The virtual dynamical articulator 208 is used to simulate the movements of the jaws 204, 205 to test for collisions between the teeth. The virtual dynamical articulator 208 is indicated by two axes, an occlusal axis 209 and a laterotrusion-mediotrusion axis 210. The jaws 204, 205 moves up and down along the occlusal axis 209, and the jaws 204, 205 performs forward-sideward movements to both left and right along the laterotrusion-mediotrusion

axis 210. The jaws 204, 205 can also perform protrusion, which is direct forward movement, and retrusion, which is direct backward movement. The axes for these movements are not shown in the figure.

In the figure only movement along the occlusal axis 209 is shown, while there is no movement along the laterotrusion-mediotrusion axis 210 or along the protrusion-retrusion axes (not shown). This is also seen in the window 211 in the upper left of the figure, where the parameter "occlusion" is 6.60 and the parameter "laterotrusion" is 0.00, and the parameter "pro-/retrusion" is also 0.00. The different movement directions possible may be:

- 10 - protrusion;
- retrusion;
- laterotrusion to the right;
- laterotrusion to the left;
- mediotrusion to the right;
- 15 - mediotrusion to the left;
- latero-re protrusion to the right;
- latero-re protrusion to the left.

Fig. 5b) shows another virtual dynamical articulator 208 with setting opportunities 209, 210 for controlling the movement of the jaws 204, 205 along an occlusal axis, a laterotrusion-mediotrusion axis, a protrusion-retrusion axis etc. The indentations 240 indicate where the dental technician will arrange a default occlusal plane in the form of a rubber band.

25 Fig. 6 shows an example of a collision between a tooth in the upper jaw and the opposing tooth in the lower jaw.

Fig. 6 shows the upper jaw 204, turned around relative to the preceding figures, with a first tooth 207a, a second tooth 207, and a third tooth 206. The first tooth 207a has collided with a tooth in the lower jaw, and the collision points 214 are indicated on the first tooth 207a. The shades of the collision points may indicate the penetration depth or the pressure with which the first

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tooth 207a and the tooth in the lower jaw collided. Thus the shades from light to dark indicate a depth mapping or pressure mapping, where light shade indicates low depth or light pressure and dark shade indicates large depth or hard pressure.

- 5 It may be so that the teeth are not completely rigid, but are a little bit soft, and the teeth may therefore give or deform a little when colliding with each other. Thus it may be so that the virtual teeth are not defined to be completely rigid, but are a little bit soft or resilient, and the virtual teeth may therefore give or deform a little when virtually colliding with each other.

10

The change of the arrangement of the teeth provided by using the orthodontic appliance can be evaluated using the virtual model of the orthodontic appliance and the virtual dynamical articulator.

- For instance in the case where the position of one tooth is to be corrected,
15 the virtual dynamical articulator can show the collision points before, during and after the treatment with a specific orthodontic appliance.

- Collision points between the teeth during the occlusion will change corresponding to the change of the arrangement of the patient's teeth, and the orthodontic appliance may be designed to provide that a tooth can be
20 arranged such that there will no longer be any collision with the teeth in the lower jaw, and the collisions points otherwise seen in the virtual dynamical articulation will then disappear from the tooth indicating that the tooth has been arranged to avoid collisions with opposing teeth.

- In some cases, a well-defined collision with the opposing tooth is preferred
25 over the situation where there is no collision at all.

Fig. 7 shows a schematic example of movement along the occlusal axis.

- The figure shows the upper jaw 204 with teeth 206 and the lower jaw 205 with teeth 206. The occlusion may be tested during a treatment provided by
30 an orthodontic appliance.

The occlusal axis 209 is indicated, and the upper jaw 204 is shown to be fixed to the occlusal axis. The lower jaw 205 can move relative to the upper jaw 204 and therefore the lower jaw can rotate around the occlusal axis 209.

Thus the virtual dynamical articulator performs collision test and evaluate the response along the occlusal axis 209, i.e. for any given configuration of the other degrees of freedom, i.e. the other axes, and thereby finding the first position on the occlusal axis for which the two jaw models are in contact. This reduces the dimensionality of the calculation problem and allows for the use of more specialized search structures, which are aimed at calculating the first point of intersection with a 3D model along a given circular path 219 around the static rotation axis 209 of occlusion. Thus for each motion step along one of the other axes, i.e. for each degrees of freedom, it may be calculated when and at which points the teeth 206 in the jaws 204, 205 will collide along the occlusal axis 209.

15

Fig. 8 shows an example of a virtual occlusal plane.

The occlusal plane 706 is visualized as a flat, circular plane, but it is understood that the occlusal plane can have any shape etc. The occlusal plane is a plane passing through the occlusal or biting surfaces of the teeth, and it represents the mean of the curvature of the occlusal surface. Thus the occlusal plane can be flat or undulating following the different heights of the different teeth.

A contour of a standard set of teeth 707 is shown on the occlusal plane 706 for assisting the operator to better match the 3D position of the occlusal surface 706 with a 3D model of the set of teeth.

A virtual dynamical articulator 708 is indicated by two axes, an occlusal axis 709 and a laterotrusion-mediotrusion axis 710. The upper and lower arches of the virtual model can move up and down along the occlusal axis 709, and the arches can perform forward-sideward movements to both left and right along the laterotrusion-mediotrusion axis 710. The arches can also perform protrusion, which is direct forward movement, and retrusion, which is direct

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backward movement. The axes for these movements are not shown in the figure.

The different movement directions possible may be:

- protrusion;
- 5 - retrusion;
- laterotrusion to the right;
- laterotrusion to the left;
- mediotrusion to the right;
- mediotrusion to the left;
- 10 - latero-re surtrusion to the right;
- latero-re surtrusion to the left.

Fig. 9 shows a first example of a virtual occlusal plane and a virtual model before they are adjusted relative to each other's positions.

- 15 The occlusal plane 806 with the standard set of teeth 807 and the virtual model of the lower arch 802 are shown together. The occlusal plane 806 is shown to be inclined relative to the virtual model of the lower arch 802, and the occlusal plane 806 and the virtual model of the lower arch 802 are intersecting each other as seen by the intersection line 811.

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Fig. 10 shows a second example of a virtual occlusal plane and a virtual model while they are adjusted relative to each other's positions.

- The occlusal plane 906 with the standard set of teeth 907 and the virtual model of the lower arch 902 are shown together. The occlusal plane 906 and the virtual model of the lower arch 902 are nearly aligned as their inclinations are the same or almost the same, but the occlusal plane 906 and the virtual model of the lower arch 902 are still intersecting each other a little bit as seen by the intersection line 911 because some of the teeth of the lower arch 902 are a little bit higher than the vertical position of the occlusal plane 906. The
- 25
- 30 occlusal plane 906 and the lower arch 902 are not aligned horizontally yet,

because the standard set of teeth 907 on the occlusal plane 906 are not overlapping with the teeth of the lower arch 902.

Fig. 11 shows an example of a virtual occlusal plane and a virtual model after they are adjusted relative to each other's positions.

The occlusal plane 1006 with the standard set of teeth 1007 and the virtual model of the lower arch 1002 are shown together. The occlusal plane 1006 and the virtual model of the lower arch 1002 are aligned as their inclinations are the same, and the occlusal plane 1006 and the virtual model of the lower arch 1002 are still intersecting each other a little bit as seen by the intersection line 1011 because some of the teeth of the lower arch 1002 are a little bit higher than the vertical position of the occlusal plane 1006. The occlusal plane 1006 and the lower arch 1002 are aligned horizontally, because the standard set of teeth 1007 on the occlusal plane 1006 are overlapping with the teeth of the lower arch 1002. The alignment may be a 3-point alignment, i.e. using three points for performed the alignment.

Fig. 12 shows an example of a virtual dynamical articulator.

The virtual dynamical articulator 1108 is a virtual version of a physical, mechanical device used in dentistry to which casts of the upper and lower teeth are fixed and reproduces recorded positions of the lower teeth in relation to the upper teeth. An articulator can be adjustable in one or more of the following areas: condylar angle, Bennett side-shift, incisal and cuspid guidance, and shape of the glenoid fossae and eminintiae. An articulator may reproduce normal lower movements during chewing. An articulator may be adjusted to accommodate the many movements and positions of the lower teeth in relation to the upper teeth as recorded in the mouth. Thus the virtual dynamical articulator may perform all the movements etc. as the mechanical articulator.

The virtual dynamical articulator 1108 comprises a bottom base 1109 onto which the virtual model of the lower teeth or lower jaw is adapted to be arranged, a top base 1110 onto which the virtual model of the upper teeth or upper jaw is adapted to be arranged. The different virtual joints, slides or setting means 1111 indicates the joints, slides and other settings of a mechanical articulator where the different areas mentioned above can be adjusted to the features of a specific patient.

Fig. 13 shows an example of a flow chart of a virtual dynamical articulation of a set of teeth.

In step 1201 the movement of the virtual upper jaw and the virtual lower jaw relative to each other is started.

In step 1202 all collisions during the movement of the virtual upper jaw and the virtual lower jaw relative to each other are registered.

In step 1203 the movement of the virtual upper jaw and the virtual lower jaw relative to each other is finished.

In step 1204 each area of the restorations where a collision point was registered is modeled.

Fig. 14 shows an example of a movement of the virtual upper jaw and the virtual lower jaw relative to each other.

Fig. 14a) shows the first position of a movement between the upper jaw 1304 and the lower jaw 1305. Both the lower jaw and the upper jaw comprise teeth 1306, and the upper jaw comprises a number of restorations 1307.

Fig. 14b) shows a position during the movement of the jaws. The upper jaw 1304 is moved relative to the lower jaw 1305, and the restoration 1307 is colliding with a tooth 1306 as seen by the collision point 1314 comprising a contact area.

Fig. 15 shows an example of an occlusal compass.

The occlusal compass indicates movements during dynamic occlusion in the following directions:

- protrusion;
- retrusion;
- 5 - laterotrusion to the right;
- laterotrusion to the left;
- mediotrusion to the right;
- mediotrusion to the left;
- latero-re surtrusion to the right;
- 10 - latero-re surtrusion to the left.

The occlusal compass indicates the contact or collision in different movement directions with different colors. The colors may be according to the international colouring scheme. The occlusal compass used in the virtual simulation is a unique digital tool.

15

Fig. 16 shows an example of playing a recording of the jaw movements.

The movement of the virtual upper jaw and the virtual lower jaw relative to each other has been recorded, and before and/or after modeling a restoration, the recording can be played to test the modeling. A predefined motion sequence may also be played.

20

Fig. 17 shows an example of how the use of an orthodontic appliance may provide that collisions with the opposite teeth are avoided.

During the movement of the virtual upper jaw and the virtual lower jaw relative to each other the collisions, marked with on the tooth, occlusion between teeth are registered, and after the movement is finished, modeling of the collision points of the restoration is performed.

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Fig. 18 shows an example of how the use of an orthodontic appliance may provide that occlusal forces are applied to a tooth during occlusion.

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During the movement of the virtual upper jaw and the virtual lower jaw relative to each other, the orthodontic appliance may itself contact the tooth and apply a force to the tooth, or the orthodontic appliance may provide that the opposite collides with the tooth. The collision between the tooth and the orthodontic appliance or the opposite tooth is marked on the tooth. The collision determines the distribution of the occlusal force over the occlusal surface of the tooth.

Fig. 19 shows a boundary curve defined on a virtual 3D teeth model.

10 A number of points 1901 are defined either manually or automatically using e.g. computer implemented algorithms, and the boundary curve 1902 is generated by connecting the defined points by e.g. a 3D spline.

Fig. 20 shows the use of a predefined bar-structure to form the virtual orthodontic appliance.

Fig. 20a) shows the boundary curve 2002 which is generated on a first section of the virtual 3D teeth model, the first section comprising 4 teeth.

Fig. 20b) shows a bar-structure 2003, which is superimposed on the virtual 3D teeth model, such that it is bounded by the boundary curve 2002. The bar-structure 2003 may be selected from a library.

The tooth connecting surface of the virtual orthodontic appliance may be defined by subtracting the first section from the bar-structure.

Fig. 21 shows examples of the traces of movement.

25 Fig. 21a) shows an example of a first collision point 2114 between one tooth 2106 and another tooth 2107 at time t1.

Fig. 21b) shows an example of a subsequent collision point 2114 between the one tooth 2106 and the other tooth 2107 at time t2.

Fig. 21c) shows an example of another subsequent collision point 2114 between the one tooth 2106 and the other tooth 2107 at time t3.

Fig. 21d) shows the trace of the motion for the other tooth 2107 and the one tooth 2106 at the three time instances, t1, t2, and t3.

The trace of the motion between the one tooth 2106 and the other tooth 2107 is indicated by the arrows 2120. The surface of collision points 2114 may be denoted the trace motion, the motion trace surface etc.

Some simulations of the occlusion of the teeth are such that the motion traces or surfaces of the teeth cannot penetrate each other. However, it may alternatively be the case that when one tooth and another tooth are simulated relative to each other, the motion surface of the one tooth may penetrate the unmodified tooth.

Thus the term collision surface or trace of collisions points or collision point surface is used in relation to when teeth are simulated to move relative to each both with the teeth colliding and when they do not penetrate each other. The simulated collisions or collision surfaces between teeth may determine the motion which can be performed between the upper and lower teeth models.

The occlusal force distribution provided by the orthodontic appliance on a tooth may be modeled using the trace.

The virtual model of the orthodontic appliance is adjusted until the trace is such that the occlusal force applied to the tooth is as desired. The desired occlusal force depends among other things on the treatment that the orthodontic appliance is aiming at providing.

This determined motion may then be used and studied when designing the virtual model of the orthodontic appliance.

Fig. 21e) shows the trace 2120 of a motion for the other tooth 2107 and the one tooth 2106 at the four time instances, t1, t2, t3, and t4. The motion is shown at the four time instances t1, t2, t3, and t4 and time instances lying in between and before and after these four time instances.

In fig. 21e) the other tooth 2107 and the one tooth 2106 are shown to penetrate each other in the motion.

The surface of collision or penetration points may be denoted the trace motion 2120.

The tooth 2106 is shown to move relative to the other tooth 2107, however it may be vice versa, i.e. that the other tooth 2107 moves relative to the one
5 tooth 2107.

Fig. 22 shows an example of virtual simulation of orthodontic treatment planning.

Fig. 22a) shows a virtual orthodontic model of teeth with an upper model
10 2204 and a lower model 2205 in a virtual dynamical articulator 2208 for simulating the occlusion. The simulation of occlusion in the virtual dynamical articulator can detect and study malocclusion, and assist and/or determine an orthodontic treatment planning. An orthodontic treatment can also be performed for pure cosmetic reasons, such that the patient's teeth are
15 arranged in a more aesthetic configuration after the treatment.

Fig. 22b) shows a zoom-in on the teeth in the virtual models 2204, 2205, where contact areas or collision points 2214 are registered during simulation of the occlusion. The detected contact areas or collision points 2214 can be used in determining the treatment planning to be performed.

20

Fig. 23 shows an example of virtual simulation of dental displacement procedure.

Fig. 23a) shows a virtual upper teeth model 2304 of a patient's teeth before orthodontic treatment, where the teeth 2307 are not arranged aesthetically.
25 The contact areas or collision point 2314 detected or registered in a virtual dynamical articulator simulation are shown on the teeth.

Fig. 23b) shows an example of the virtual upper teeth model 2304 with a suggested final result which can be obtained after change in the arrangement of the teeth 2307. This is done by using a segmented virtual upper teeth
30 model 2304 where the user is able to move and rotate the teeth independent

of each other. Thus, by moving them into a specific arrangement the user may check for contact areas and collision points in the virtual articulator.

Based on the image in fig. 23b) a patient can decide whether he wishes to
5 have the malocclusion treatment performed for obtaining the aesthetic set of front teeth.

Moreover, the orthodontist can use the visualized target model to simulate articulation in the virtual articulator and based on e.g. the contact areas or
10 collision points 2314 verify whether proper occlusion is obtained by the target model. Based on this the orthodontic may proceed to design the virtual orthodontic appliance or element. For example as described in Fig. 24.

Fig. 24 shows an example of an orthodontic appliance for displacing teeth.

15 Fig. 24a) shows a virtual upper model 2404 and a virtual lower model 2405, where a virtual orthodontic appliance 2430 in the form of a splint is shown to be arranged in the teeth in the upper model 2404. The corresponding physical appliance may be worn by a patient on his teeth for treating temporal mandibular dysfunction. The appliance 2430 can be virtually
20 designed using a virtual dynamical articulator, e.g. as shown in fig. 22a).

Fig. 24b) shows a top view of the appliance 2430 on the virtual teeth model 2404.

Fig. 24c) shows a perspective side view of the appliance 2430 on the virtual teeth model 2404.

25 Fig. 24d) shows a bottom view of the appliance 2430.

The appliance design in figures 24 are the courtesy of and kindly provided by Tridentestense Ortodonzia S.r.l, Italy.

FIG 25 shows virtual dynamical articulator wherein the articulation of an assembly of the virtual 3D teeth model and the virtual orthodontic appliance is examined.

The bar-shaped virtual orthodontic appliance is positioned at the teeth in the lower jaw. The occlusion guiding surface of a bar-shaped virtual orthodontic
5 appliance is substantially planar.

The result of a virtual dynamical articulation is seen as collision points on the occlusion guiding surface. From the distribution of these collision points it is possible to derive the orthodontic force provided by the manufactured
10 orthodontic appliance on the teeth in the patient's upper jaw. The deriving may comprises applying different rules relating to the relative effect of collisions at difference teeth or different portions of the occlusal surface of a tooth.

15 Figs. 26 and 27 show two principles of how to design a virtual orthodontic element.

Figs. 26a, b, c, d and e illustrates a virtual orthodontic element 2600 designed with a bar 2601 based on a spline 2602 and a profile 2603
20 principle, which will be described in the following. A bar is in many cases used when the orthodontist desires a spacer element, for example to prevent the opposing jaws to close together, or to apply force to different parts of an appliance when the patient moves his jaw. Bars are especially suited when designing functional orthodontic appliances in which the orthodontist uses the
25 patient's own masticatory characteristics and forces in order to correct malocclusion.

A virtual dental model 2604 of the mandible is shown in a top view in Fig. 26a. The virtual dental model 2604 is formed of a model base 2605 and a
30 dental arch 2606 defined by teeth 2607.

When designing the bar 2601 a spline 2602 is initially drawn across a section of the model 2604 when seen from above as shown in fig. 26a. A number of control points 2602', in this case four, define the spline. The control points may be manipulated to e.g. change the length, curvature or orientation of the spline.

When viewing the dental model of mandible 2604 from the side it can be seen that the spline has been drawn offset from the model. In the current embodiment it has been drawn in a plane A – A, which is arranged between the dental model of the mandible 2604 and the maxilla 2608.

The cross-section of the bar is provided by a profile 2603. When designing the bar the profile 2603 is bound to the spline 2602 at a junction point on the profile. The bar 2601 is then created by extruding the profile along the spline. Subsequent modifications to the design of the bar can for example be done by moving control points on the profile in order to change the shape or size of the profile and thus the cross-section of the bar in desired location.

When the desired design is achieved the bar is modified to fit inside the mouth of a patient. First the mandible model is subtracted from the bar. This modification is illustrated by the broken mandible tooth curve 2609 in fig. 26c.

Subsequently the opposing arch model, in this case the maxilla, is brought into contact and intersects the bar design. Advantageously this is done within the virtual articulator so that the resulting design fits properly in the patient's mouth when finally manufactured. The modified part of the bar is illustrated by the broken maxilla tooth curve 2610.

As shown the maxilla facing surface 2611 of the bar 2601 was designed by using a plane A – A placed between the models as a reference surface. Designing using such planes can be very effective and provide good results

in the final product. In particular when the dental models 2604 and 2608 are placed in an virtual articulator such design planes can be arranged with respect to the articulation of the models and thus ensure the fit and function of the final manufactured appliance. In some embodiment, the plane can represent the occlusal plane as defined by the orthodontist or the dental technician. Thus, appliances may be designed based on the bar principle as described where the occlusal plane may easily be considered when designing.

10 Figs. 27a, b and c illustrated a virtual orthodontic element 2700 designed with a shell 2701 based on a boundary curve 2702. A shell is a design option which is typically used when the orthodontist needs an appliance, or part thereof, in which the outer surface follows the curvature of the teeth or gingiva and/or which has anatomical visual properties.

15 As shown in fig. 27a the boundary curve 2702 is a closed curve enclosing the teeth on which the shell 2701 is to be arranged. The boundary curve is placed on the dental model 2703 and defines the part of the model that is to be used as basis for defining the shell.

20 A copy of the surface of the dental model enclosed by the boundary curve is generated and defines a tooth contacting surface 2704. In the current embodiment the material used to manufacture the shell is flexible and resilient whereby the tooth contacting surface 2704 may be designed with no offset. This allows the shell to snap on to the teeth in a tight and sealing manner.

25 However, if for example a rigid material is used some offset may be provided. The offset and size of the gap which then occurs between the tooth model and the tooth contacting surface 2704 is determined individually based on the

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desired fit and connection strength. Moreover, the orthodontist or dental technician may also need to consider possible undercuts.

5 A copy of the tooth contacting surface 2704 is then generated and this surface is offset away from the model. This new surface defines the outer shell surface 2706. The tooth contacting surface and the outer shell surface is at their open end closed by a closing surface 2707, thereby generating a fully closed shell 2701. The outer shell surface, or a part thereof in other embodiment, corresponds to the occlusion guiding surface as previously
10 discussed and the closing surface corresponds to the first connecting surface as previously discussed.

In other embodiments the outer shell surface 2706 can be generated with other shapes than that based on the tooth contact surface. It can for example
15 be a simple curved shape or alternatively a bar shape, such as a square or a rectangle. Thus, it can be seen how the different examples of designing a virtual orthodontic elements as described with respect to figs. 26 and 27 may be combined. As another example a part of the outer shell surface can be aligned with a plane defined by the orthodontist or dental technician, such
20 plane may for example represent the occlusal plane of the patient.

In one embodiment as shown in fig. 28 the shell 2800 is modified based on a tooth motion 2810 simulated in the virtual articulator. The shell 2800 is similar to that described with respect to fig. 27 except that the outer shell surface
25 2806 defines an evenly curved surface.

The simulated tooth motion 2810 represented by a number of tooth positions 2811' of the antagonist tooth 2811 in the virtual articulator illustrates the movement path of the antagonist tooth relative to the shell 2800. In the
30 current embodiment this movement is defined by four tooth positions 2811'.

The overlapping section between the tooth and the shell during the simulated tooth motion 2810 will be removed from the shell. This will generate an occlusion guiding surface 2812 on the shell illustrated by the broken line.

5 The occlusion guiding surface 2812 may be further processed if so desired. It can for example be automatically smoothed to prevent any sharp edges or it may be further manually manipulated to match the desired shape of the orthodontist or dental technician.

10 A virtual orthodontic appliance 2900 formed of a maxilla orthodontic element 2901 and a mandible orthodontic element 2902 is shown in fig. 29. Both orthodontic element have been designed according to the bar principle described in fig. 26. The elements have been designed in a virtual articulator where the mandible and maxilla dental model has been arranged so to
15 represents a natural position of the patient's jaw. The element have been designed with a preset plane B – B as a reference ensuring that when the orthodontic appliance is placed in the patient the elements will come together in an even bite distributing the biting force evenly along the contact surfaces 2901' and 2902' of the respective elements.

20

In another embodiment as shown in fig. 30, an orthodontic appliance 3000 is designed by first creating a shell 3001 by using the shelling process as described above with respect to fig. 27. An attachment 3002 is subsequently added to the design of the orthodontic appliance.

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The attachment is chosen from a library of components. Such components may be stored as STL-files or other CAD-files which may be imported into the program wherein the virtual orthodontic appliance or element is designed. The attachment 3002 is added to the shell 3001.

30

In another embodiment as illustrated in fig. 31 the orthodontic appliance is in the form of an occlusion guide 3100. The occlusion guide is designed by first providing a main bar 3101 by using the bar design principle as explained. Then two smaller bars (not shown) were designed around the respective
5 teeth in the maxilla and the mandible. The two smaller bars were then subtracted from the main bar 3101, thereby creating two bar cavities 3102 and 3103.

While designing the two smaller bars the virtual articulator was
10 advantageously used to analyze the occlusion between the two bars. This ensures that after subtracting the smaller bars from the main bar the maxilla occlusal surface 3104 and the mandible occlusal surface 3105 of the occlusal guide 3100 provides proper fit and occlusal properties.

15 In some embodiments, the method comprises applying rules in the generation of the virtual orthodontic appliance. The rules may take medical, biological, physical and/or orthodontic parameters and effects into account. For example, the forces applied in the articulation or coming from the soft tissues may be factored in when determining the shape of the orthodontic
20 appliance.

Although some embodiments have been described and shown in detail, the invention is not restricted to them, but may also be embodied in other ways within the scope of the subject matter defined in the following claims. In
25 particular, it is to be understood that other embodiments may be utilized and structural and functional modifications may be made without departing from the scope of the present invention.

In device claims enumerating several means, several of these means can be
30 embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims or described in

different embodiments does not indicate that a combination of these measures cannot be used to advantage.

A claim may refer to any of the preceding claims, and “any” is understood to
5 mean “any one or more” of the preceding claims.

It should be emphasized that the term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one
10 or more other features, integers, steps, components or groups thereof.

The features of the method described above and in the following may be implemented in software and carried out on a data processing system or other processing means caused by the execution of computer-executable
15 instructions. The instructions may be program code means loaded in a memory, such as a RAM, from a storage medium or from another computer via a computer network. Alternatively, the described features may be implemented by hardwired circuitry instead of software or in combination with
software.

20

CLAIMS

1. A method for generating a virtual orthodontic element for use in manufacturing an orthodontic appliance for a patient, the method comprising,
- obtaining a patient data set for said patient, the patient data set comprises a
5 virtual 3D teeth model, where said virtual 3D teeth model comprises a virtual upper jaw and a virtual lower jaw resembling the upper jaw and lower jaw, respectively, of the patient's mouth;
 - arranging the virtual upper jaw and the virtual lower jaw in an initial relative configuration in a virtual articulator which is able to simulate the articulation
10 between the virtual upper jaw and the virtual lower jaw based at least on motion relative to at least one axis representing the terminal hinge axis of the patient;
 - designing the virtual orthodontic element based on at least a part of the virtual 3D teeth model and the arrangement of the 3D teeth model in the
15 virtual articulator.
2. A method according to claim 1, wherein the step of designing the virtual orthodontic element comprises designing an intermediate part of the virtual orthodontic element in the virtual articulator.
20
3. A method according to claim 1 or 2, wherein the virtual orthodontic element represents the orthodontic appliance to be manufactured.
4. A method according to claim 1 or 2, wherein the virtual orthodontic
25 element represents at least a part of the orthodontic appliance to be manufactured.
5. A method according to claim 1 or 2, wherein the virtual orthodontic
30 element represents a negative of the orthodontic appliance to be manufactured.

6. A method according to any one of the preceding claims, wherein the step of designing the virtual orthodontic element comprises that the virtual upper and lower jaw is arranged in a modified relative configuration in the virtual articulator and that the virtual orthodontic element is at least partly designed
5 in the modified relative configuration.

7. A method according to any one of the preceding claims, wherein the step of designing the virtual orthodontic element comprises
- obtaining a dynamic occlusion surface from a dynamic occlusion simulation
10 of the teeth,
- arrange the virtual upper and lower jaw in a modified relative configuration in the virtual articulator,
- design an intermediate part of the virtual orthodontic element in the modified relative configuration, and
15 - designing the virtual orthodontic element by applying the dynamic occlusion surface to the intermediate part of the virtual orthodontic element.

8. A method according to any one of the preceding claims, wherein the step of designing the virtual orthodontic element comprises arranging an
20 intermediate part of the virtual orthodontic element on the virtual 3D model within the virtual articulator and modifying the intermediate part of the virtual orthodontic element based on the movement of virtual upper jaw and virtual lower jaw in the virtual articulator.

25 9. A method according to claim 8, wherein the intermediate part of the virtual orthodontic element is modified based on collision on the intermediate part during movement of virtual upper jaw and virtual lower jaw in the virtual articulator.

10. A method according to claim 9, wherein the collision is between the intermediate part of the orthodontic element and an opposing virtual element, such as an opposing jaw or an opposing virtual orthodontic element.

5 11. A method according to claim 9 or 10, wherein the collision is visually illustrated as collision paths on the virtual orthodontic element.

12. A method according to any one of the claims 8 – 11, wherein the step of designing the virtual orthodontic element comprises arranging an intermediate part of the virtual orthodontic element on the virtual 3D model within the virtual articulator and visually illustrate collisions on the intermediate part as collision paths.

13. A method according to claim 12, wherein the intermediate part of the virtual orthodontic element is modified based on the collision paths.

14. A method according to claim 12 or 13, wherein material is virtually added or virtually removed from the intermediate part of virtual orthodontic element along the contact paths.

20 15. A method according to any one of the preceding claims, wherein collision between the virtual orthodontic element and an opposing virtual element when placed in the virtual articulator is visually illustrated as collision paths on the virtual orthodontic element.

25 16. A method according to any one of the preceding claims, wherein the method comprises the additional step of arranging the virtual lower and upper jaw in a target relative configuration in the virtual articulator.

30 17. A method according to claim 16, wherein the step of designing the virtual orthodontic element comprises designing at least an intermediate part of the

virtual orthodontic element based on the difference between the initial relative configuration and the target relative configuration.

5 18. A method according to claim 16 or 17, wherein the step of designing the virtual orthodontic element comprises designing at least an intermediate part of the virtual orthodontic element based on the target relative configuration.

10 19. A method according to claim 16, 17 or 18, wherein the step of designing the virtual orthodontic element comprises designing at least an intermediate part of the virtual orthodontic element based on a sequence of intermediate relative configurations of the virtual lower and upper jaw in the virtual articulator.

15 20. A method according to any one of the preceding claims, wherein the movement of the virtual articulator is constrained by the surfaces of the 3D teeth model and the virtual orthodontic element.

20 21. A method according to claim 20, wherein the constraints by the surfaces prevents surfaces of the 3D teeth model and the virtual orthodontic element to intersect.

25 22. A method according to any one of the preceding claims, wherein the virtual orthodontic element is at least partly designed based on a library component.

23. A method according to claim 22, wherein the library component is a digital data file.

30 24. A method according to claim 23, wherein the digital data file defines a standard component, such as a Herbst rod, an attachment, a bracket or drive.

25. A method according to claim 22 or 23, wherein the movement of the virtual articulator is constrained by the surfaces of the 3D teeth model, the virtual orthodontic element and the library component.

5

26. A method according to claim 25, wherein the constraints by the surfaces prevents surfaces of the 3D teeth model, the virtual orthodontic element and the library component to intersect.

10 27. A method according to any one of the preceding claims, wherein the tooth arrangement of the 3D teeth model can be changed in the virtual articulator.

15 28. A method according to claim 27, wherein the tooth arrangement is changed based on the virtual orthodontic element.

29. A method according to any one of the preceding claims, wherein the step of designing the virtual orthodontic element further comprises

- 20
- designing an intermediate part of the virtual orthodontic element based on the initial relative configuration,
 - adjust the virtual articulator to fit the intermediate part of the virtual orthodontic element,
 - design the virtual orthodontic element based on the adjusted virtual articulator.

25

30. A method according to anyone of the preceding claims, wherein the step of designing the virtual orthodontic element comprises

- 30
- generating a bar spline,
 - generating a bar profile,
 - generating a bar element having a profile defined by the bar profile and an extent defined by the bar spline.

31. A method according to claim 30, wherein the bar profile is bound to the bar spline.

5 32. A method according to claim 30 or 31, wherein the bar spline is arranged in a virtual occlusal plane representing the occlusal plane of the patient.

33. A method according to claim 30 or 31, wherein the bar spline follows the contour of at least a part of the teeth surface of the 3D teeth model.

10

34. A method according to any one of the claims 1 - 29, wherein the step of designing the virtual orthodontic element comprises,

- generating a first boundary curve for the virtual orthodontic appliance,
- generating a first tooth contacting surface of the virtual orthodontic

15 appliance, where said first tooth contacting surface at least partly is shaped according to teeth in the first section of the virtual 3D teeth model and is bounded by said first boundary curve,

- generating an outer shell surface, and

20 - generating a first connecting surface configured for connecting the first boundary curve and the outer shell surface.

35. A method according to claim 34, wherein the first tooth contacting surface at least partly comprises a first occlusion guiding segment of the virtual orthodontic appliance, where the first occlusion guiding segment is

25 configured to provide that an orthodontic appliance manufactured from the virtual orthodontic appliance is capable of guiding the patient's upper and lower jaw towards a target geometrical relationship during occlusion or of maintaining the patient's upper and lower jaw in a target geometrical relationship

30

10

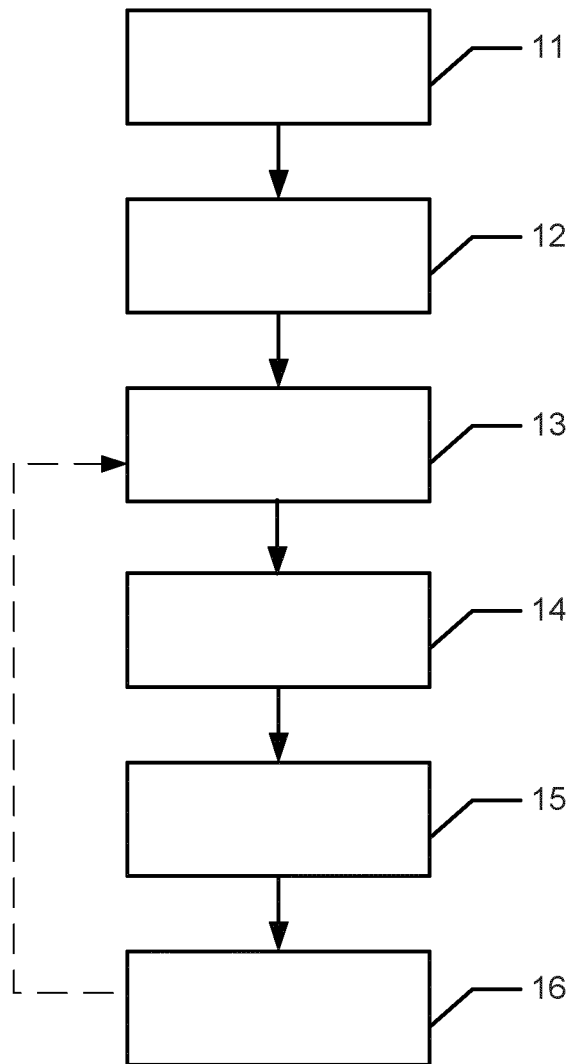


Fig. 1

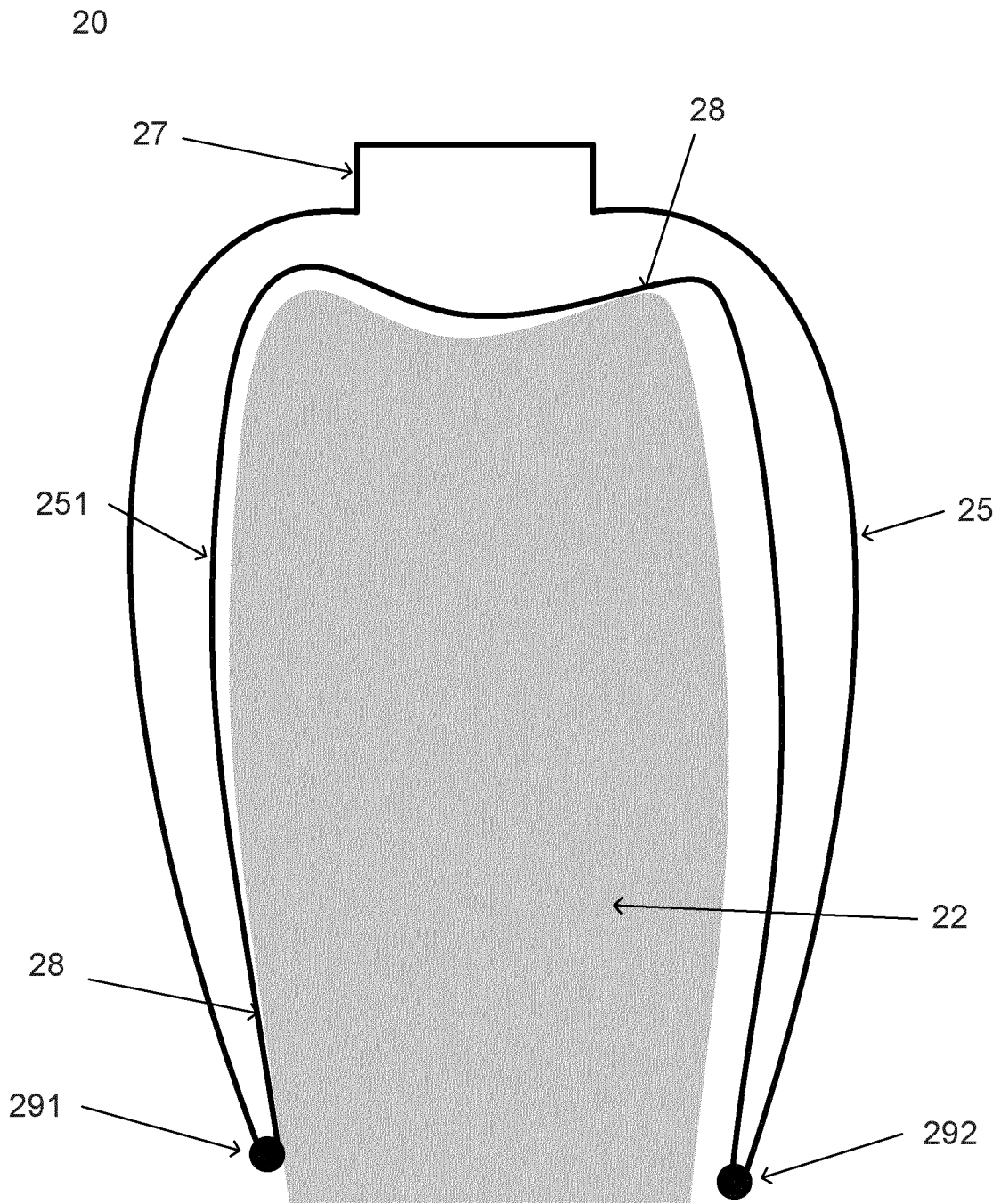


Fig. 2

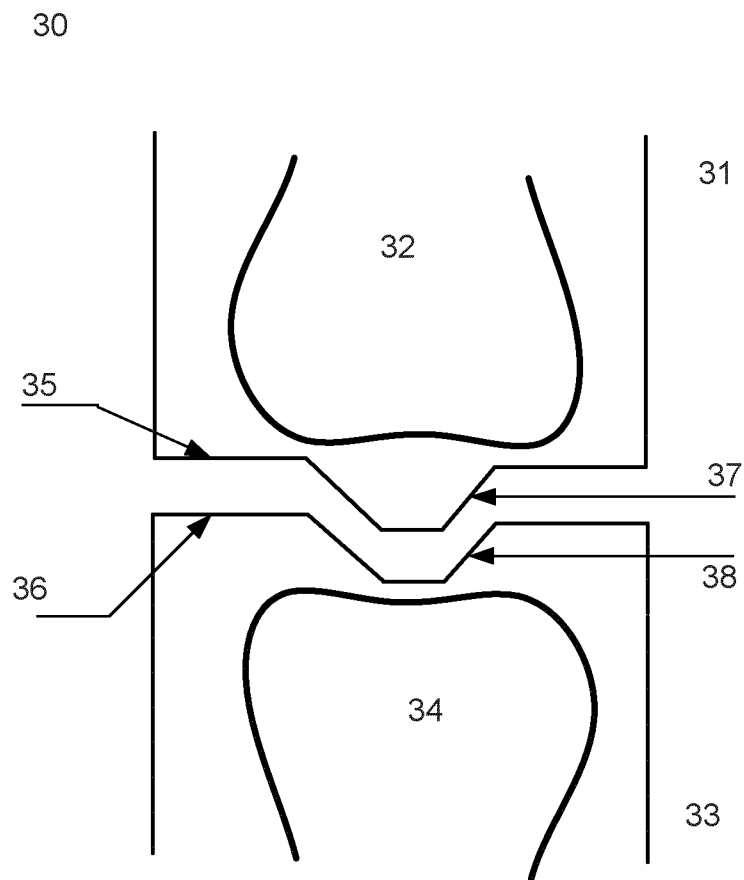


Fig. 3

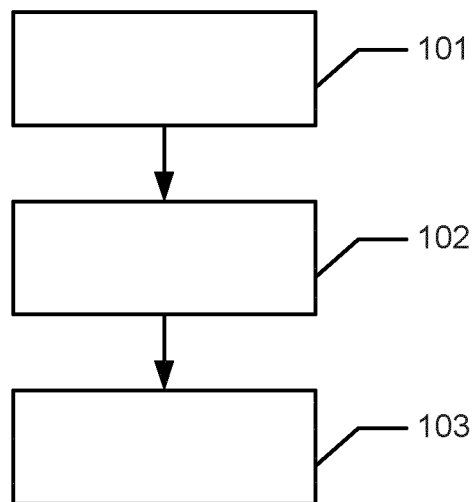


Fig. 4

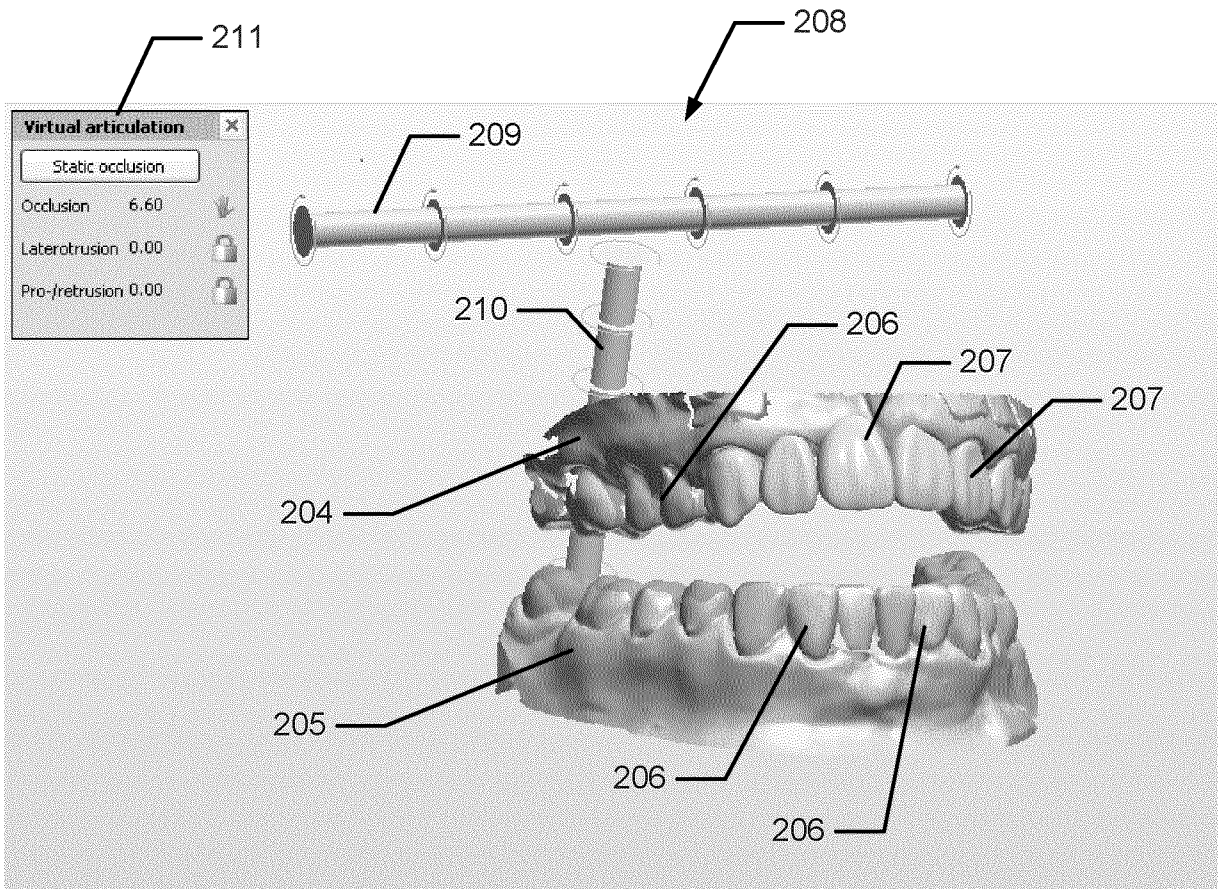


Fig. 5a)

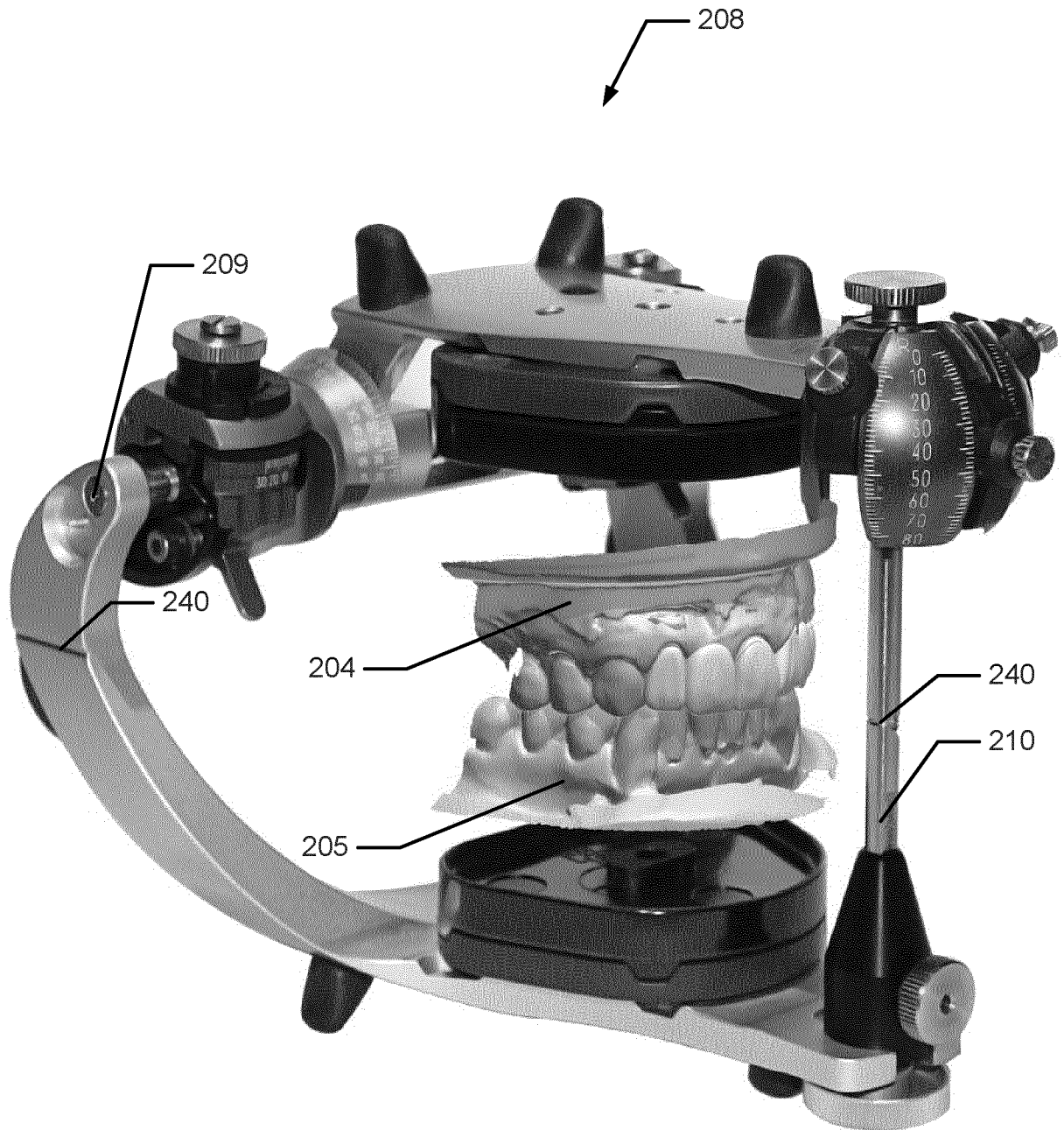


Fig. 5b)

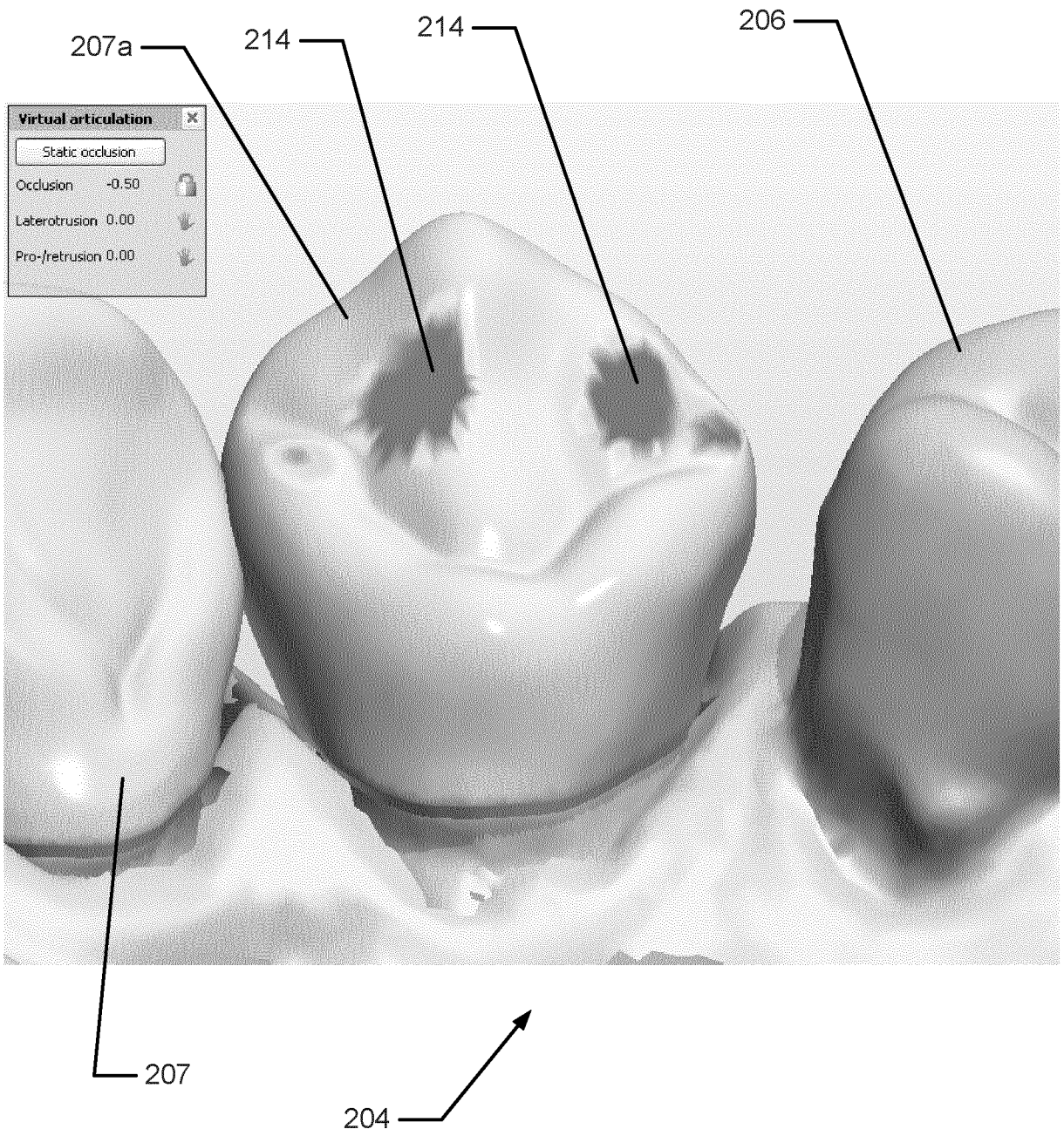


Fig. 6

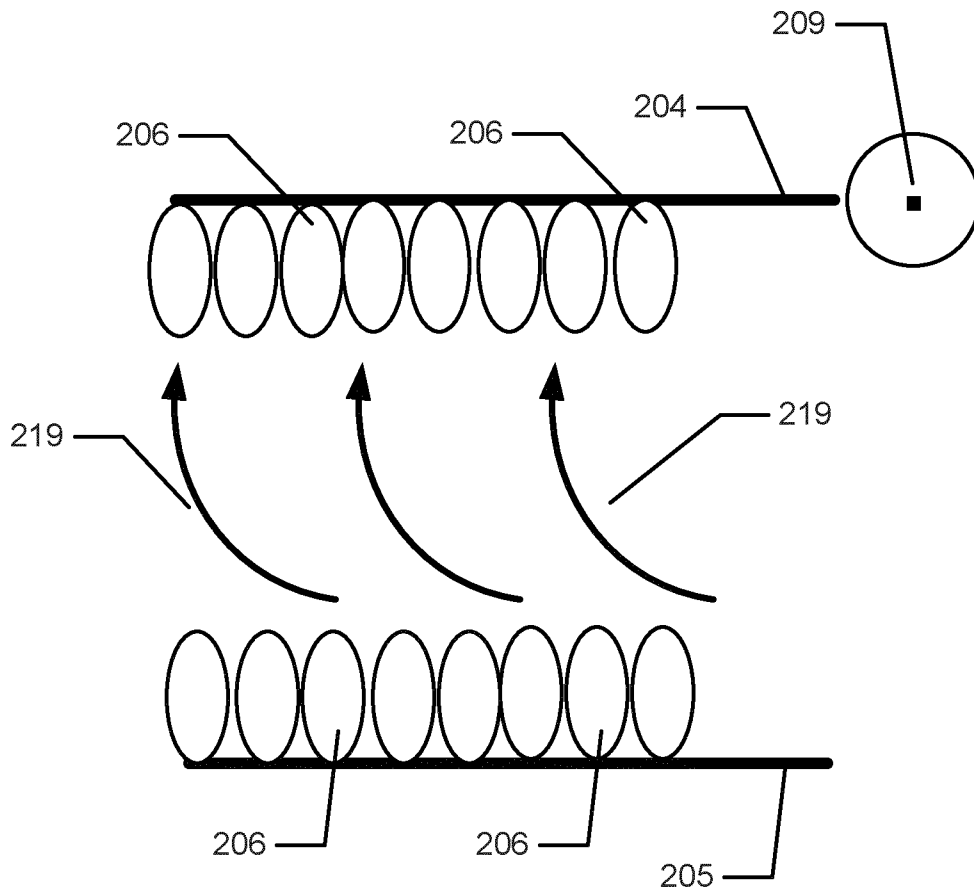


Fig. 7

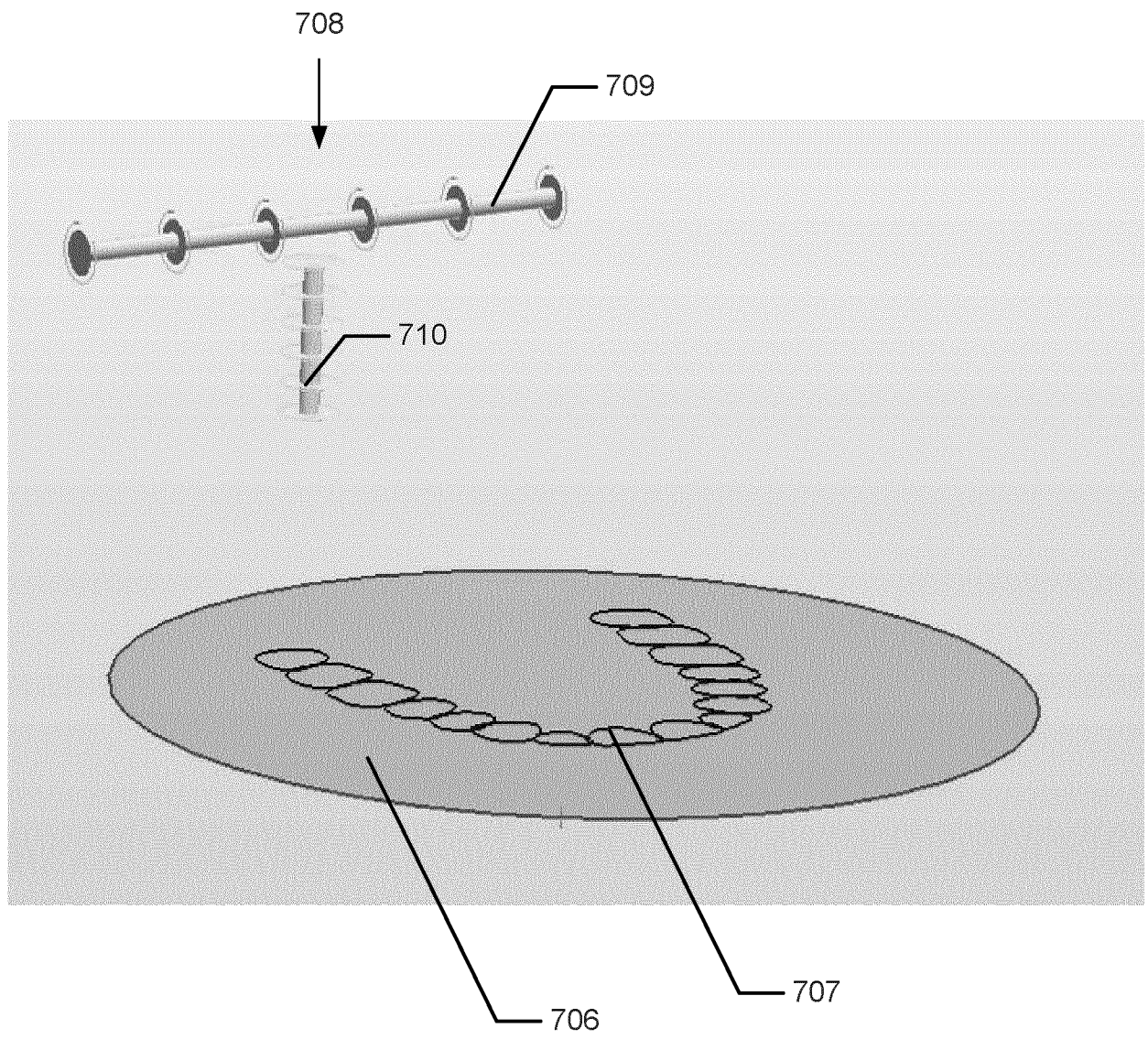


Fig. 8

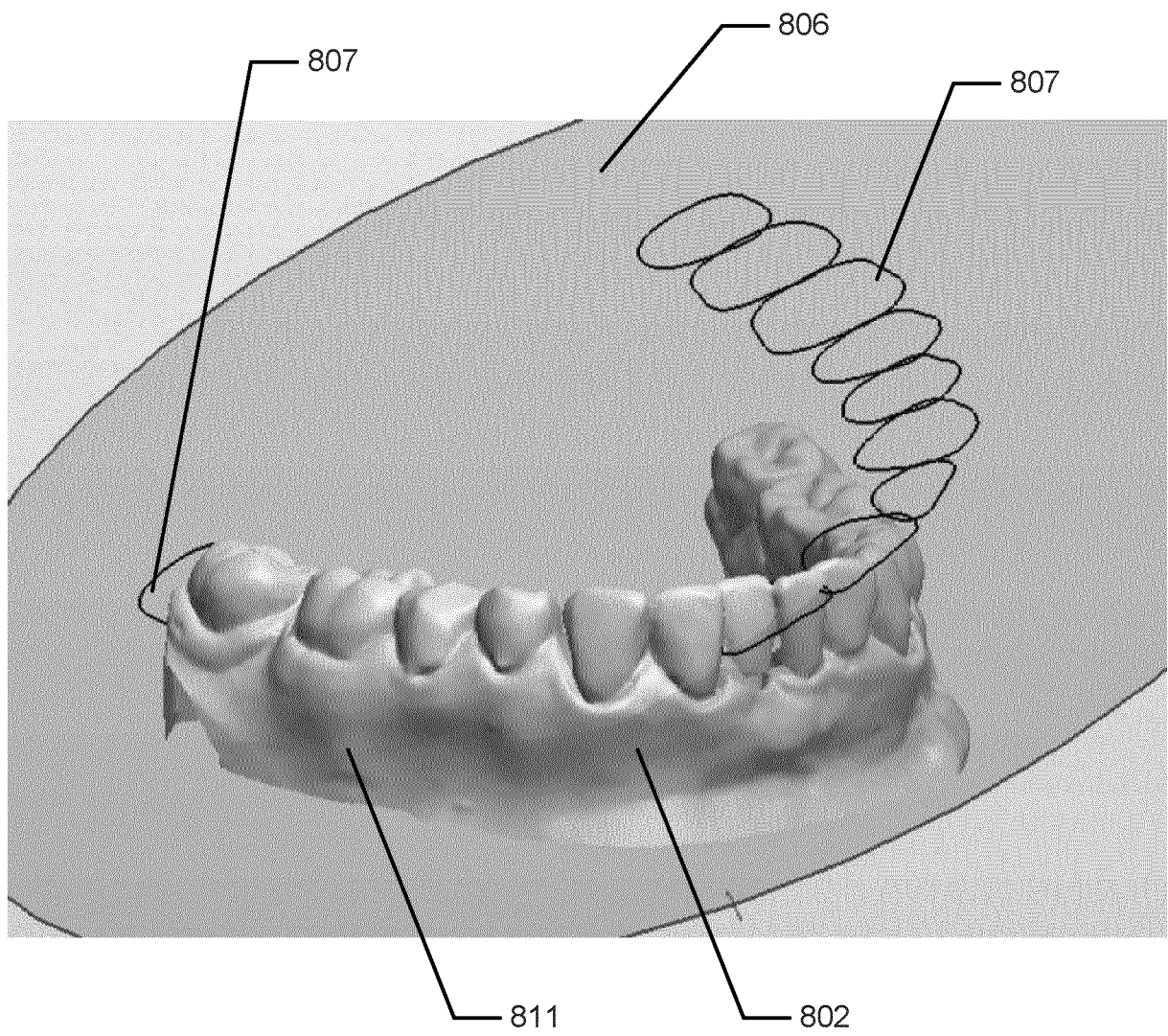


Fig. 9

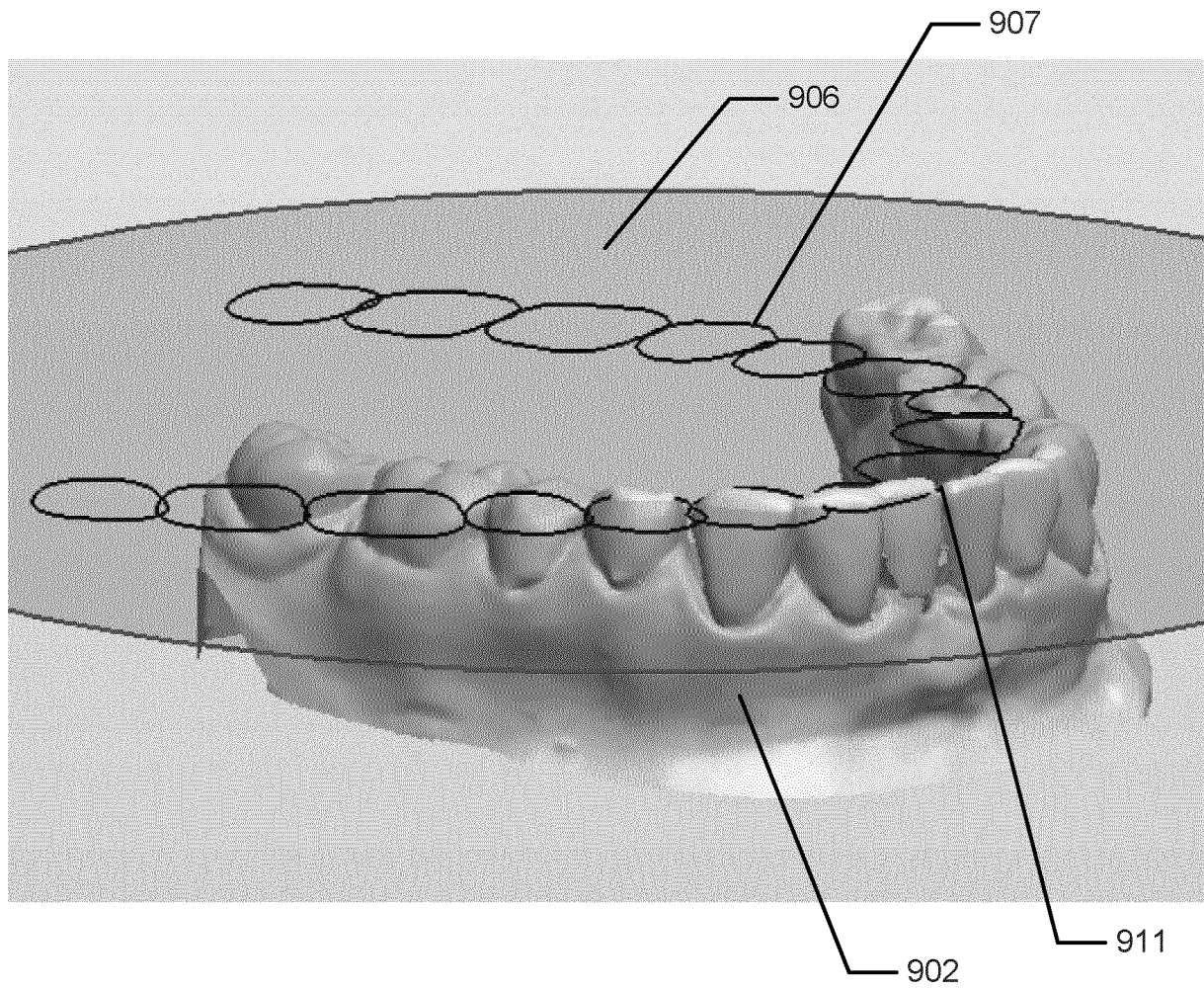


Fig. 10

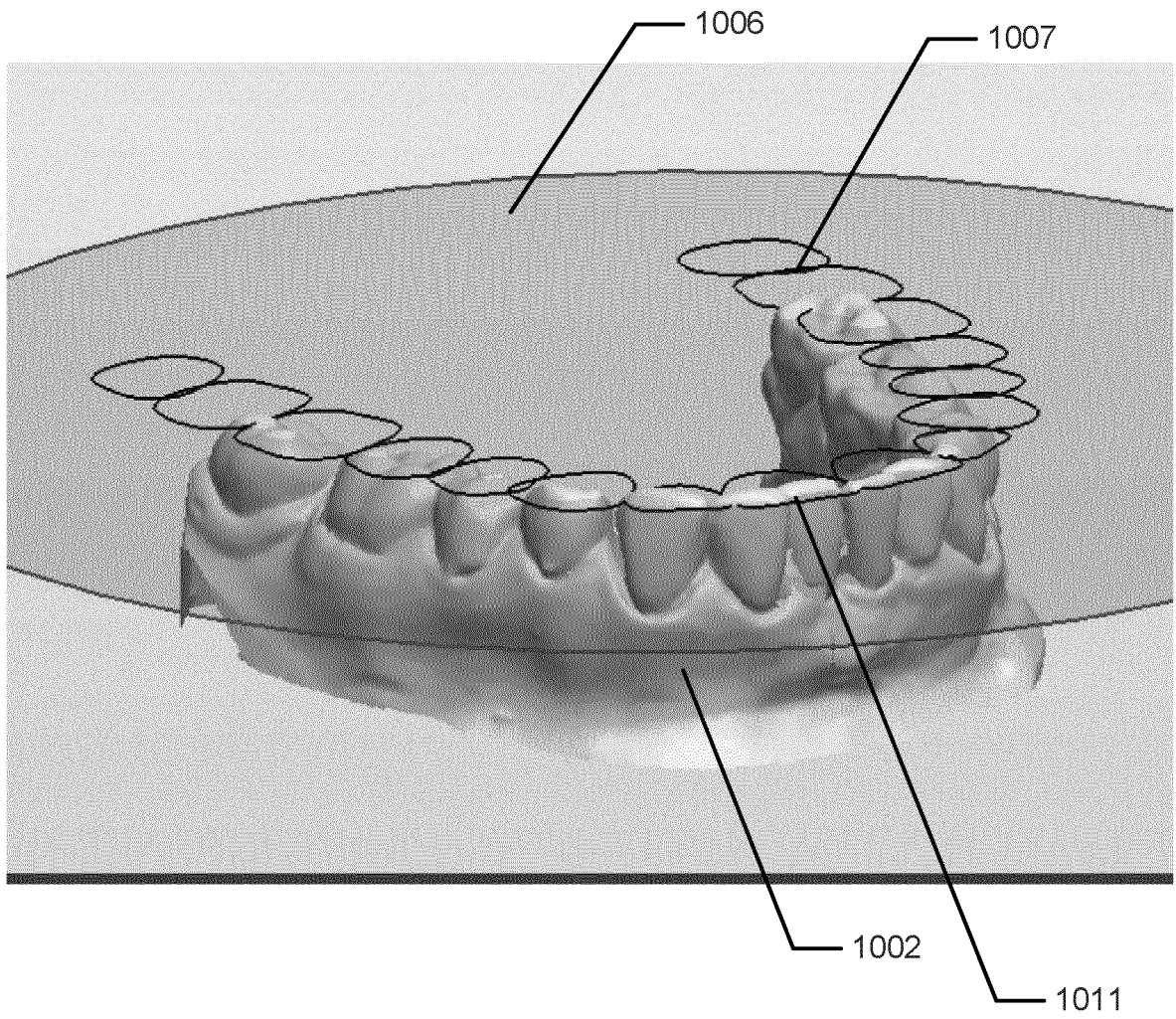


Fig. 11

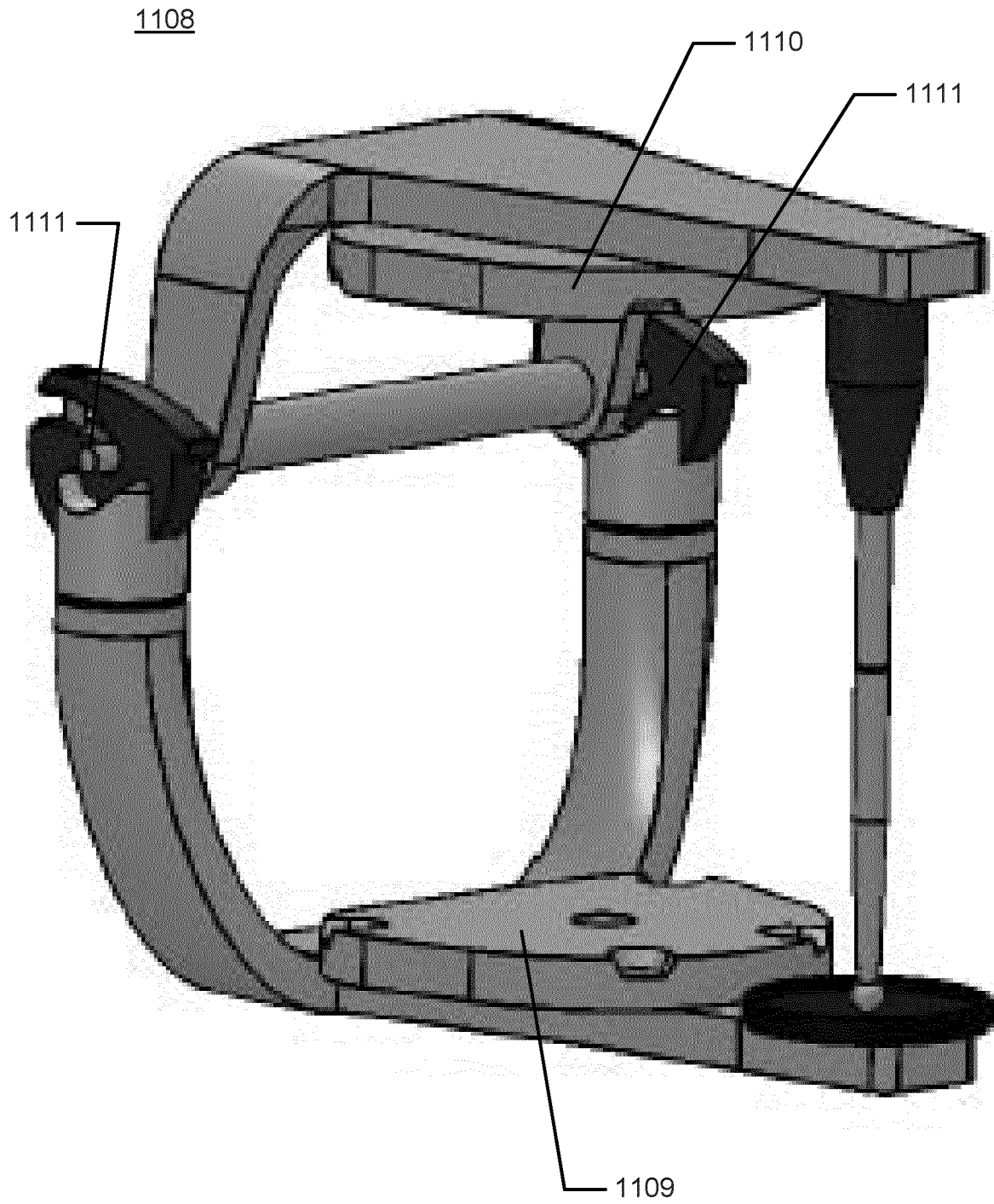


Fig. 12

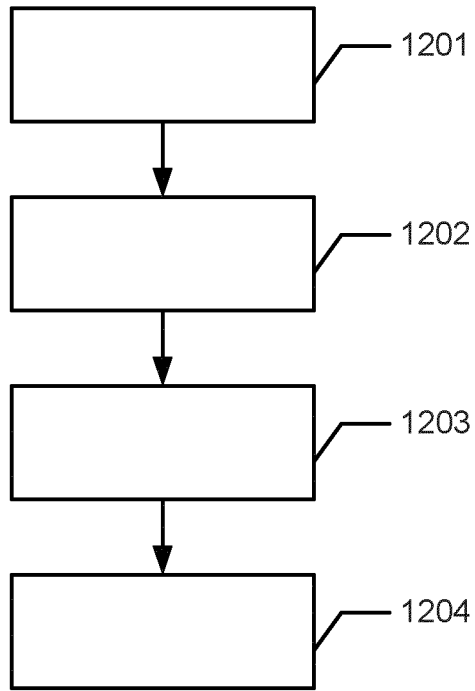


Fig. 13

Fig. 14a)

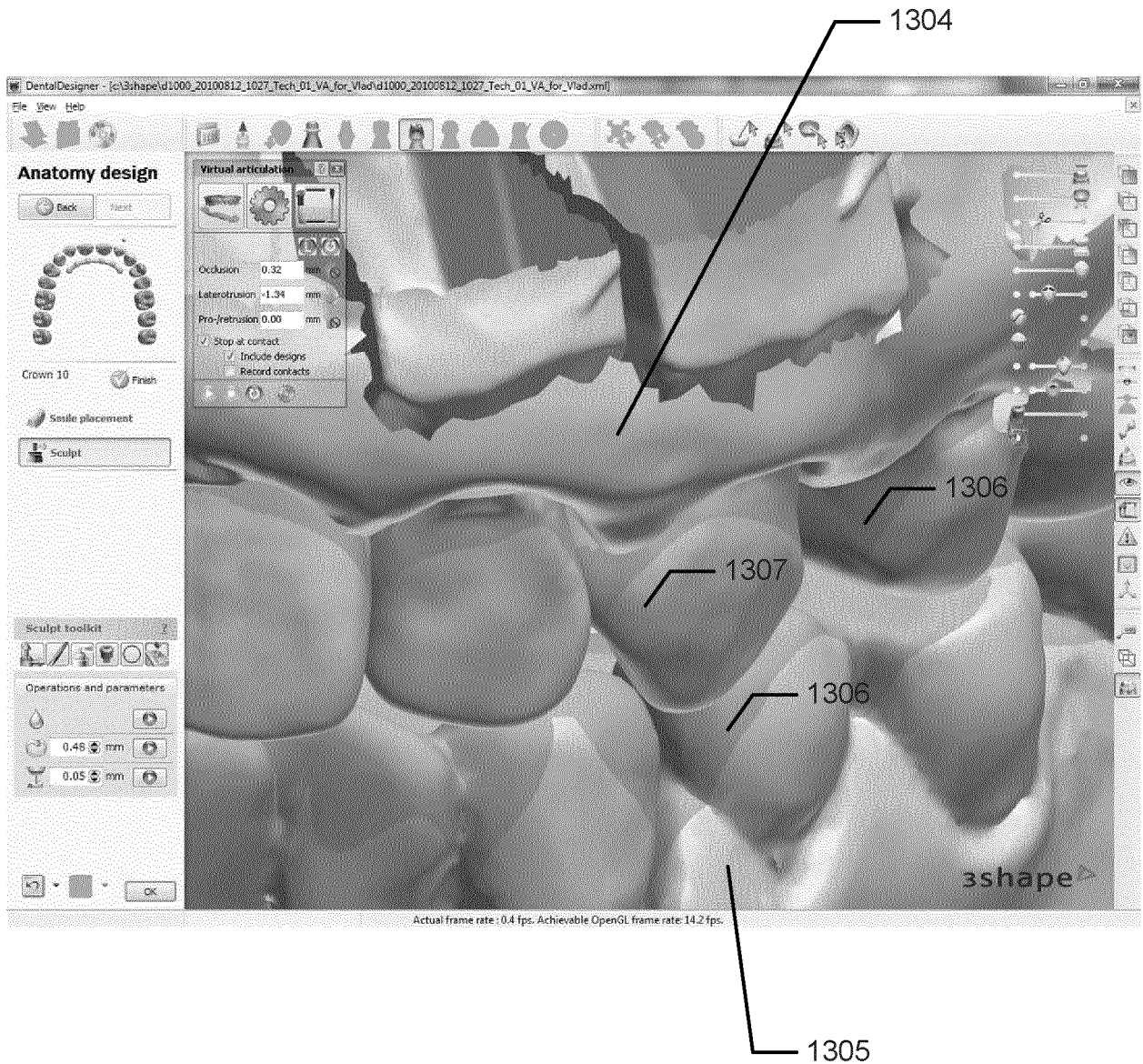


Fig. 14b)

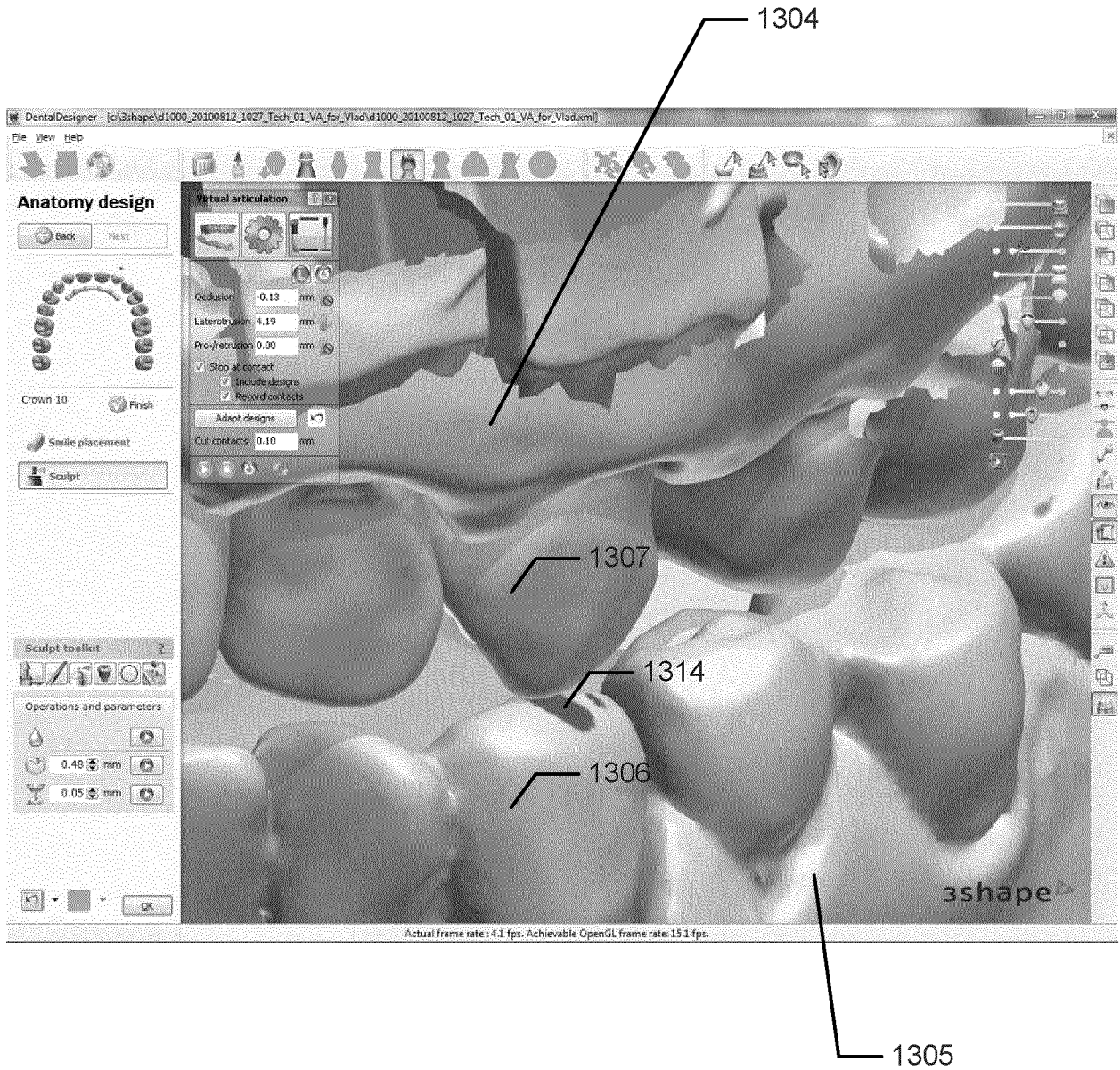


Fig. 15

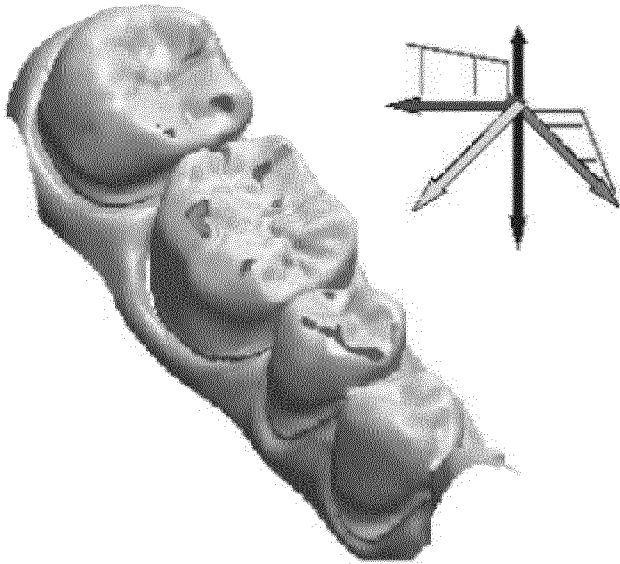


Fig. 16

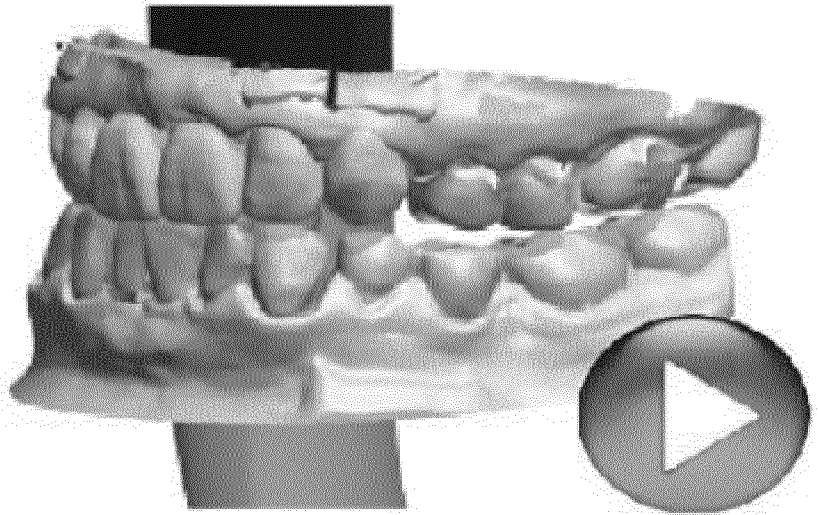


Fig. 17

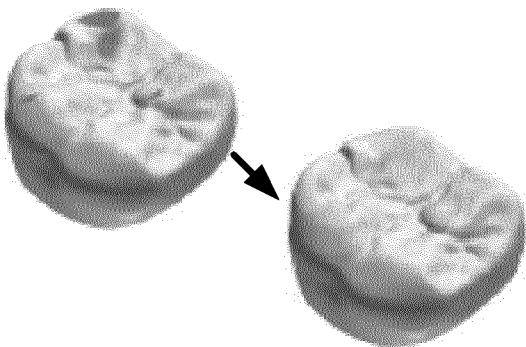
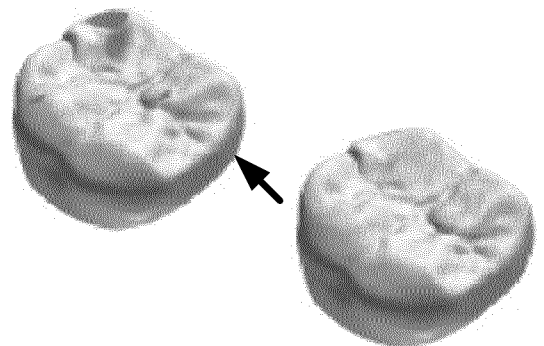


Fig. 18



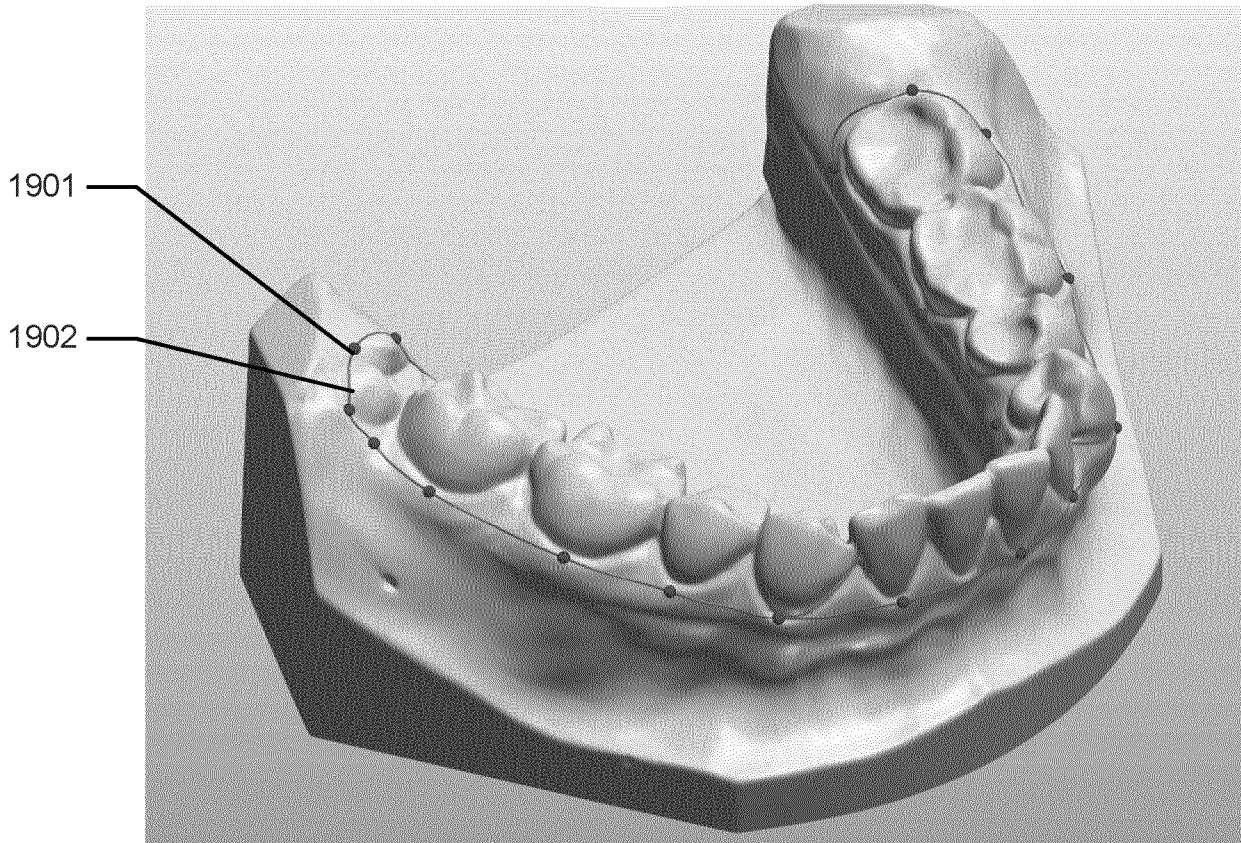


Fig. 19

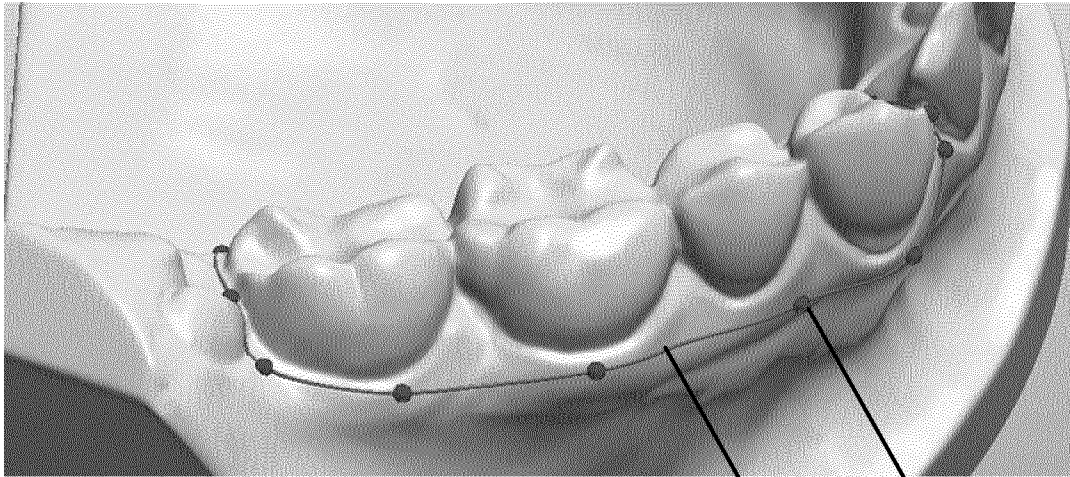


Fig. 20a

2001
2002

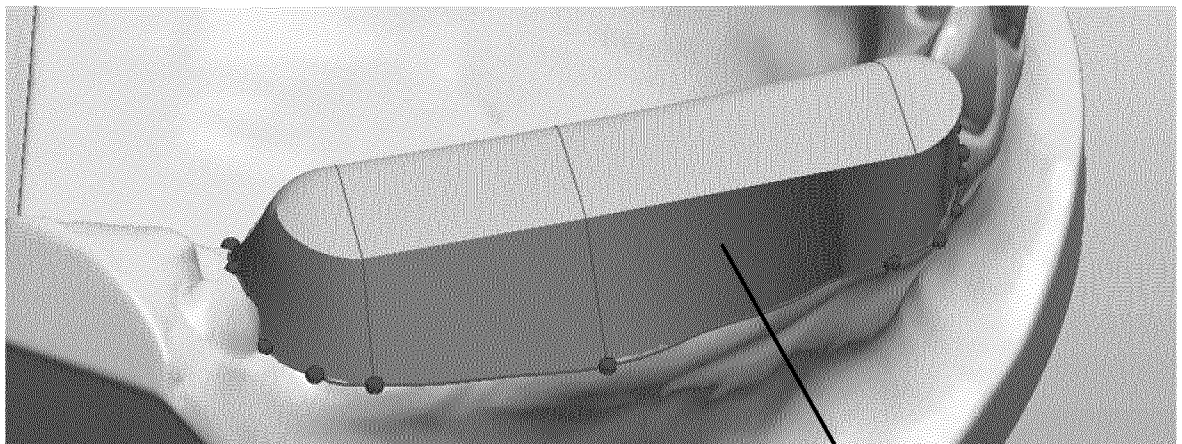


Fig. 20b

2003

Fig. 21a)

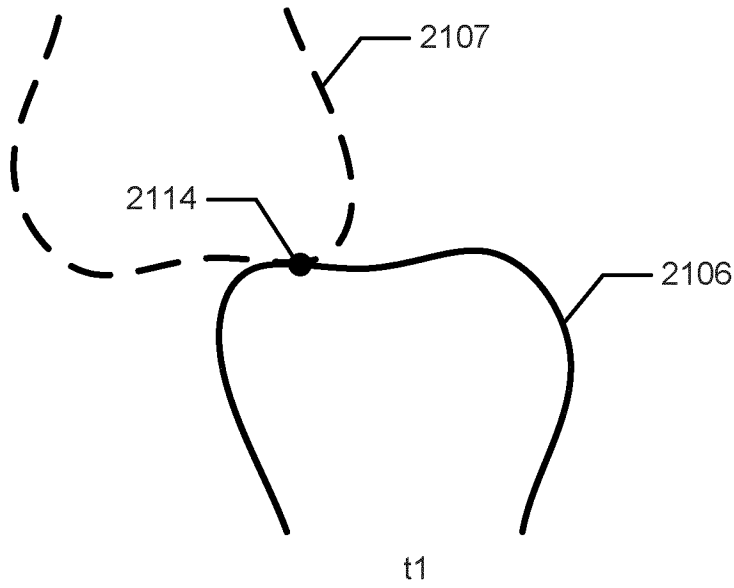


Fig. 21b)

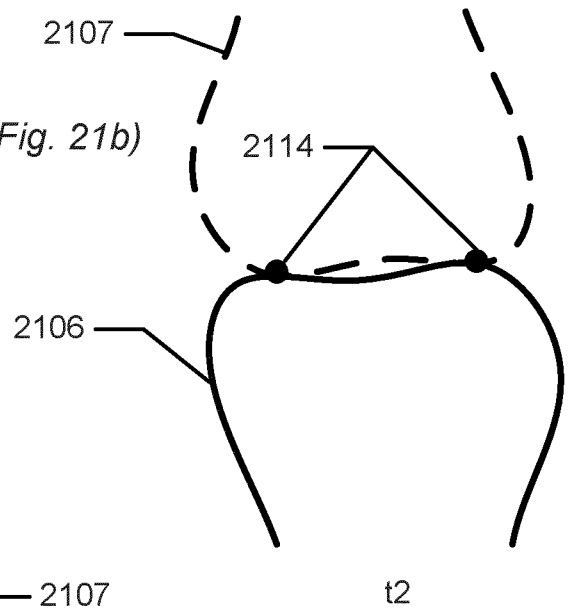


Fig. 21c)

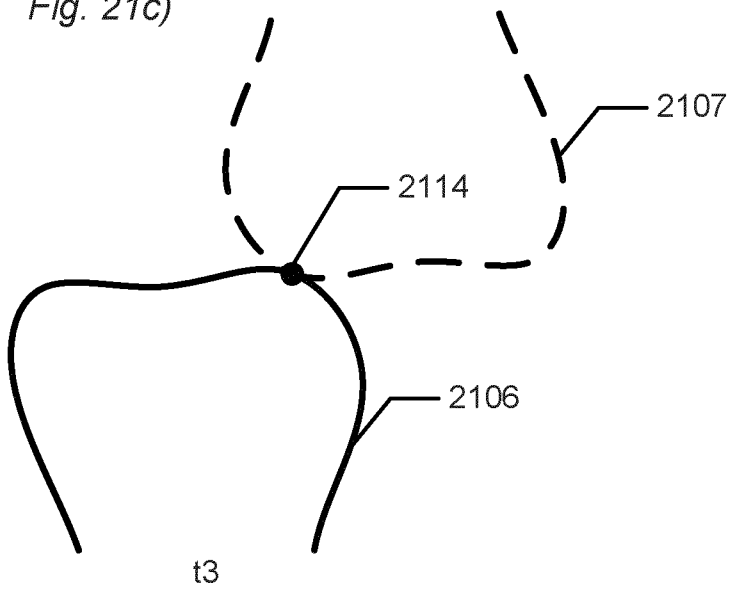


Fig. 21d)

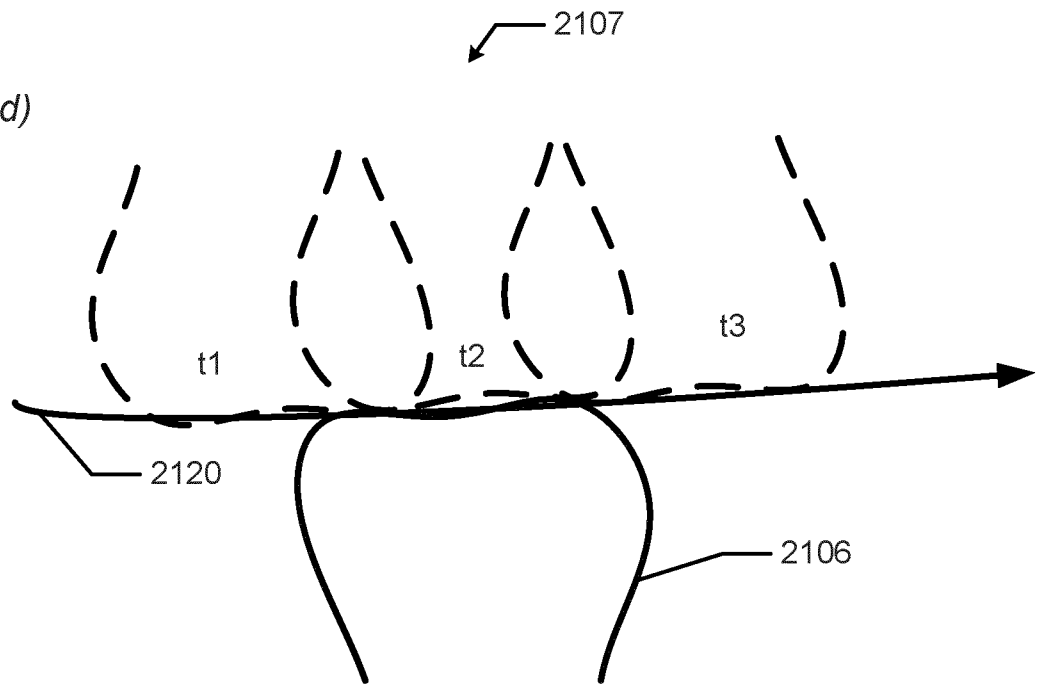


Fig. 21e)

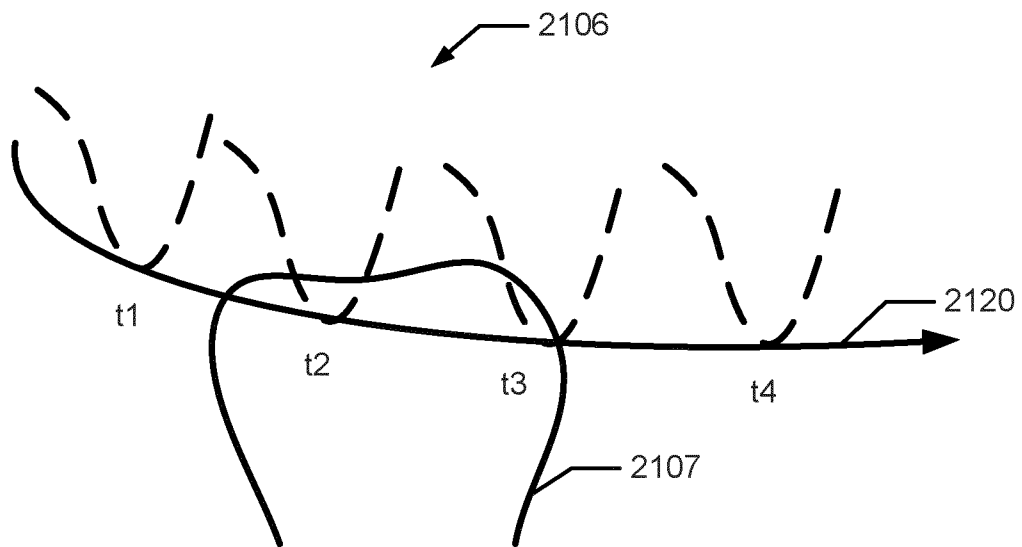


Fig. 22a)

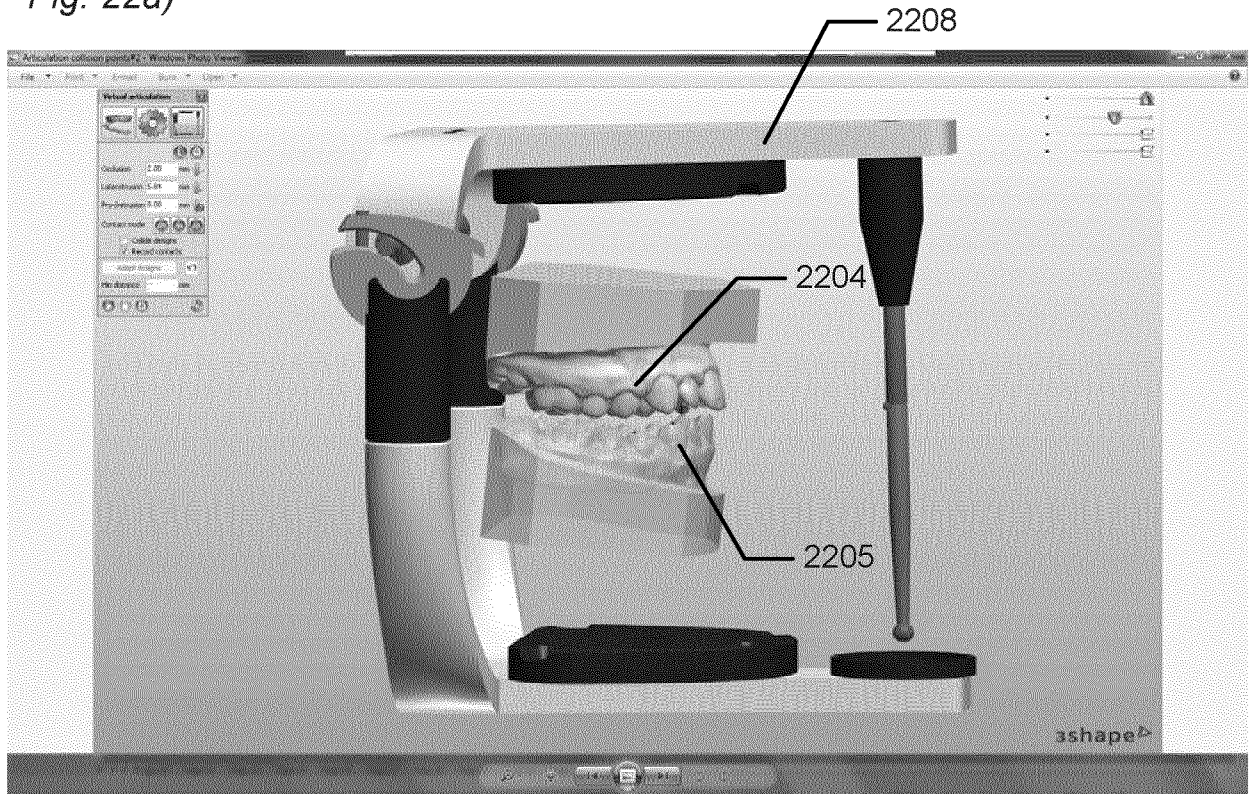


Fig. 22b)

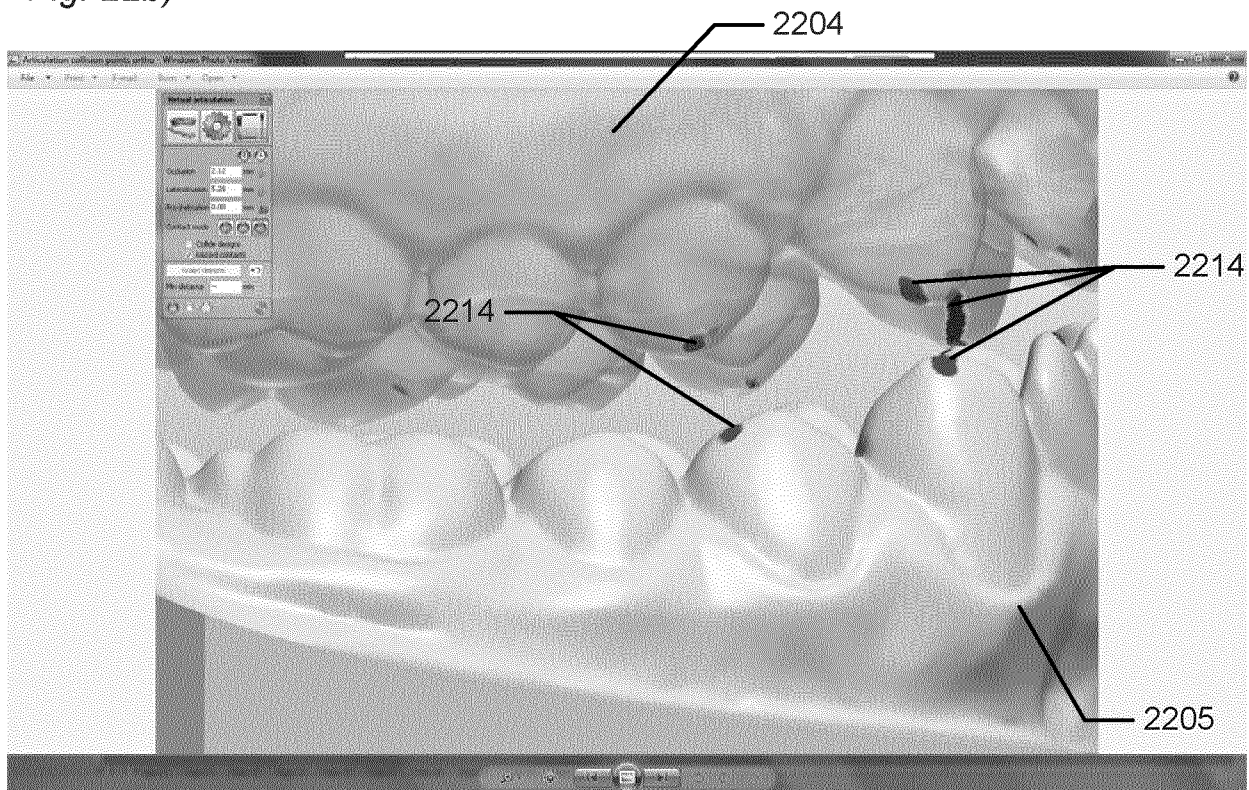


Fig. 23a)

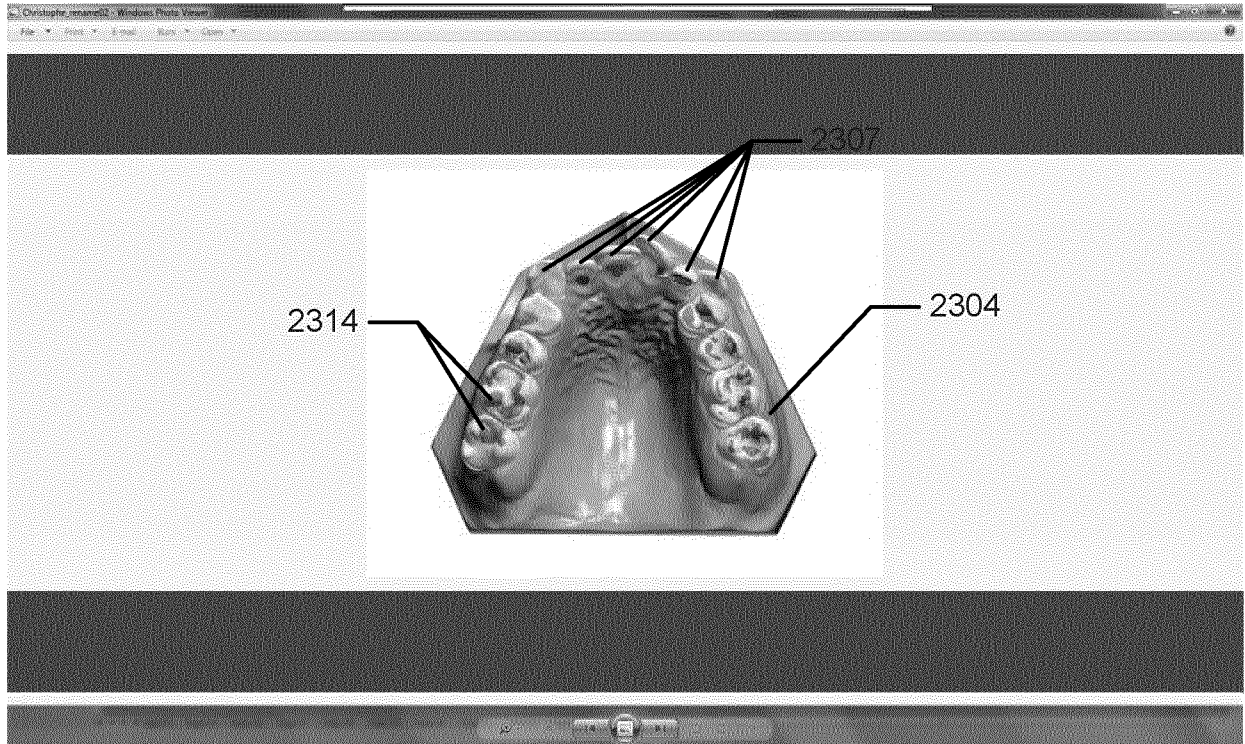


Fig. 23b)

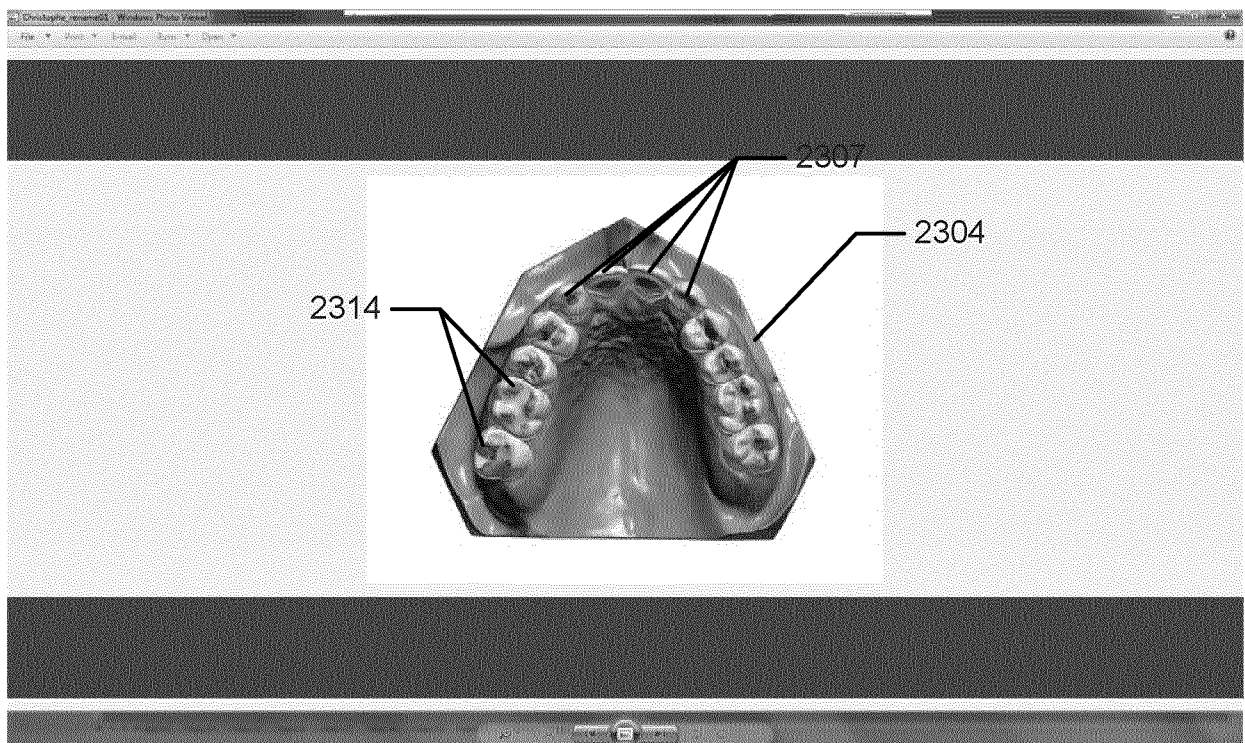


Fig. 24a)

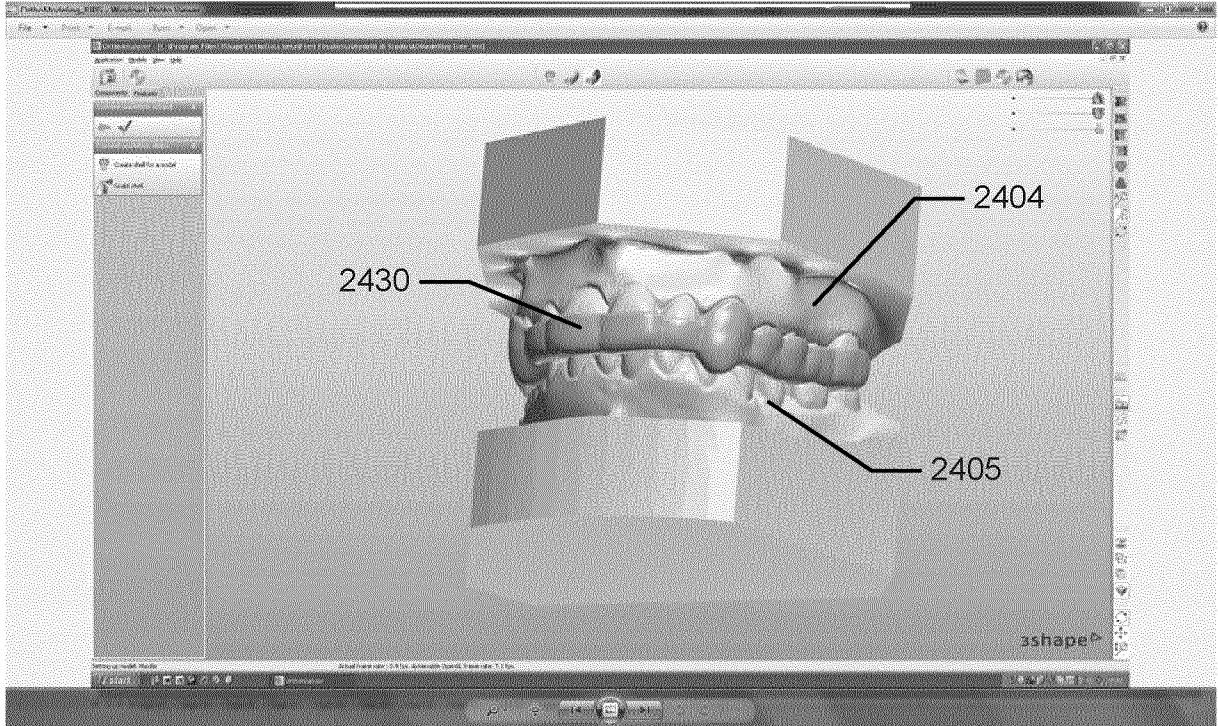


Fig. 24b)

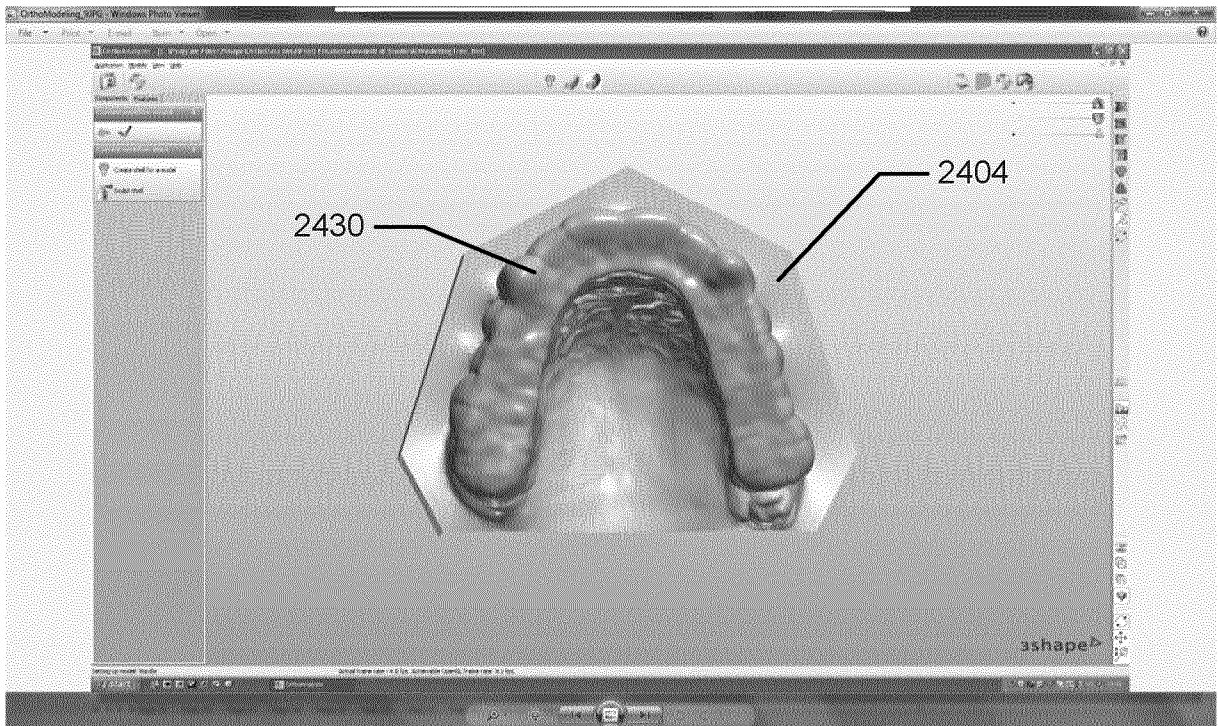


Fig. 24c)

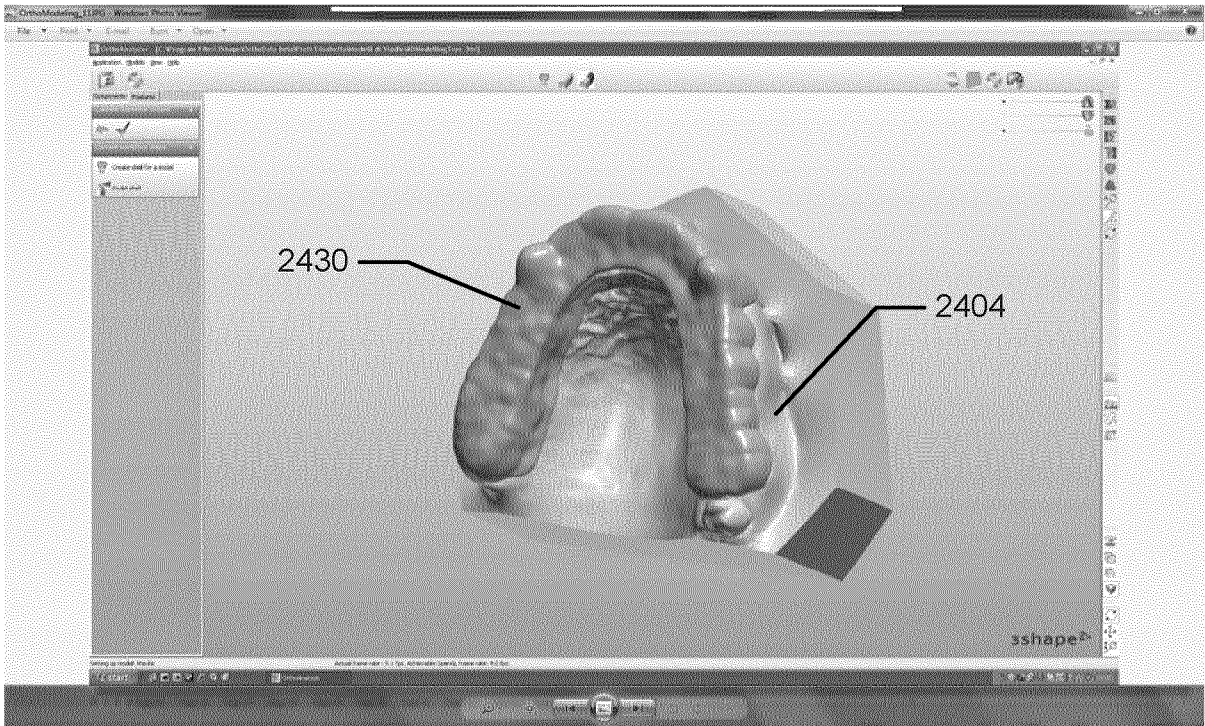
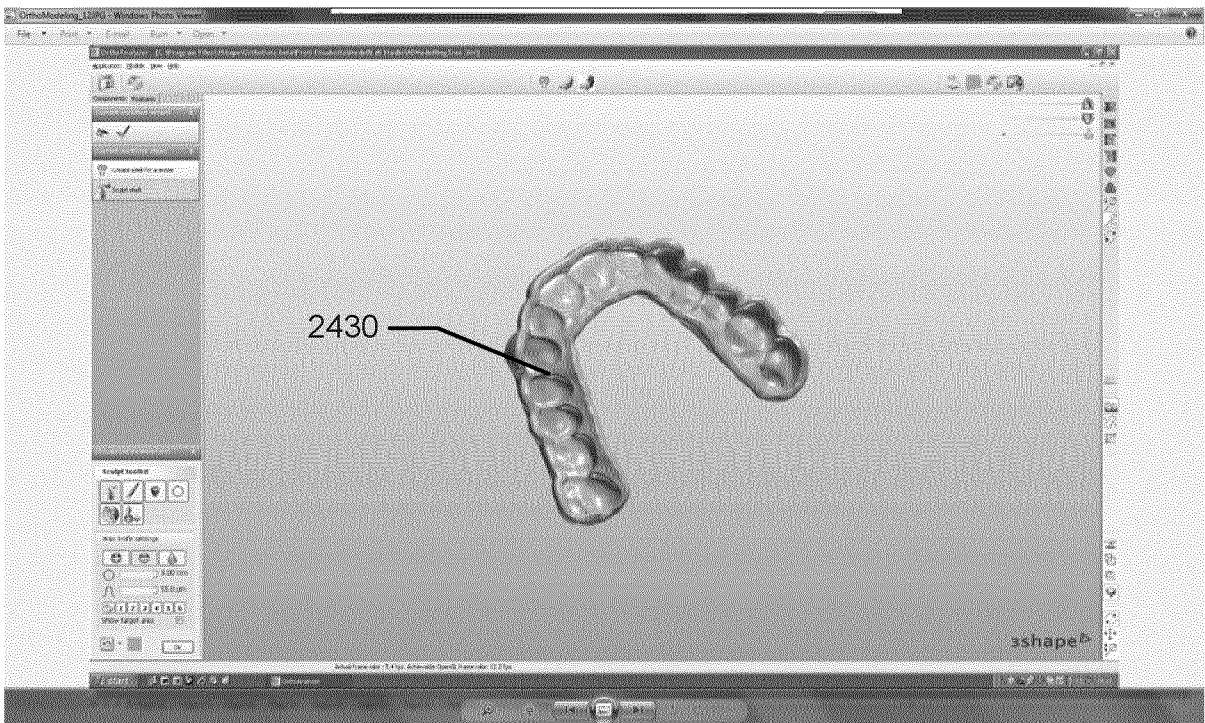


Fig. 24d)



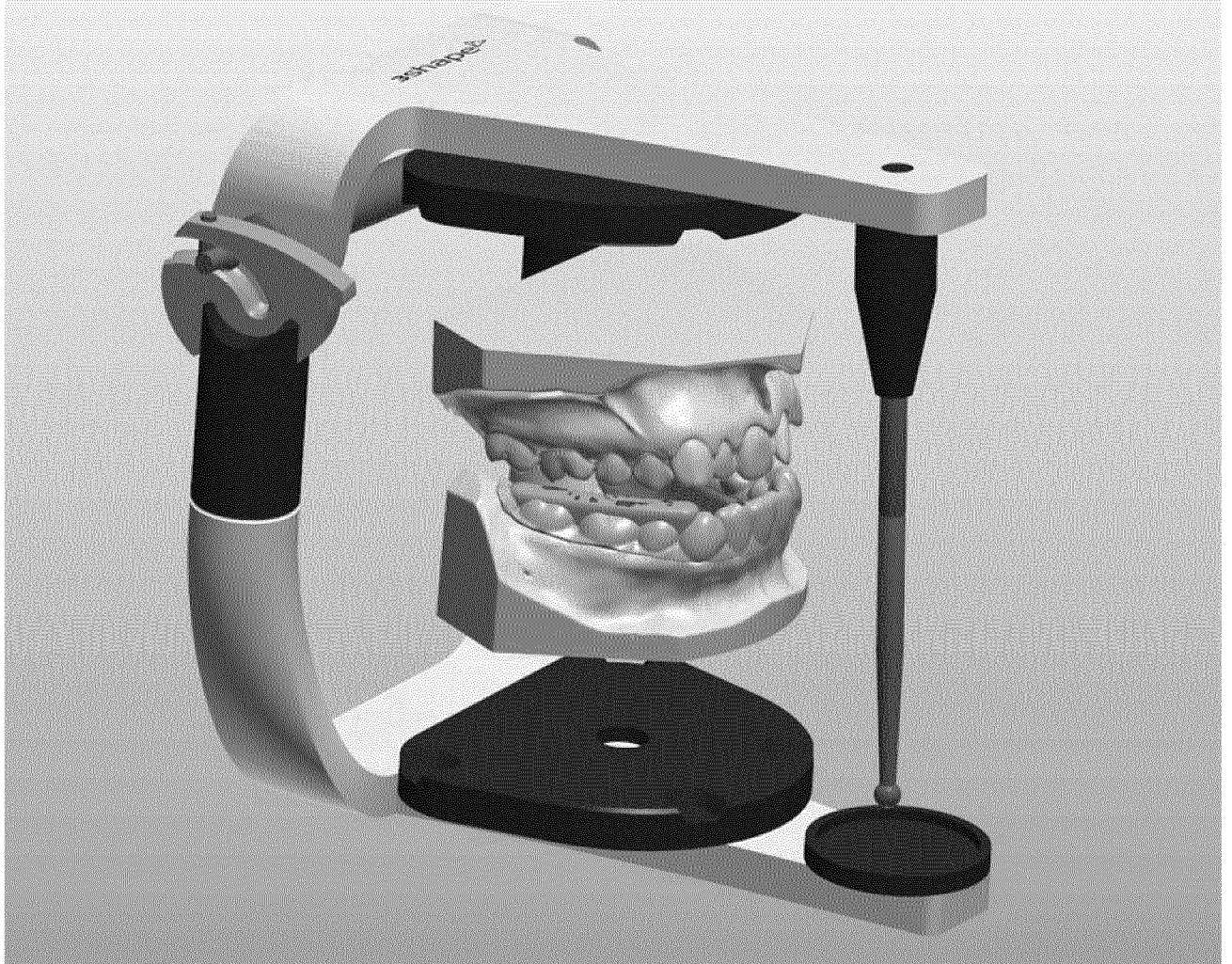


Fig. 25

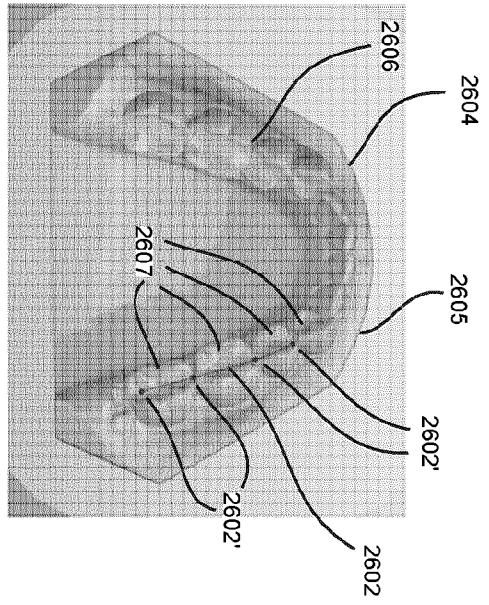


Fig. 26a

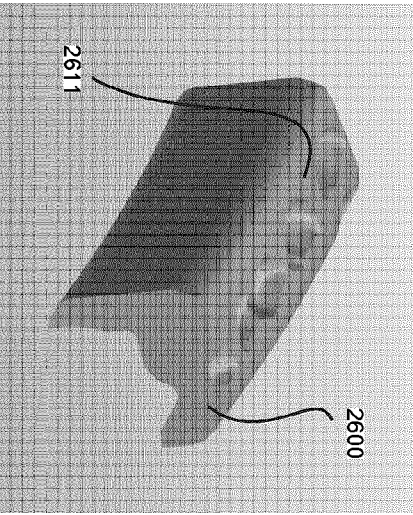


Fig. 26d

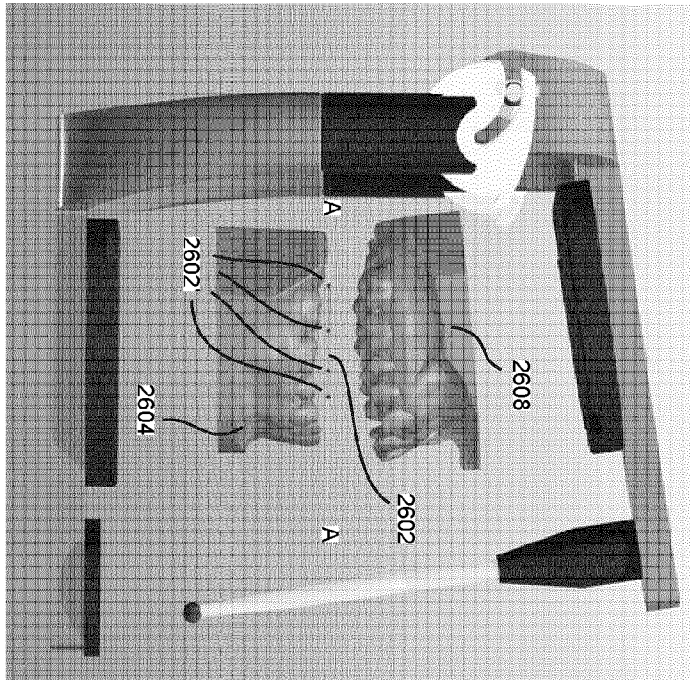


Fig. 26b

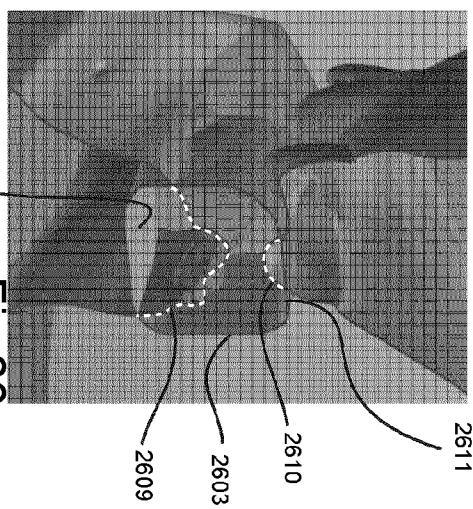


Fig. 26c

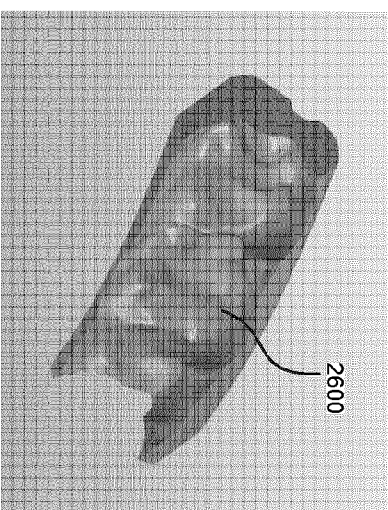


Fig. 26e

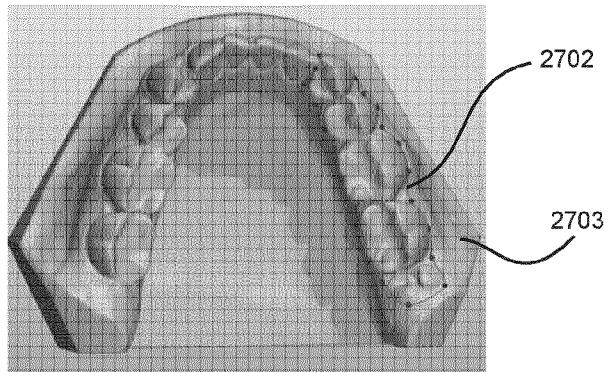


Fig. 27a

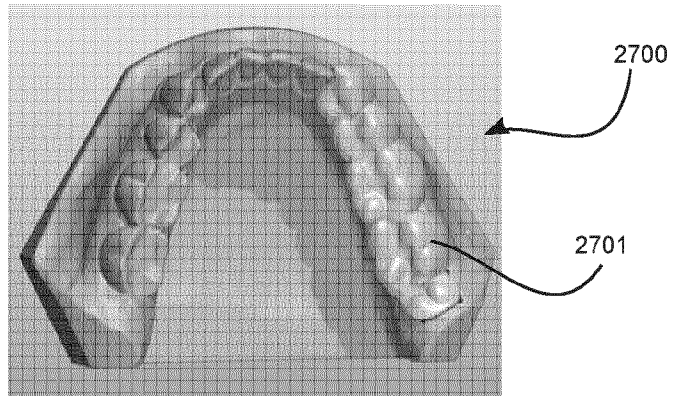


Fig. 27b

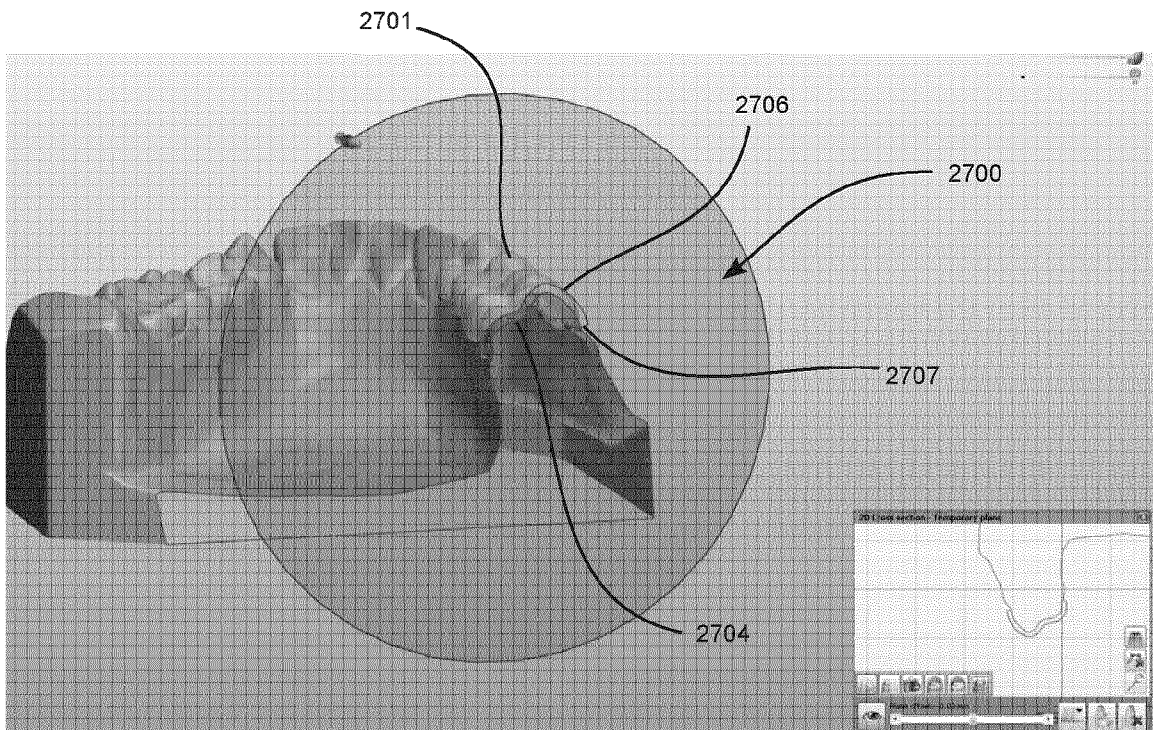


Fig. 27c

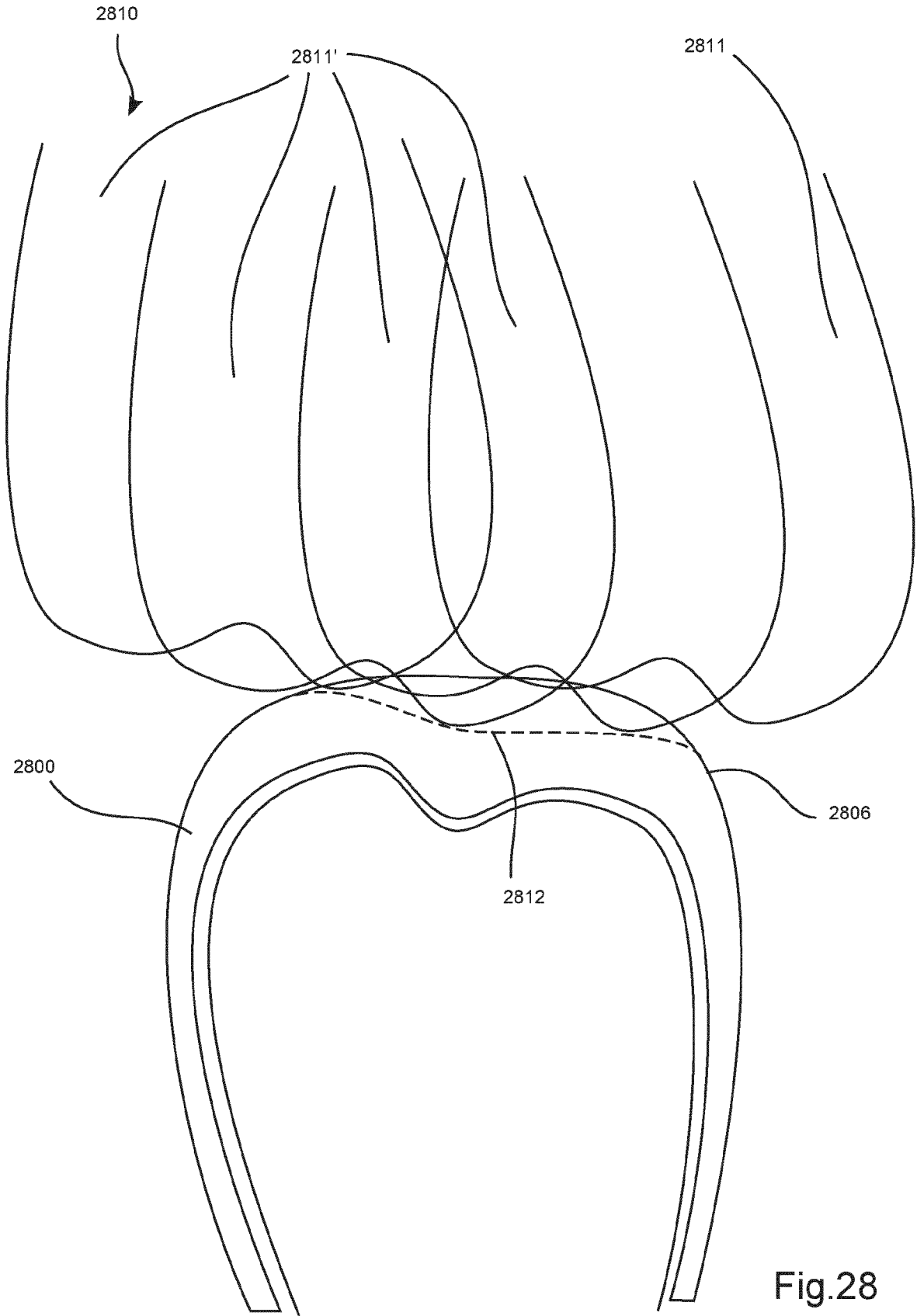


Fig.28

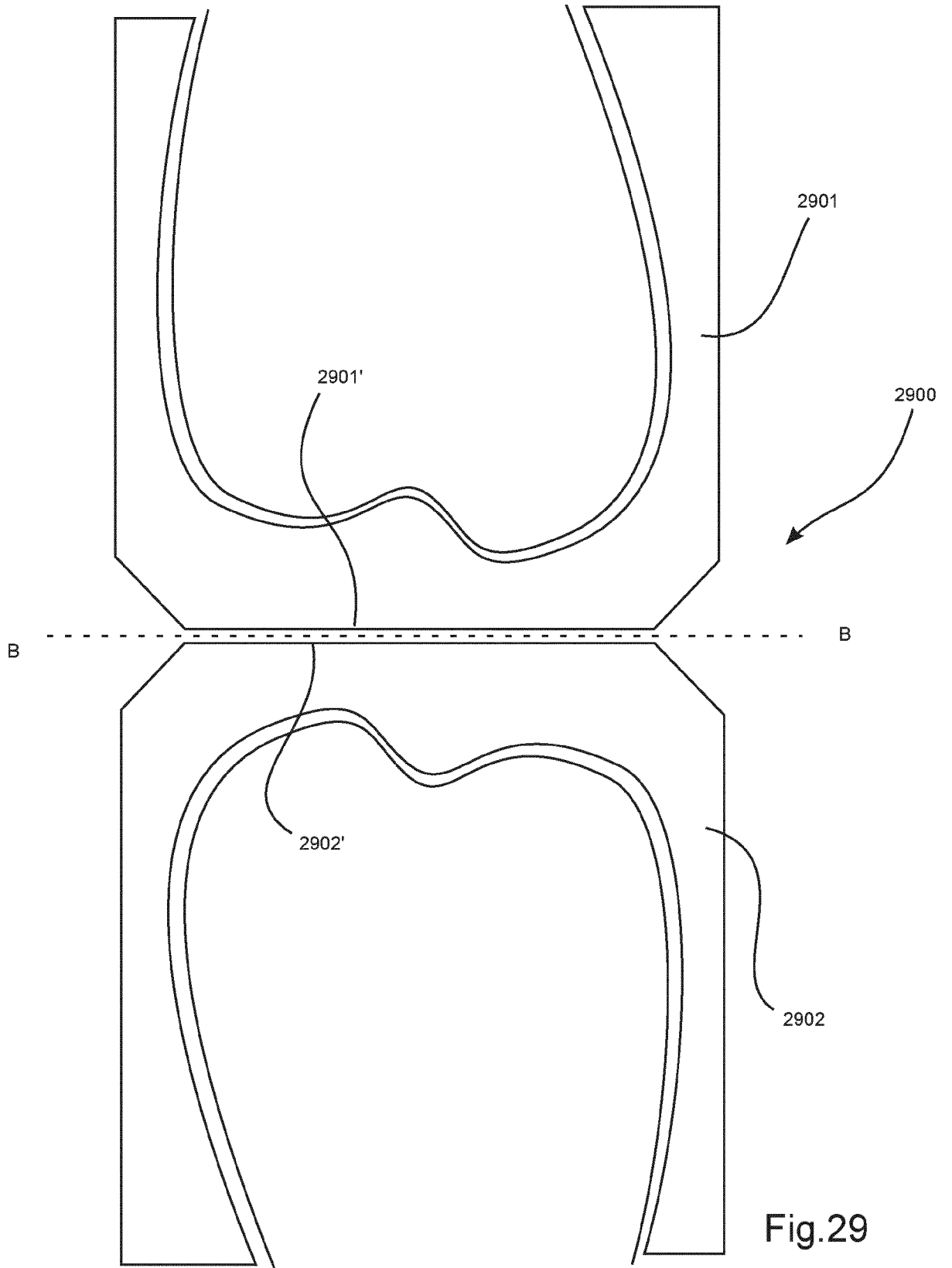


Fig.29

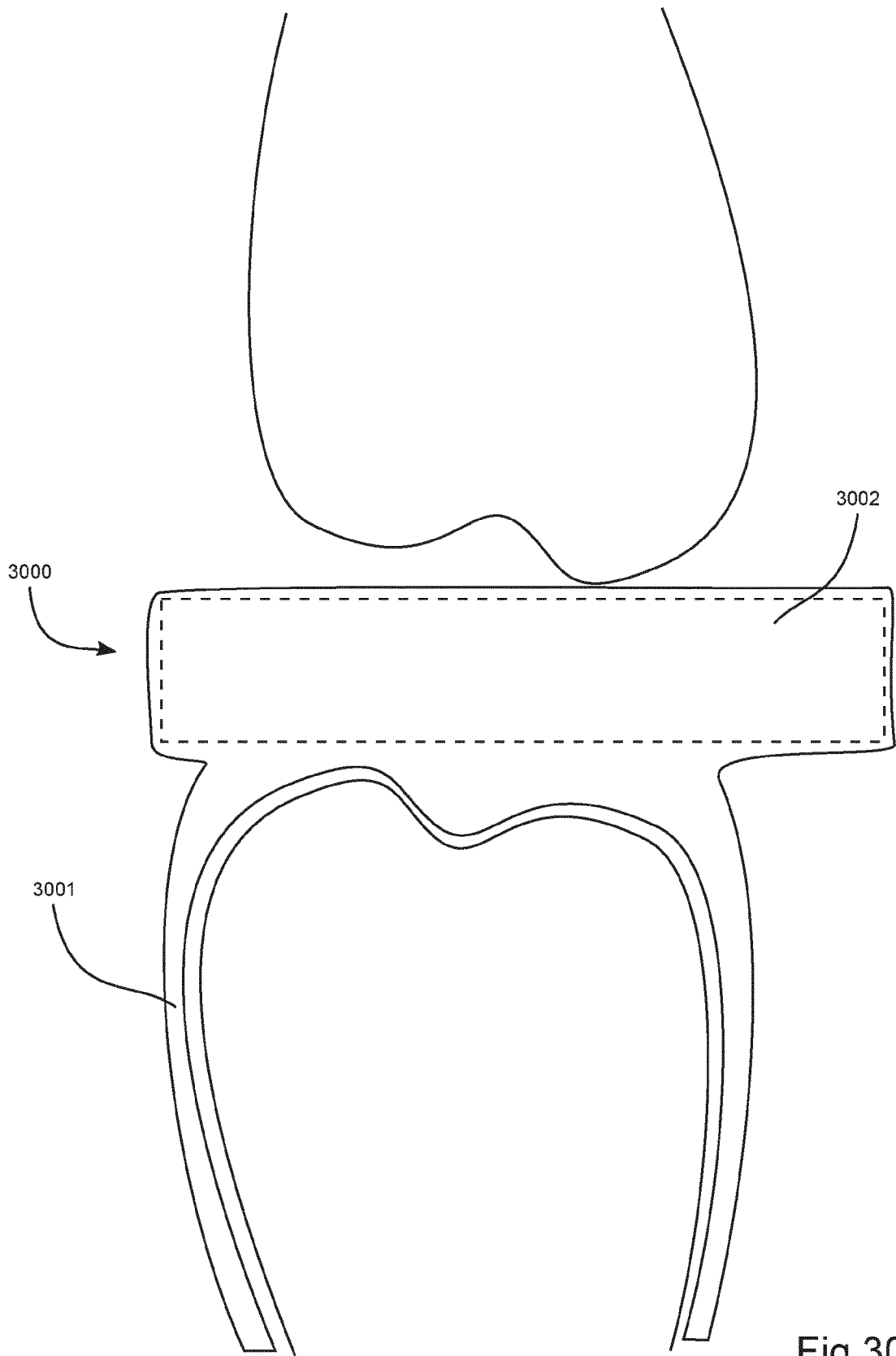


Fig.30

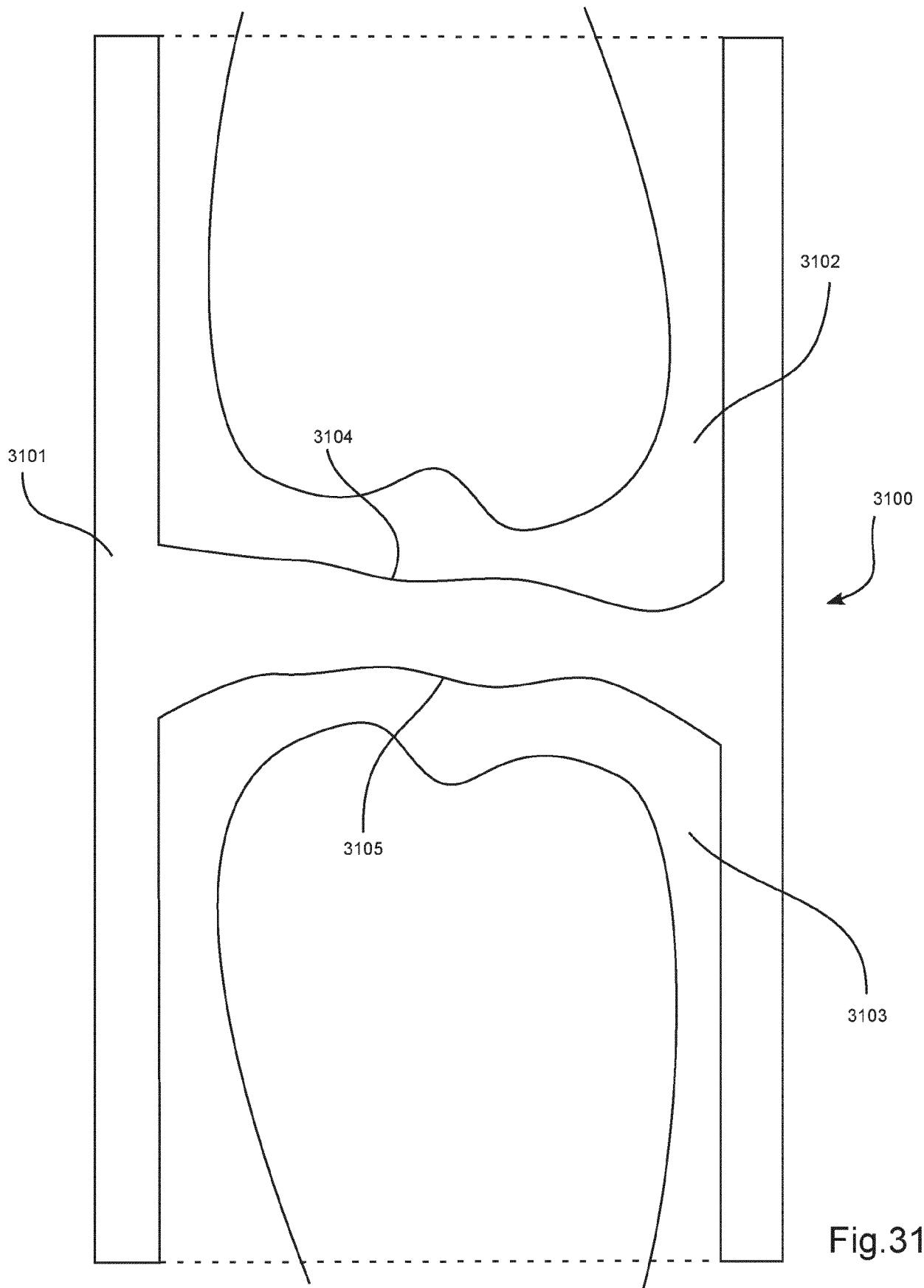


Fig.31