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(54) Title: METHOD AND SYSTEM FOR GUIDING AN INTRA-ORAL SCAN

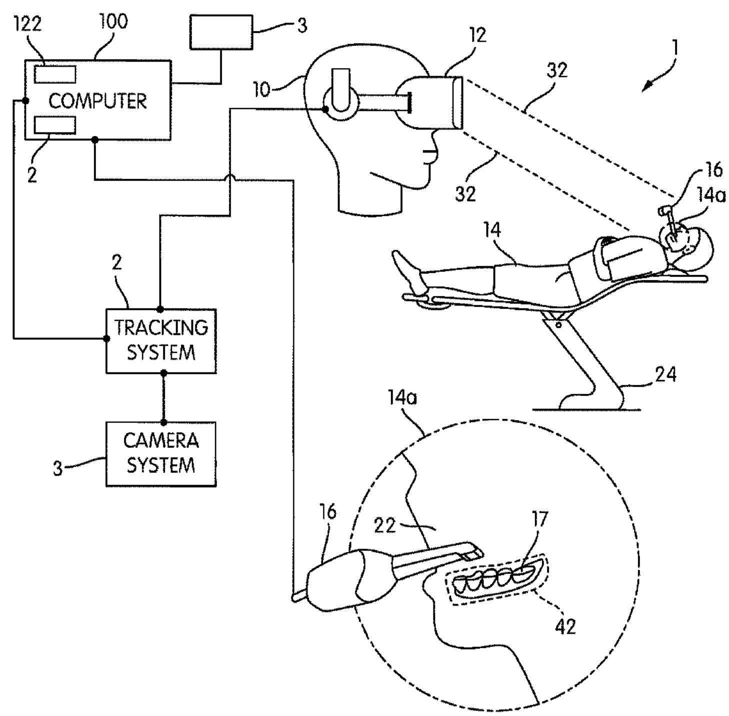

FIG. 2

(57) Abrégé/Abstract:
A method, system and computer readable storage media for guiding an intra-oral scan utilizing augmented reality. By visualizing a scan strategy in a field of view of a clinician during an intra-oral scanning scan procedure, a need to monitor the progress of the intra-oral scan on a separate monitor may be eliminated or reduced in order to save time.

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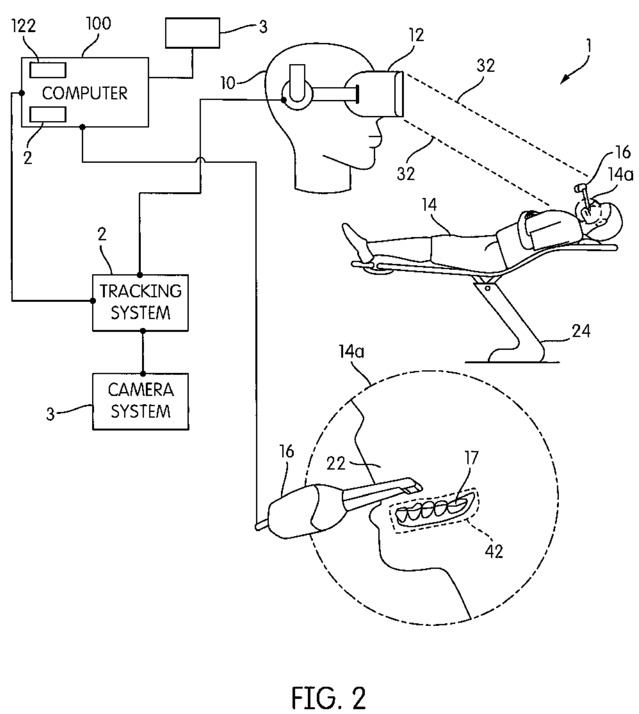

FIG. 2

(57) Abstract: A method, system and computer readable storage media for guiding an intra-oral scan utilizing augmented reality. By visualizing a scan strategy in a field of view of a clinician during an intra-oral scanning scan procedure, a need to monitor the progress of the intra-oral scan on a separate monitor may be eliminated or reduced in order to save time.

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METHOD AND SYSTEM FOR GUIDING AN INTRA-ORAL SCAN

CROSS-REFERENCE TO RELATED APPLICATIONS

This International Application claims the benefit of and priority to European Application Ser. No. 19000056.2, filed on January 30, 2019, which is herein incorporated by reference for all purposes.

FIELD OF THE INVENTION

The present application generally relates to a method, a system and a computer readable storage media for guiding an intraoral scan and, more particularly, to a method, system and a computer readable storage media for visualizing a scan strategy in a patient's mouth.

BACKGROUND OF THE INVENTION

Users of intra-oral cameras may determine by an alteration in an audio output if a scanning process has been interrupted. To check whether all necessary areas of an intra-oral cavity have been scanned, the user may turn his/her head away from the scanning site to visually look at a display/monitor showing a three-dimensional (3D) reconstruction of scanned areas of the cavity. It may therefore be useful to have a procedure wherein a user may continue to look in a patient's mouth during intra-oral scanning without having to turn away to a monitor to view a 3D reconstruction of a jaw or strategy for scanning the jaw.

U.S. Patent Application Publication No. 2017/0056136A1 discloses a method for performing an optical three-dimensional recording wherein scanning instructions are displayed on a monitor that is away from a scanning site for user to view.

U.S. Patent Application No. 2017202633 discloses an imaging and display system for guiding medical interventions comprising a wearable display for viewing by a user wherein the display presents a composite, or combined image that includes pre-operative surgical navigation images, intraoperative images, and in-vivo microscopy images or sensing data.

U.S. Patent Application No. 20020082498 discloses a method for image-guided surgery comprising capturing 3-dimensional (3D) volume data of a portion of a patient, processing the volume data so as to provide a graphical representation of the data, capturing a stereoscopic video view of a scene including a portion of said patient, rendering the graphical representation and the stereoscopic video view in a blended manner so as to provide a stereoscopic augmented image, and displaying said stereoscopic augmented image in a video-see-through display.

U.S. Patent Application Publication No. 20160191887 describes a real-time surgery navigation method and apparatus for displaying an augmented view of a patient from a static or dynamic viewpoint of a surgeon. A surface image, a graphical representation of the internal anatomic structure of the patient processed from preoperative or intraoperative images, and a computer geometrically registering both images may be used. Responsive to geometrically registering the images, a head mounted display may present to a surgeon an augmented view of the patient.

SUMMARY OF THE INVENTION

Existing limitations associated with the foregoing, as well as other limitations, can be overcome by the method according to claim 1, the system according to claim 11 and the computer readable storage media according to claim 12 for the visualization of a strategy for intra-oral scanning.

In an aspect herein, the present invention provides a method for guiding a scan of a jaw utilizing augmented visualization, the method comprising: obtaining a jaw model; providing a scan strategy including the jaw model and a first and second control points; overlaying the scan strategy as an augmentation on a target site through a display device for augmented visualization such that the scan strategy appears directly superimposed on said target site; determining a recording path based on the first and second control points; positioning an intra-oral camera over an area of the jaw corresponding to the first control point; acquiring a plurality of three-dimensional optical recordings by moving the intra-oral camera over the jaw along the determined recording path such that a corresponding region of the jaw defined by the determined recording path is recorded; and registering the plurality of three-dimensional optical recordings into an overall three-dimensional recording.

In another aspect herein, the method further comprises one or more of the steps: (i) wherein the jaw model is a standard three-dimensional jaw model or an ongoing three dimensional reconstruction of scanned teeth, (ii) wherein the standard three-dimensional jaw model is modified to correspond to a tooth situation of a patient, (iii) wherein the standard three-dimensional jaw model and the ongoing three-dimensional reconstruction of scanned teeth are displayed separately in the field of view of the a user of the display device for augmented visualization, (iv) wherein the scan strategy is overlaid to guide a measurement process selected from the group consisting of an occlusal measurement, a lingual measurement, a first step of a buccal measurement, a second step of a buccal measurement, a fringe measurement, a bite block measurement, and a palate measurement (v) wherein the scan strategy is automatically updated in order to record different portions of the jaw, (vi) further comprising determining areas of the plurality of three-dimensional optical recordings that have gaps, and providing additional control points and/or additional recording paths on the scan strategy in succession for further recording, (vii) wherein a success of the registering step is tracked in order to update the scan strategy, (viii) further comprising updating an orientation of the scan strategy in real time based on a tracking system, said tracking system including information from the intra-oral camera, information tracking patient movements and/or information tracking clinician movements, (ix) wherein said target site is a site selected from the group consisting of the actual teeth, or a site in a field of view of a user of the display device for augmented visualization.

In another aspect, a system for guiding a scan of a jaw utilizing augmented visualization is provided, the system comprising: a display device for augmented visualization, and at least one processor configured to perform the steps of; obtaining a jaw model; providing a scan strategy including the jaw model and a first and second control points; overlaying the scan strategy as an augmentation on a target site through a display device for augmented visualization such that the scan strategy appears directly superimposed on said target site; determining a recording path based on the first and second control points; positioning an intra-oral camera over an area of the jaw corresponding to the first control point; acquiring a plurality of three-dimensional optical recordings by moving the intra-oral camera over the jaw along the determined recording path such that a corresponding region of the jaw defined by the determined recording path is recorded; and registering the plurality of three-dimensional optical recordings into an overall three-dimensional recording. In a further aspect, patient and jaw movements is tracked such that gaps resulting from scanning during such movements are filled by a re-scan of corresponding areas of the teeth. Moreover, portions in the overall three-dimensional recording with poor image quality/resolution (inadequate 3D point density) is determined and filled by a re-scan of corresponding areas of the teeth.

In another aspect herein, the system further comprises one or more of the configurations: (i) wherein the jaw model is a standard three-dimensional jaw model or an ongoing three dimensional reconstruction of scanned teeth. (ii) wherein the processor is further configured to modify the standard three-dimensional jaw model to correspond to a tooth situation of a patient,

(iii) wherein the processor is further configured to display the standard three-dimensional jaw model and the ongoing three-dimensional reconstruction of scanned teeth separately in a field of view of a user of the display device for augmented visualization, (iv) wherein the processor is further configured to overlay the scan strategy to guide a measurement process, said measurement process being selected from the group consisting of an occlusal measurement, a lingual measurement, a first step of a buccal measurement, a second step of a buccal measurement, a fringe measurement, a bite block measurement and a palate measurement, (v) wherein the processor is further configured to update the scan strategy automatically in order to record different portions of the jaw, (vi) wherein the processor is further configured to perform the steps of determining areas of the plurality of three-dimensional optical recordings that have gaps, and providing additional control points and/or additional recording paths on the scan strategy in succession for further recording, (vii) wherein the processor is further configured to track a success of the registering step in order to update the scan strategy, (viii) further comprising the processor being further configured to perform the step of updating an orientation of the scan strategy in real time based on a tracking system, said tracking system including information from the intra-oral camera, information tracking patient movements and/or information tracking clinician movements, (ix) wherein said target site is a site selected from the group consisting of the actual teeth, or a site in a field of view of a user of the display device for augmented visualization.

In even yet another aspect, a non-transitory computer-readable storage medium is provided, the non-transitory computer-readable storage medium storing a program which, when executed by a computer system, causes the computer system to perform a procedure comprising: obtaining a jaw model; providing a scan strategy including the jaw model and a first and second control points; overlaying the scan strategy as an augmentation on a target site through a display device for augmented visualization such that the patient scan strategy appears directly superimposed on said target site; determining a recording path based on the first and second control points; acquiring a plurality of three-dimensional optical recordings corresponding to a region of the jaw defined by the determined recording path; and registering the plurality of three-dimensional optical recordings into an overall three-dimensional recording.

BRIEF DESCRIPTION OF THE DRAWINGS

Example embodiments will become more fully understood from the detailed description given herein below and the accompanying drawings, wherein:

FIG. 1 is a top view illustrating overlapping three-dimensional optical recordings according to an embodiment of the present invention;

FIG. 2 is a system diagram illustrating a visualization system according to an embodiment of the present invention;

FIG. 3a illustrates a top view of a standard model according to an exemplary embodiment of the present invention;

FIG. 3b illustrates top view of a three-dimensional scan according to an exemplary embodiment of the present invention;

FIG. 4 is a block diagram showing a computer system according to an embodiment of the present invention;

FIG. 5 is a flow chart showing a method according to an exemplary embodiment of the present invention;

FIG. 6 is a flow chart showing a further method according to an exemplary embodiment of the present invention;

FIG. 7 a top view of a scan strategy for an occlusal measurement;

FIG. 8 a top view of a scan strategy for a lingual measurement;

FIG. 9 is a top view of a scan strategy for a first step of a buccal measurement;

FIG. 10 is a top view of a scan strategy for a second step of a buccal measurement;

FIG. 11 is a top view of a scan strategy illustrating a plurality of fringe recording sequences;

FIG. 12 is a sketch illustrating a linking of the different clusters;

FIG. 13 is a top view of a scan strategy illustrating a bite block registration.

DETAILED DESCRIPTION OF THE INVENTION

In accordance with example aspects described herein, a method, system and computer readable storage media are provided for proposing and visualizing an optimal scan strategy for intra-oral scans.

System for Guiding an Intra-Oral Scan

During intra-oral scanning, an intra-oral camera **16** (FIG. 1) may automatically record or be manually operated to record a plurality of individual three-dimensional optical recordings **4** in succession at a set frequency during the measurement. The individual three-dimensional optical recordings **4** may then be combined by means of a registration method into an overall three-dimensional recording of a dental subject to be measured. During the measurement, the intra-oral camera **16** may be moved relative to the dental subject (such as a lower jaw or an upper jaw), wherein the three-dimensional optical images are generated at regular time intervals. The individual images can, for example, be generated at a clock frequency between **10** Hz and **20** Hz. The registration may be performed by means of a computer system **100** which may evaluate the individual three-dimensional optical recordings **4** recorded. Iterative Closest Point algorithm (ICP) may be used as the registration method. This algorithm is a known process for registering two-dimensional or three-dimensional subjects. Herein different rotations and translations may be applied to corresponding pairs of points of the two individual three-dimensional optical recordings **4** to be registered, thereby minimizing a quadratic error of the distances between the pairs of points. This iterative convergence may be performed until the two recordings coincide within the overlapping area.

Alternatively, the registration may take place on the basis of the color of the recorded subject, the surface curvature of the recorded subject or on the basis of characteristic geometries of the subject. Given registration on the basis of characteristic geometries, a pattern recognition algorithm may be used wherein the two individual three-dimensional optical recordings **4** to be registered may be searched for a specific geometric pattern, such as for an occlusal surface of a specific tooth.

However, a registration process may include registration errors if, for example, the intra-oral camera moves too quickly in relation to the subject, resulting in the size of the overlapping area **5** being insufficient. Moreover, a focus of the intra-oral camera **16** may not be sharply set, thereby causing the subject to be indistinctly imaged such that the recording quality of the image is insufficient. An additional reason could be that movable objects such as the tongue of the patient or a finger of the treating dentist are recorded during measurement. Consequently, the overlapping areas of the images may not correspond.

Therefore one or more scan strategies **42** may be displayed to a clinician **10** in an augmented fashion (as shown in the visualization system of FIG. 2 and as described hereinafter), wherein different recordings made be acquired separately using optimized recording paths and clusters from the different recordings may be registered to each other in a stable framework for a global registration said global registration being enabled due to the optimized recording paths. The augmented display of the scan strategy **42** in the mouth area may eliminate or substantially eliminate the need for the clinician to look away from the mouth of the patient **14** to a separate screen.

As part of the scan strategy **42**, a first control point **13** (FIG. 3a) may be displayed by means of a display device **12** on a jaw model **26** also displayed by means of the display device **12**. The intra-oral camera **16** may therefore automatically record a plurality of individual three-dimensional optical recordings **4** during the measurement, for example at a frequency of **18** Hz, wherein individual recordings may not need to be triggered manually as the camera is moved relative to the actual teeth **17**. The intra-oral camera **16** may function, for example, according to fringe projection methods or confocal measurement methods.

FIG. 2 illustrates a visualization system **1** comprising a display device **12** for augmented visualization such as head mounted augmented reality glasses, an HUD display, or a stereoscopic display capable of receiving stereoscopic video images, or otherwise display device **12** that may be used for overlaying the scan strategy **42** (such as, for example a first control point **13**, a second control point **15**, and or recording path **23** on a jaw model **26** (preferably a three-dimensional jaw model) which may be a standard three-dimensional jaw model **26a** or an ongoing three dimensional reconstruction of scanned teeth **26b** , FIG. 3a, **3**b) in an augmented manner on a target site **14**a, (such as on the jaw or actual teeth **17** of a patient **14** or anywhere within a field of view **32** of a clinician **10** who is looking through the display device **12**) or on a stereoscopic video of the target site such that the scan strategy **42** appears to be directly superimposed on the target site **14**a. A control point may have different forms such as different shapes, sizes, colors, structures etc. and may be any object that defines a start, end or otherwise position of a recording.

Alternatively the scan strategy **42** may be displayed directly on a screen of a smart see-through glass worn by the clinician without being superimposed directly on the target site. Moreover the scan strategy **42** may be automatically updated on an ongoing basis to record different portions of the patient's actual teeth **17**. By using the display device **12**, the clinician **10** may visualize, where in the intra oral cavity **22** of a patient **14** he/she may start scanning from and the optimal scan strategy including a recording direction may be shown to the clinician **10**. A software may indicate on the display device **12**, based on predetermined criteria such as an adequate overlap of three-dimensional optical recordings **4**, which areas of the jaw are not scanned yet and/or which areas may be rescanned to achieve a complete scan.

The display device **12** may be connected to or form part of a computer system **100**. With the aid of the computer system, it may be possible to automatically determine which areas of the registered three-dimensional optical recordings **4** have gaps, such that additional control points and/or additional recording paths may be displayed in succession in these areas on the jaw model **26** for user guidance. Therefore the guidance may take place control point for control point until all gaps are filled.

The computer system **100** (also shown in FIG. 4) may include a tracking system **2** and a processor **122**. The tracking system **2** may alternatively be separate from the computer system and may form at least part of any of the devices, components, and/or systems discussed herein. The tracking system **2** may be electrically connected to a processor **122** and may offer real-time location data for a precise location and orientation of images (e.g. scan strategy **42**) and objects (e.g. target site **14**a) in a common coordinate system. In an exemplary embodiment herein, the tracking system **2** may be vision based, for example as cameras for visual tracking of the patient **14**, features of the patient (such as the head or intra-oral cavity), and/or predetermined markers (not shown) placed on the patient **14**. Said visual tracking may be achieved using, for example object/pattern recognition. A camera system **3** such as a **3**D optical tracking system and/or stereoscopic camera system may be included in the computer system and/or may form or be a part of the tracking system **2**. The camera system **3** may also be embedded in the display device **12** of the clinician **10**. The camera system may operate under one of several depth sensing principles including, for example, (i) structural light, (ii) Time of Flight (ToF) and/or (iii) stereoscopic principles explained hereinafter. For cameras employing structural light, a light source may be used to project a known pattern onto the patient **14**, and a receiver may detect the distortion of the reflected pattern to calculate depth map based on geometry. For cameras employing Time of Flight (ToF) principles, a light source may send out a pulse, and a sensor may detect a reflection of the pulse from the patient **14** in order to record it's time of flight. Knowing that and the constant speed of light, the system may calculate how far away the patient **14** is. Alternatively, a modulated light source may be sent and a phase change of light reflected from the patient may be detected. For cameras employing stereoscopic principles, multiple cameras may be placed at different positions to capture multiple images of the patient, and a depth map may be calculated based on geometry. This depth information may be used to track the patient's location during treatment (e.g. during dental treatment).

The tracking system **2** may also include data from the intra oral camera **16** wherein a success of the registration process may be tracked during intra-oral scanning in order to update the scan strategy **42** when needed.

In an exemplary embodiment of the present invention, scan strategy **42** may optionally be overlaid on a target site **14a** after a request is received from the clinician **10** through a user interface **126** of the computer system **100** (such as a gesture recognition system and/or a voice recognition system or the like) before or during a scanning procedure. Overlaying of the scan strategy **42** on the target site **14**a through the display **12** may be performed dynamically and in real time and may be achieved by the processor **122** working in tandem with the tracking system **2** wherein changes in position of (i) the patient **14** and/or (ii) the clinician **10**, captured by the tracking system **2**, may be translated into corresponding changes in positions of the overlaid patient scan strategy **42** such that said scan strategy **42** routed to a screen of the display device **12** appears directly superimposed on the target site **14a** of the patient **14** even as the patient **14** and/or or clinician **10** moves. Moreover, responsive to a request from the clinician **10** the processor may be configured to provide ongoing or predetermined changes/adaptations to the scanning process based on already scanned teeth.

Computer System for Guiding an Intra-Oral Scan

Having described a system **1** for guiding an intra-oral scan using augmented reality, reference will now be made to FIG. 4, which shows a block diagram of a computer system **100** that may be employed in accordance with at least some of the example embodiments herein. Although various embodiments may be described herein in terms of this exemplary computer system **100**, after reading this description, it may become apparent to a person skilled in the relevant art(s) how to implement the disclosure using other computer systems and/or architectures.

In one example embodiment herein, the computer system **100** may include at least one computer processor **122** and may include a tracking system **2**, user interface **126** and input unit **130.** The input unit **130** may be used by to send information to the computer processor **122**. In one exemplary embodiment herein, the input unit **130** is a finger or stylus to be used on a touchscreen interface (not shown). The input unit **130** may alternatively be a gesture/voice recognition device, a trackball, a mouse or other input device such as a keyboard or stylus. In one example, a display unit **128**, the input unit **130**, and the computer processor **122** may collectively form the user interface **126**.

The computer processor **122** may include, for example, a central processing unit, a multiple processing unit, an application-specific integrated circuit ("ASIC"), a field programmable gate array ("FPGA"), or the like. The processor **122** may be connected to a communication infrastructure **124** (e.g., a communications bus, or a network). In an embodiment herein, the processor **122** may receive a request for a scan strategy **42** and may obtain instructions concerning the request from one or more storage units of the computer system **100**. The processor **122** may then load said instructions and execute the loaded instructions such as routing the scan strategy **42** to a screen of the display device **12** such that the scan strategy **42** may be overlaid on the target site **14a** such that said scan strategy **42** appears directly superimposed on said target site **14a**.. In yet another alternative embodiment of the present invention, the computer system may use projection based augmented reality systems wherein, for example, a projector and depth sensors, along with the tracking system **2** and/or markers on the patient **14** (e.g. hidden markers) may be used to project the scan strategy **42** directly onto target sites **14a** (e.g. buccal cavity) of the patient. Herein, the display device **12** such as augmented reality glasses may not be needed to view the projected scan strategy **42**

One or more steps/procedures for visually communicating the scan strategy **42** to the clinician **10** may be stored on a non-transitory storage device in the form of computer-readable program instructions. To execute a procedure, the processor **122** loads the appropriate instructions, as stored on a storage device, into memory and then executes the loaded instructions as shown in FIG. 4 discussed hereinafter.

The computer system **100** may further comprise a main memory **132**, which may be a random access memory ("RAM") and also may include a secondary memory **134**. The secondary memory **134** may include, for example, a hard disk drive **136** and/or a removable-storage drive **138** (e.g., a floppy disk drive, a magnetic tape drive, an optical disk drive, a flash memory drive, and the like). The removable-storage drive **138** may read from and/or write to a removable storage unit **140** in a well-known manner. The removable storage unit **140** may be, for example, a floppy disk, a magnetic tape, an optical disk, a flash memory device, and the like, which may be written to and read from by the removable-storage drive **138**. The removable storage unit **140** may include a non-transitory computer-readable storage medium storing computer-executable software instructions and/or data.

In further alternative embodiments, the secondary memory **134** may include other computer-readable media storing computer-executable programs or other instructions to be loaded into the computer system **100**. Such devices may include a removable storage unit **144** and an interface **142** (e.g., a program cartridge and a cartridge interface); a removable memory chip (e.g., an erasable programmable read-only memory ("EPROM") or a programmable read-only memory ("PROM")) and an associated memory socket; and other removable storage units **144** and interfaces **142** that allow software and data to be transferred from the removable storage unit **144** to other parts of the computer system **100**.

The computer system **100** also may include a communications interface **146** that enables software and data to be transferred between the computer system **100** and external devices. Such an interface may include a modem, a network interface (e.g., an Ethernet card or a wireless interface), a communications port (e.g., a Universal Serial Bus ("USB") port or a FireWire® port), a Personal Computer Memory Card International Association ("PCMCIA") interface, Bluetooth®, and the like. Software and data transferred via the communications interface **146** may be in the form of signals, which may be electronic, electromagnetic, optical or another type of signal that may be capable of being transmitted and/or received by the communications interface **146**. Signals may be provided to the communications interface **146** via a communications path **148** (e.g., a channel). The communications path **148** may carry signals and may be implemented using wire or cable, fiber optics, a telephone line, a cellular link, a radio-frequency ("RF") link, or the like. The communications interface **146** may be used to transfer software or data or other information between the computer system **100** and a remote server or cloud-based storage (not shown).

One or more computer programs or computer control logic may be stored in the main memory **132** and/or the secondary memory **134**. The computer programs may also be received via the communications interface **146**. The computer programs may include computer-executable instructions which, when executed by the computer processor **122**, cause the computer system **100** to perform the methods as described hereinafter.

In another embodiment, the software may be stored in a non-transitory computer-readable storage medium and loaded into the main memory **132** and/or the secondary memory **134** of the computer system **100** using the removable-storage drive **138**, the hard disk drive **136**, and/or the communications interface **146**. Control logic (software), when executed by the processor **122**, causes the computer system **100**, and more generally the system for guiding an intra-oral scan, to perform all or some of the some of the methods described herein.
Implementation of other hardware arrangement so as to perform the functions described herein will be apparent to persons skilled in the relevant art(s) in view of this description.

Method for Guiding an Intra-Oral Scan.

Having described the computer system **100** of FIG. 4, methods for guiding an intra-oral scan will now be further described in conjunction with FIGS. 5-13.

FIG. 5 shows a process **200** for guiding an intra-oral scan. The process may begin by obtaining a jaw model **26** as shown in Step **S100**. The jaw model may be a standard three-dimensional jaw model **26a** or an ongoing three dimensional reconstruction of scanned teeth **26b**.

In an embodiment in which the obtained jaw model **26** is a standard three-dimensional jaw model **26a**, said standard three-dimensional jaw model **26a**, may be modified (Step **S200**) to correspond to a tooth situation of the patient **14**. For example, if specific teeth of the patient's jaw are determined to be missing (such as the back molars with the Federation Dentaire Internationale (FDI) numbers **18**, **28**, **38** or **48**), these teeth may also be removed from the standard jaw model, thereby enabling the clinician **10** to establish a one-to-one correspondence between actual teeth **17** of the patient **14** and model teeth **17**a of the standard three-dimensional jaw model **26a**. However, the standard three-dimensional jaw model **26a** may preferably be obtained based on images of the actual teeth **17** of the patient **14** obtained through the camera system **3**. For example, using object recognition on images of the intra-oral cavity **22** of the patient **14** obtained by the camera system **3**, anatomical features of said intra-oral cavity **22** (such as cusp, fissures, ridges, gums etc. or the lack thereof) may be used to determine which teeth are present or missing. Based on the analysis, the standard three-dimensional model **26a** may be modelled after said images or a predetermined standard model of human teeth may be modified to correspond to the actual teeth **17** of the patient **14**.

In an embodiment in which the obtained jaw model **26** is an ongoing three-dimensional reconstruction of scanned teeth **26b**, the jaw model **26** may begin as a standard three-dimensional jaw model **26a** and portions of the standard three-dimensional jaw model **26a** corresponding to actual teeth **17** of the patient **14** that have been scanned and successfully registered may be replaced/covered/overlaid with a three-dimensional reconstruction of the corresponding three dimensional optical recordings **4** obtained by the intra-oral camera **16**. In a further embodiment, the ongoing three-dimensional reconstruction of scanned teeth **26b** may begin as an empty model and may be filled in continuously by the three-dimensional reconstruction of the three-dimensional optical recordings **4** that are being acquired.

In an embodiment in which the obtained jaw model **26** is a standard three-dimensional jaw model **26a**, an ongoing three-dimensional reconstruction of teeth that are being scanned may also be separately displayed alongside the standard three-dimensional jaw model **26a** in the field of view **32** of the clinician **10** to indicate progress.

In Step **S300**, the jaw model **26** may be overlaid in an augmented manner over the target site **14a** as part of the scan strategy **42**. Thereafter, an orientation of the jaw model **26**(and thus the scan strategy **42**) may be continuously updated in real-time based on the real time data from the tracking system **2** tracking patient movements **206** and clinician movements **202**. (Step **S400**).

In Step **S500**, the scan strategy **42** may be modified to guide the clinician in performing an intra-oral scan using one or more control points **13**, **15**, **42**, **55**, **57**, **60**, **61**, **73**, **93**, **94**, **96**, **97** and one or more recording paths (**34**, 41, **51**, **62**, **72**, **74**, **76**, **92**, **95**) which may be displayed over the jaw model **26** as discussed hereinafter and in FIGS. 6-13. Herein, the computer system **100** may be in communication with the intra-oral camera **16** being used by the clinician **10** for the scan procedure. Based on obtained three-dimensional optical recordings **4**, and confirmations of the control points, the scan strategy **42** may be modified as follows.

As shown in FIG. 6, a first control point **13** (shown in FIG. 3a) may be displayed on the jaw model **26** in the middle of an occlusal surface **8** of a model teeth **17**a, e.g. molar **9** in Step **S502**. The first control point **13** is represented schematically as a black circle. The clinician **10** may then move the intra-oral camera **16** in an area of the molar **9** so that the camera records the first control point **13**. The intra-oral camera **16** may be held steadily over the first control point **13** for a predetermined period of time until an acoustic, visual and/or haptic signal ensues as a feedback and the position of the first control point is thereby confirmed (Step **S504**). The feedback may be based on an adequacy of obtained three-dimensional optical recordings **4** (such as adequate overlap, adequate exposure time, etc.). The first control point **13** may also be confirmed manually by operating a button **11** on the intra-oral camera **16**. Alternatively, the control point **10** can also be confirmed by means of the input unit **130** (FIG. 4) which may be for example, a gesture/voice recognition device.

A second control point **15** and a recording path **23** may be displayed in addition to the first control point **13** (Step **S506**). The displayed recording path **23** may serve as a user guidance for the clinician **10** in order to display which areas of actual teeth **17** are to be measured. The actual teeth **17** are then measured/scanned along the recording path **34** in Step **S508** to obtain a first cluster. Scanned teeth may be marked in the scan strategy **42** (for example, they may be colored differently from unscanned teeth) as a further guidance for the clinician **10**. The measurement may then be repeated (Step **S510**) for other clusters using other control points and other recording paths as described hereinafter. The clusters may then be combined in a global registration step using shared overlapping areas in Step **S512**.

In an embodiment in which the jaw model **26** is not overlaid on the actual teeth, the jaw model **26** may be pivoted in the field of view **32** such that buccal surfaces **20** of a recording area **33** (which is shown as a dashed line) that are to be recorded are displayed in the foreground, wherein the previously measured occlusal surfaces **8** may also be visible. Herein, a line of sight on the jaw model **42** may be changed during the measurement according to the movement of the intra-oral camera **16**.

FIGS. 7-13 depicts scan strategies **42** overlaid in an augmented manner on a target site **14a** or in a field of view **32** of the clinician **10** wherein the scan strategies **42** may be used in guiding the recording of the patient's actual teeth **17**.

FIG. 7 depicts a scan strategy **42** (including a jaw model **26**) for an upper jaw, wherein a first recording path **34** originating from the first control point **13** on a first molar **30** with the FDI number **37** runs up to the second control point **15** on the opposing end of the jaw arch on the second molar **31** having the FDI number **47**. The first recording path **34** thereby runs through the tooth centers **18** of the model teeth **17a** of the jaw model **26**. The intra-oral camera **16** may therefore be moved such that centers of the three-dimensional optical recordings **4** coincide or substantially coincide with the first recording path **34**. In this way, an occlusal measurement may therefore carried out from an occlusal direction of the top jaw. FIG. 8 depicts a scan strategy **42** illustrating the guidance of a lingual measurement of the upper jaw from a lingual or oral direction **40**. The intra-oral camera **16** may be positioned relative to the actual teeth **17** in such a way that the recording from the lingual direction **40** may be carried out along a second recording path **41** originating from the second control point **15** toward a third control point **43**. Therefore, the inside tooth surfaces of the upper jaw may be measured with the lingual measurement.

FIG. 9 depicts a scan strategy **42** illustrating the guidance of a buccal measurement from a buccal direction **50**, wherein the intra-oral camera **16** may be pivoted around the jaw in such a way that the buccal tooth surfaces **52** and the labial tooth surfaces **53** are measured. The teeth **54** may therefore not be measured in the first step. The third recording path **51** may thereby originate from a fourth control point **55** at the molar having the FDI number **37** across a middle **56** of the jaw arch up to a fifth control point **57**. The position of the fourth control point **55** may thereby correspond to the position of the control point **43** and the control point **13**.

FIG. 10 depicts a scan strategy **42** showing a second buccal measurement originating from a sixth control point **60** across the middle **56** of the jaw arch to a seventh control point **61** along a fourth recording path **62**. A first cluster from the first buccal measurement from FIG. 9 and a second cluster from the second buccal measurement from FIG. 10 may be registered to one another using a shared overlapping area **63** in the middle of the jaw arch.

FIG. 11 shows a scan strategy **42** illustrating first fringe recording sequence in buccal direction **70** perpendicular to a jaw curve **71** of the jaw arch to be measured along a fifth recording path **72** between the control points **73**. The fifth recording path **72** may thereby run in the area of a molar with the FDI number **14**. In addition, a second fringe recording sequence may be performed in the labial direction **75** along a sixth recording path **74** in the area of the incisor with the FDI number **11**, and a third fringe recording sequence may be performed in the buccal direction **77** along the seventh recording path **76** in the area of the molar with the FDI number **24**.

FIG. 12 depicts a sketch showing that a first cluster **80** from the occlusal measurement in FIG. 7, a second cluster **81** from the lingual measurement in FIG. 8 and a third cluster **82** from the buccal direction in FIG. 9 and FIG. 10 are linked to each other by the fourth cluster **83** of the first fringe recording sequence from FIG. 11, as well as by the fifth cluster **84** of the second fringe recording sequence and the sixth cluster **85** of the third fringe recording sequence. The linkage points **86** are indicated by the crosses.

FIG. 13 depicts a scan strategy **42** to illustrate a bite block registration, wherein a first three-dimensional model **90** of the upper jaw may be registered relative to a second three-dimensional model **91** of the lower jaw. In this way, a first buccal recording sequence may be performed along a recording path **92** between the control points **93** and **94**, and a second buccal recording sequence may be performed along the recording path **95** between a control point **96** and a control point **97**. The first buccal recording sequence may thereby run in the area of the teeth with the FDI numbers **14** and **44**. The second buccal recording sequence may run in the area of the teeth with the FDI numbers **24** and **34**.

In a further embodiment of the present invention, a palate measurement may be performed. Herein, a 3D intraoral scan may be combined with images from the camera system 3 (such as images of the palate taken by the display device 12 for augmented visualization) in order to create dentures. A digital impression may be inadequate for obtaining scans of the gingivobucal/ mucolabial fold. However by combining images of the gingivobucal/ mucolabial fold taken with the display device adequate information may be obtained for denture design/fabrication.

In view of the foregoing description, it may be appreciated that the example embodiments described herein provide a method, system and computer readable storage media for guiding an intra-oral scan.

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although methods and materials similar to or equivalent to those described herein may be used in the practice or testing of the disclosure, suitable methods and materials are described above. All publications, patent applications, patents, and other references mentioned herein are incorporated by reference in their entirety to the extent allowed by applicable law and regulations. The disclosure may be embodied in other specific forms without departing from the spirit or essential attributes thereof, and it may therefore be desired that the present embodiment be considered in all respects as illustrative and not restrictive. Any headings utilized within the description are for convenience only and have no legal or limiting effect.

CLAIMS

1. A method for guiding a scan of a jaw utilizing augmented visualization, the method comprising:

obtaining a jaw model;

providing a scan strategy including the jaw model and a first and second control points;

overlaying the scan strategy as an augmentation on a target site through a display device for augmented visualization such that the scan strategy appears directly superimposed on said target site;

determining a recording path based on the first and second control points;

positioning an intra-oral camera over an area of the jaw corresponding to the first control point;

acquiring a plurality of three-dimensional optical recordings by moving the intra-oral camera over the jaw along the determined recording path such that a corresponding region of the jaw defined by the determined recording path is recorded; and

registering the plurality of three-dimensional optical recordings into an overall three-dimensional recording.

2. The method according to claim 1, wherein the jaw model is a standard three-dimensional jaw model or an ongoing three-dimensional reconstruction of scanned teeth.

3. The method according to claim 2, wherein the standard three-dimensional jaw model is modified to correspond to a tooth situation of a patient.

4. The method according to claim 2 or 3, wherein the standard three-dimensional jaw model and the ongoing three-dimensional reconstruction of scanned teeth are displayed separately in the field of view of a user of the display device for augmented visualization.

5. The method according to any one of claims 1 to 4, wherein the scan strategy is overlaid to guide a measurement process selected from the group consisting of an occlusal measurement, a lingual measurement, a first step of a buccal measurement, a second step of a buccal measurement, a fringe measurement, a bite block measurement and a palate measurement.

6. The method according to any one of claims 1 to 5, wherein the scan strategy is automatically updated in order to record different portions of the jaw.

7. The method according to any one of claims 1 to 6, further comprising determining areas of the plurality of three-dimensional optical recordings that have gaps, and providing additional control points and/or additional recording paths on the scan strategy in succession for further recording.

8. The method according to any one of claims 1 to 7, wherein a success of the registering step is tracked in order to update the scan strategy.

9. The method according to any one of claims 1 to 8, further comprising updating an orientation of the scan strategy in real time based on a tracking system, said tracking system including information from the intra-oral camera, information tracking patient movements and/or information tracking clinician movements.

10. The method according to any one of claims 1 to 9, wherein said target site is a site selected from the group consisting of the actual teeth, or a site in a field of view of a user of the display device for augmented visualization.

11. A system for guiding a scan of a jaw utilizing augmented visualization, the system comprising:

a display device for augmented visualization, and

at least one processor configured to perform the method according to any one of claims 1 to 10.

12. A non-transitory computer-readable storage medium storing a program which, when executed by a computer system according to claim 11, causes the computer system to perform the method according to any one of claims 1 to 10.

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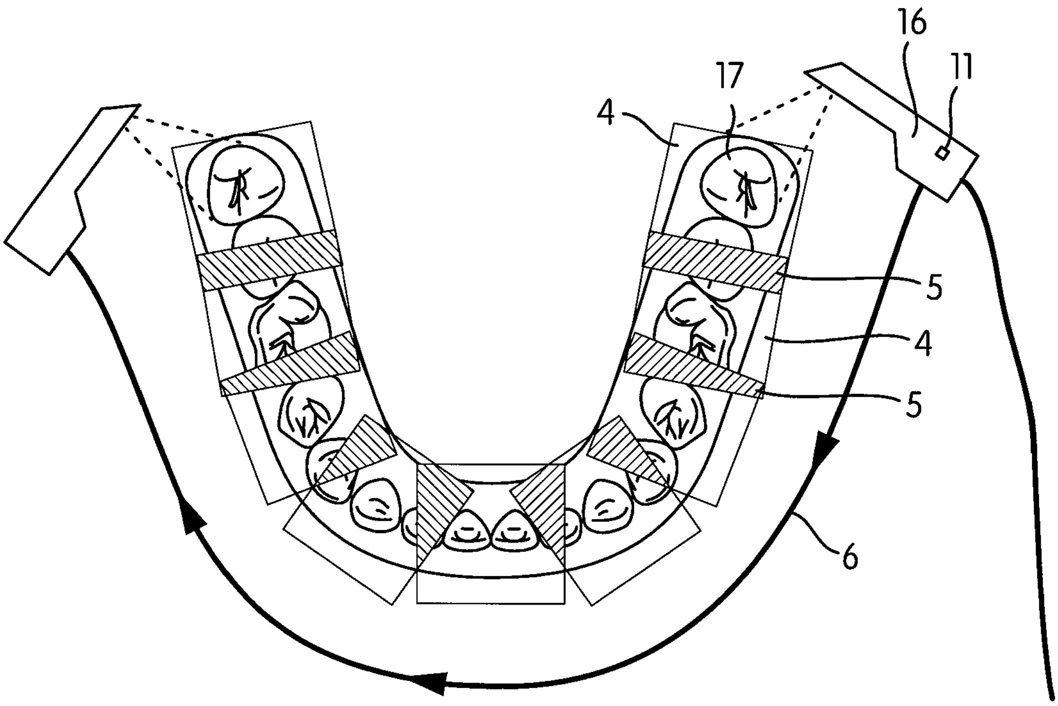

FIG. 1

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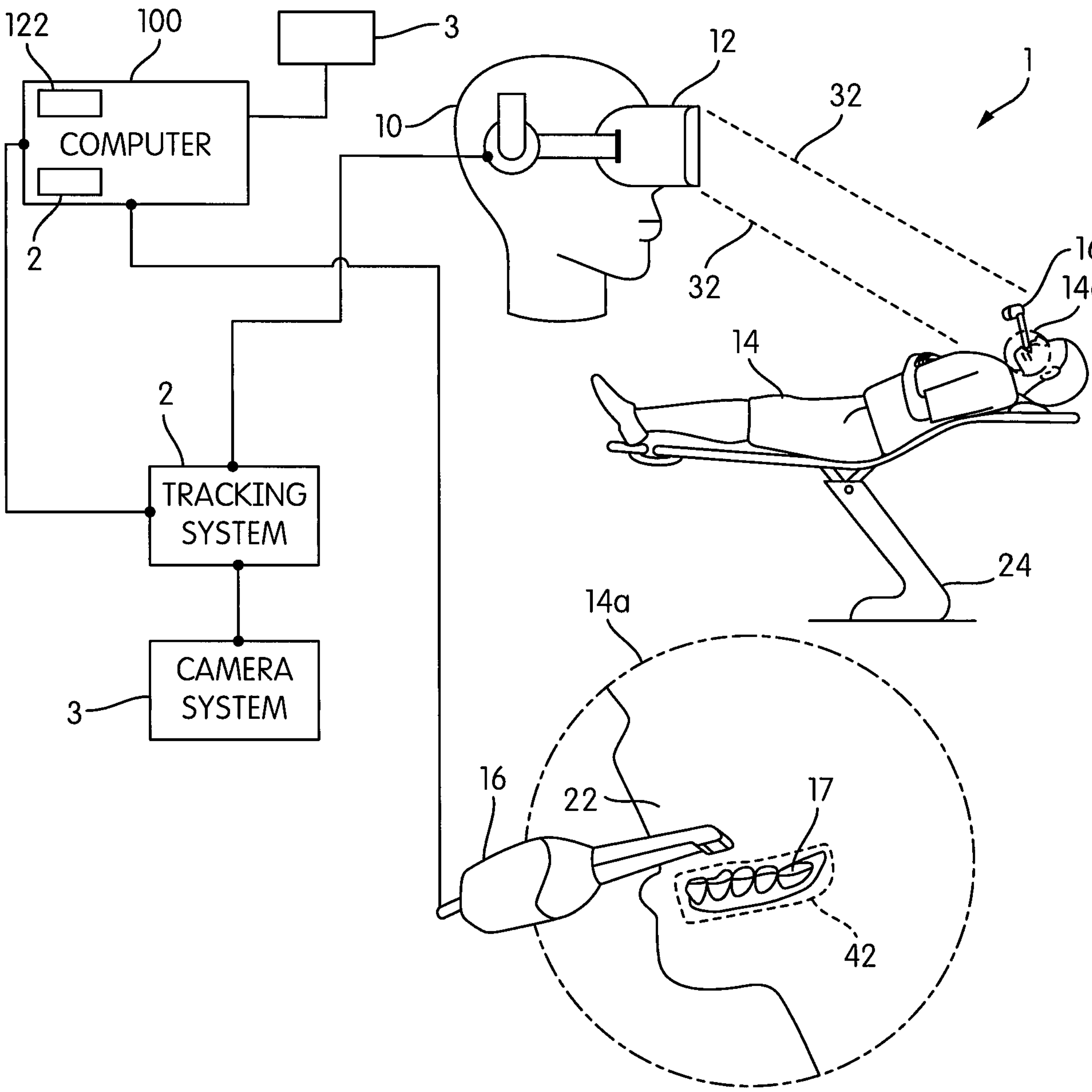
122
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3
COMPUTER
2
12
1
10
32
32
16
14a
14
2
TRACKING SYSTEM
CAMERA SYSTEM
3
24
14a
16
22
17
42

FIG. 2

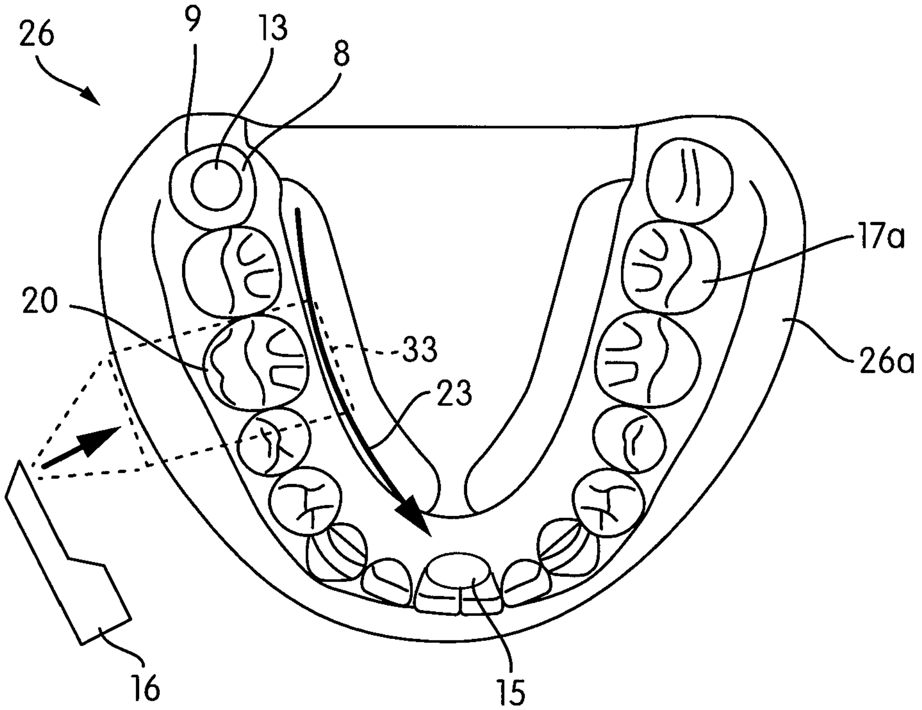

FIG. 3a

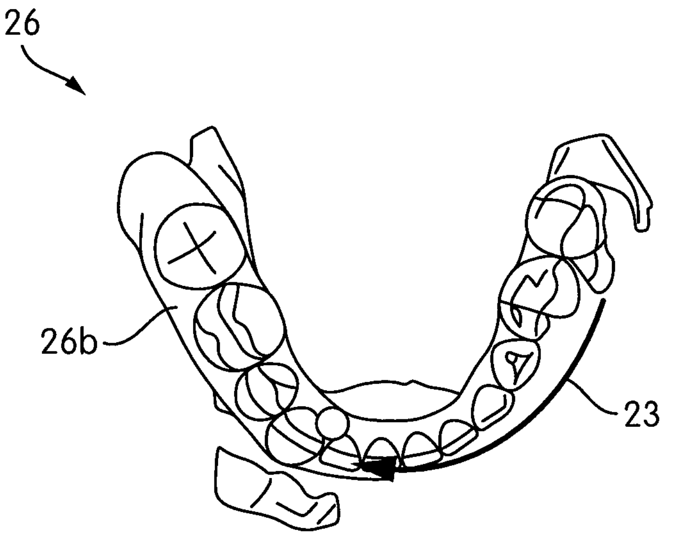

FIG. 3b

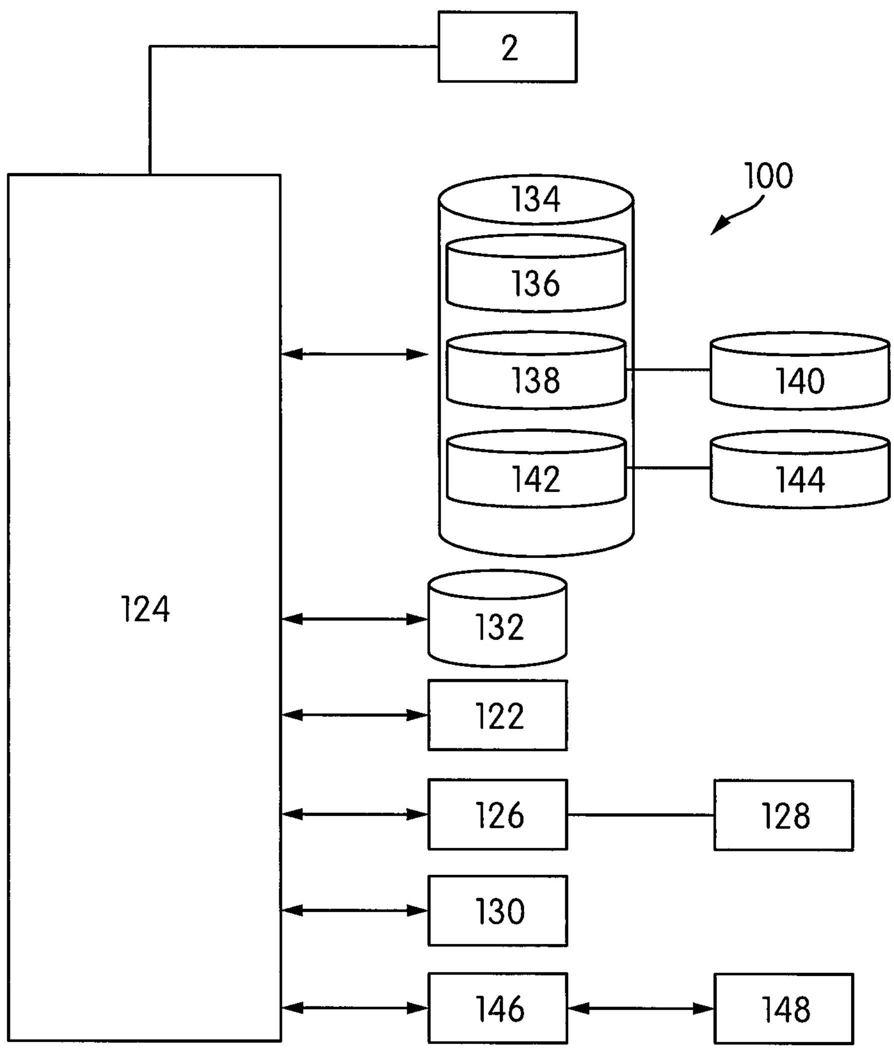

FIG. 4

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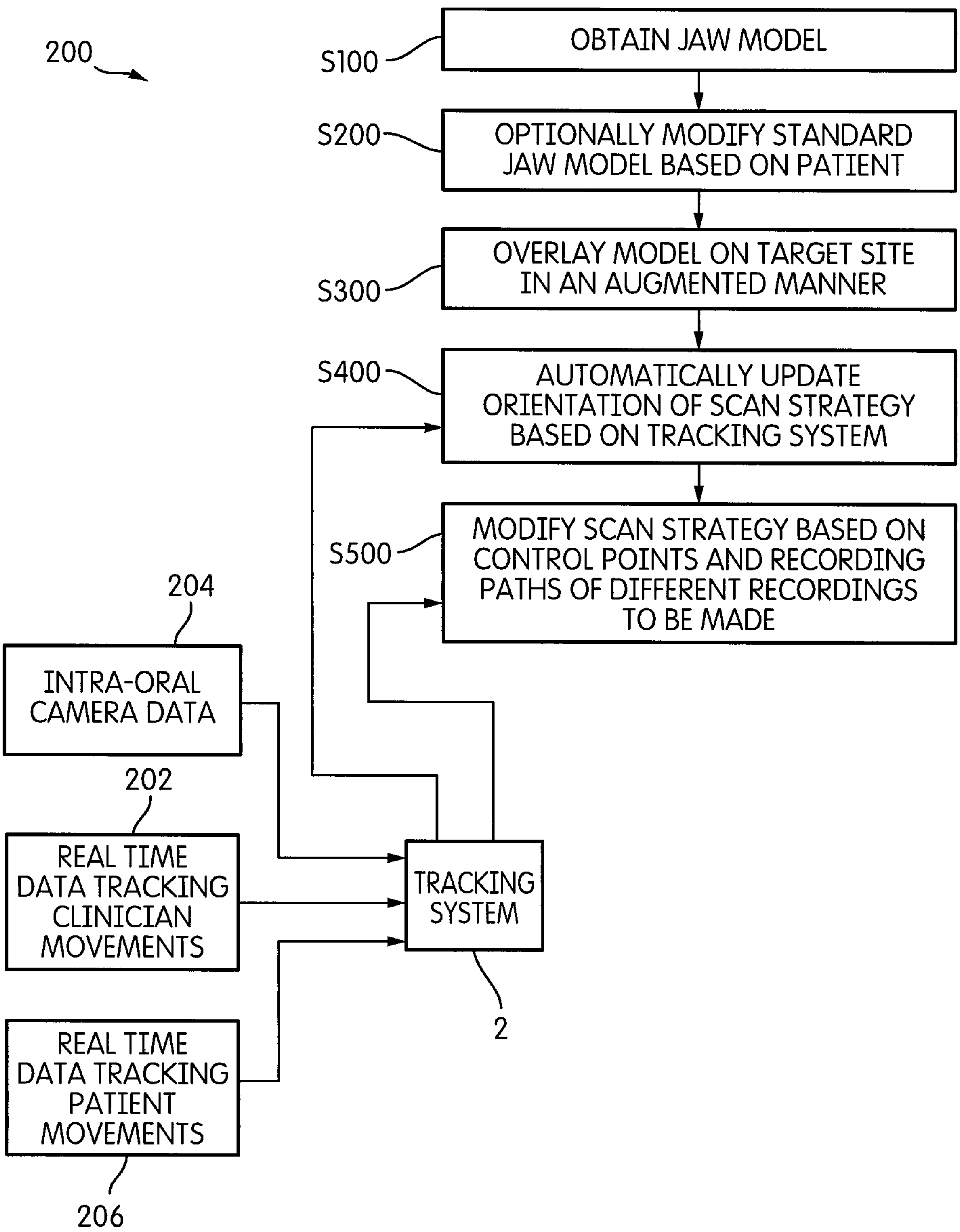

200
S100
OBTAIN JAW MODEL
S200
OPTIONALLY MODIFY STANDARD JAW MODEL BASED ON PATIENT
S300
OVERLAY MODEL ON TARGET SITE IN AN AUGMENTED MANNER
S400
AUTOMATICALLY UPDATE ORIENTATION OF SCAN STRATEGY BASED ON TRACKING SYSTEM
S500
MODIFY SCAN STRATEGY BASED ON CONTROL POINTS AND RECORDING PATHS OF DIFFERENT RECORDINGS TO BE MADE
204
INTRA-ORAL CAMERA DATA
202
REAL TIME DATA TRACKING CLINICIAN MOVEMENTS
REAL TIME DATA TRACKING PATIENT MOVEMENTS
206
TRACKING SYSTEM
2

FIG. 5

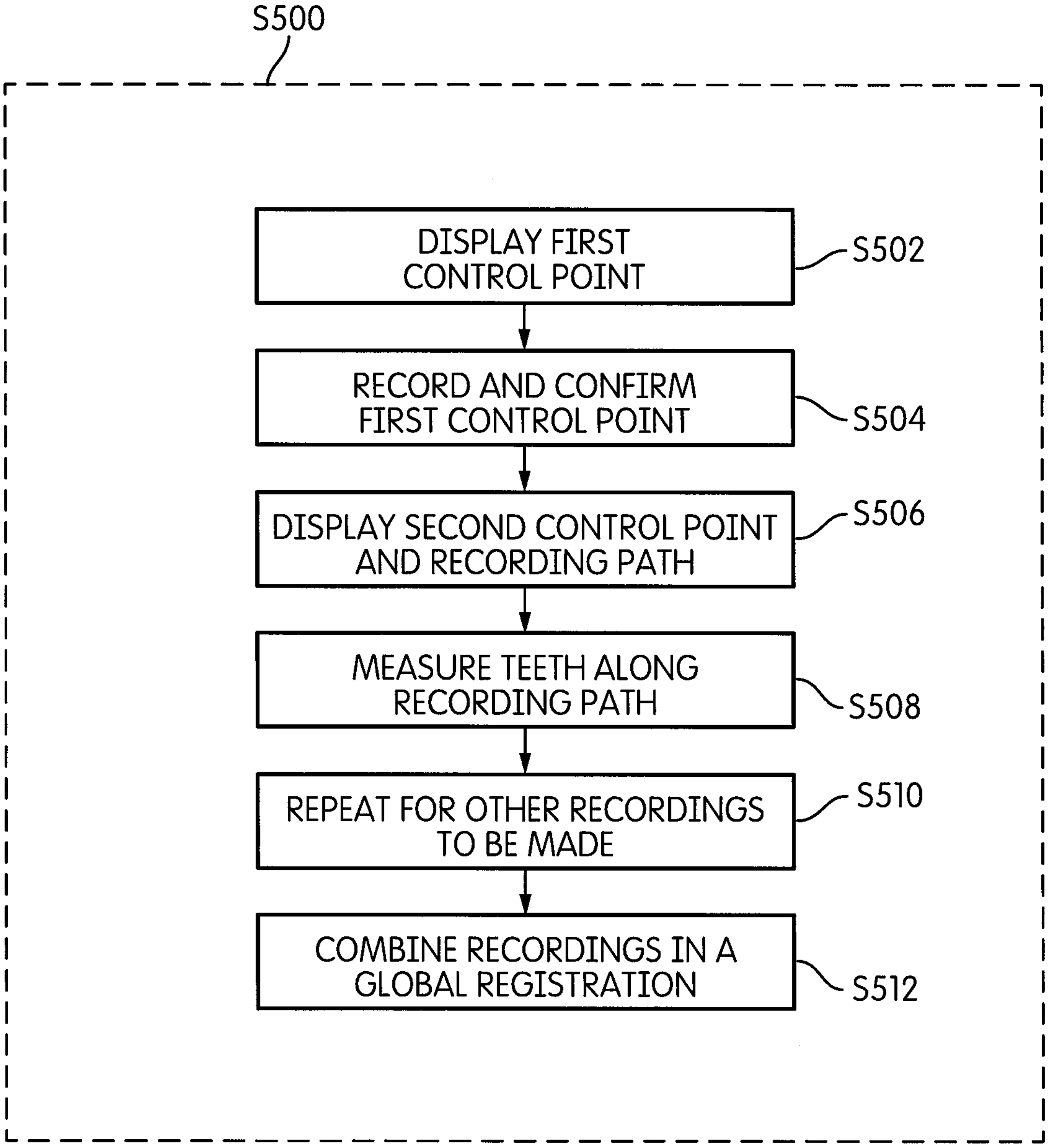

S500
DISPLAY FIRST CONTROL POINT
S502
RECORD AND CONFIRM FIRST CONTROL POINT
S504
DISPLAY SECOND CONTROL POINT AND RECORDING PATH
S506
MEASURE TEETH ALONG RECORDING PATH
S508
REPEAT FOR OTHER RECORDINGS TO BE MADE
S510
COMBINE RECORDINGS IN A GLOBAL REGISTRATION
S512

FIG. 6

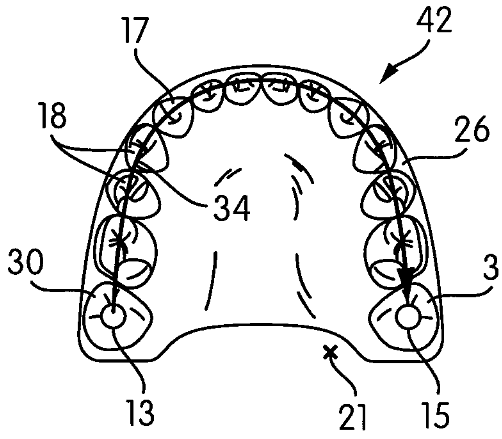


FIG. 7

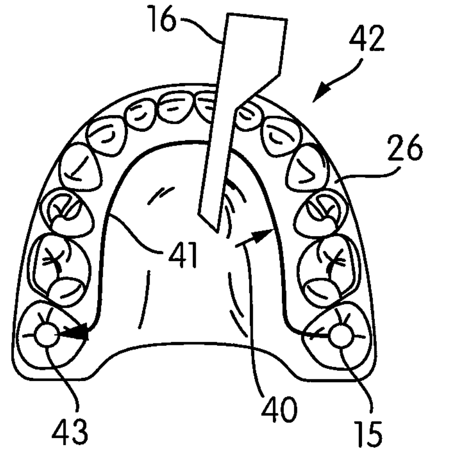


FIG. 8

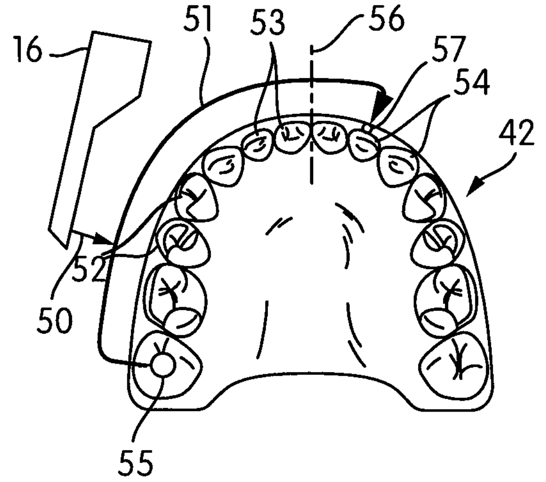


FIG. 9

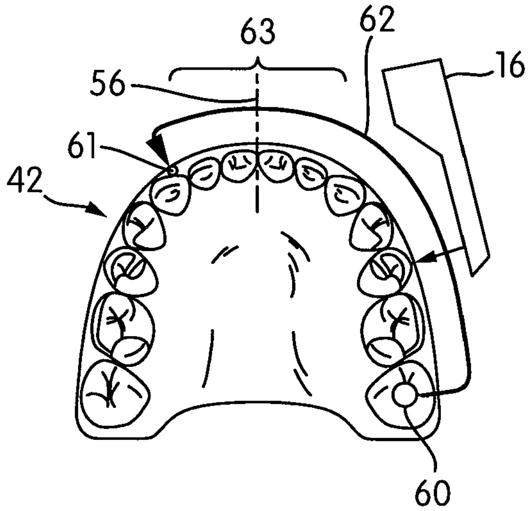


FIG. 10

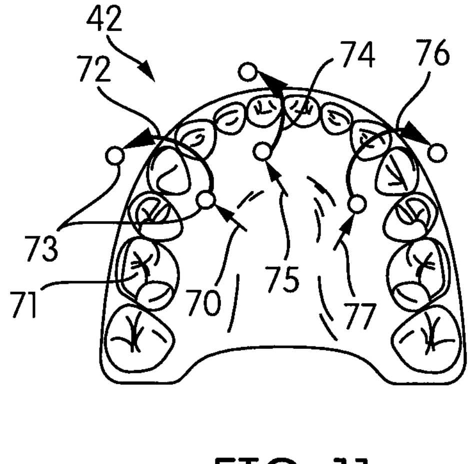


FIG. 11

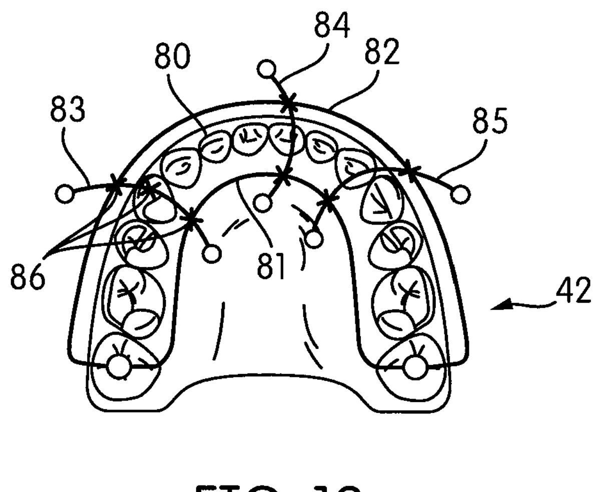


FIG. 12

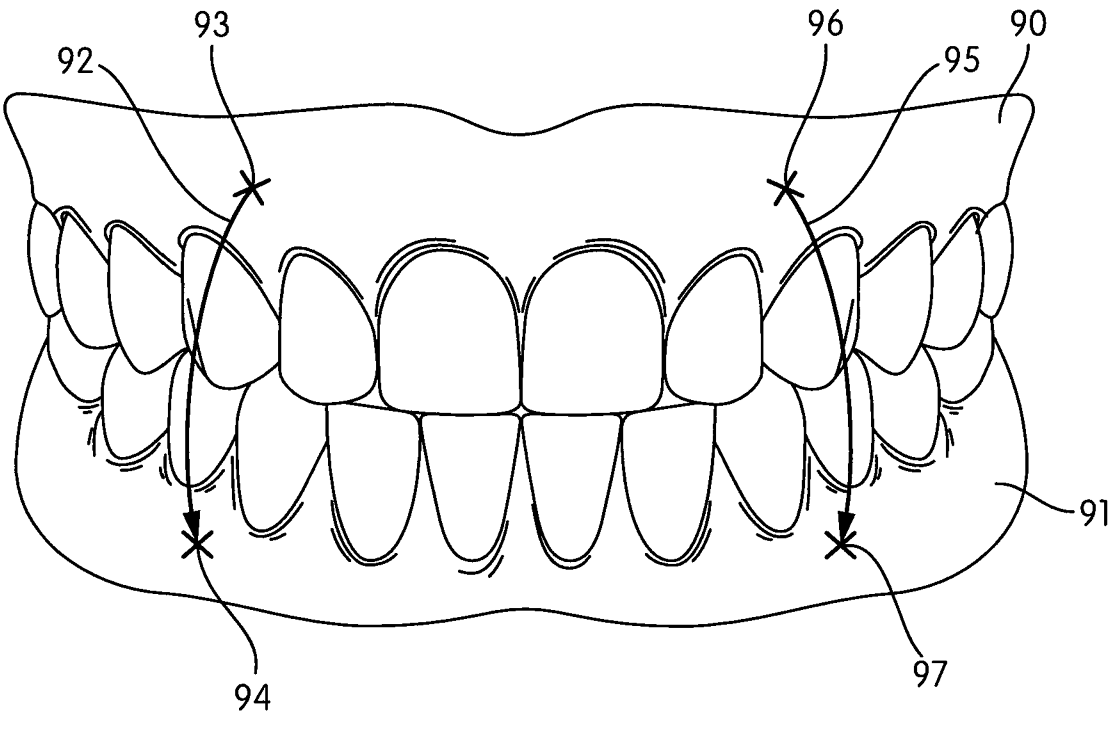
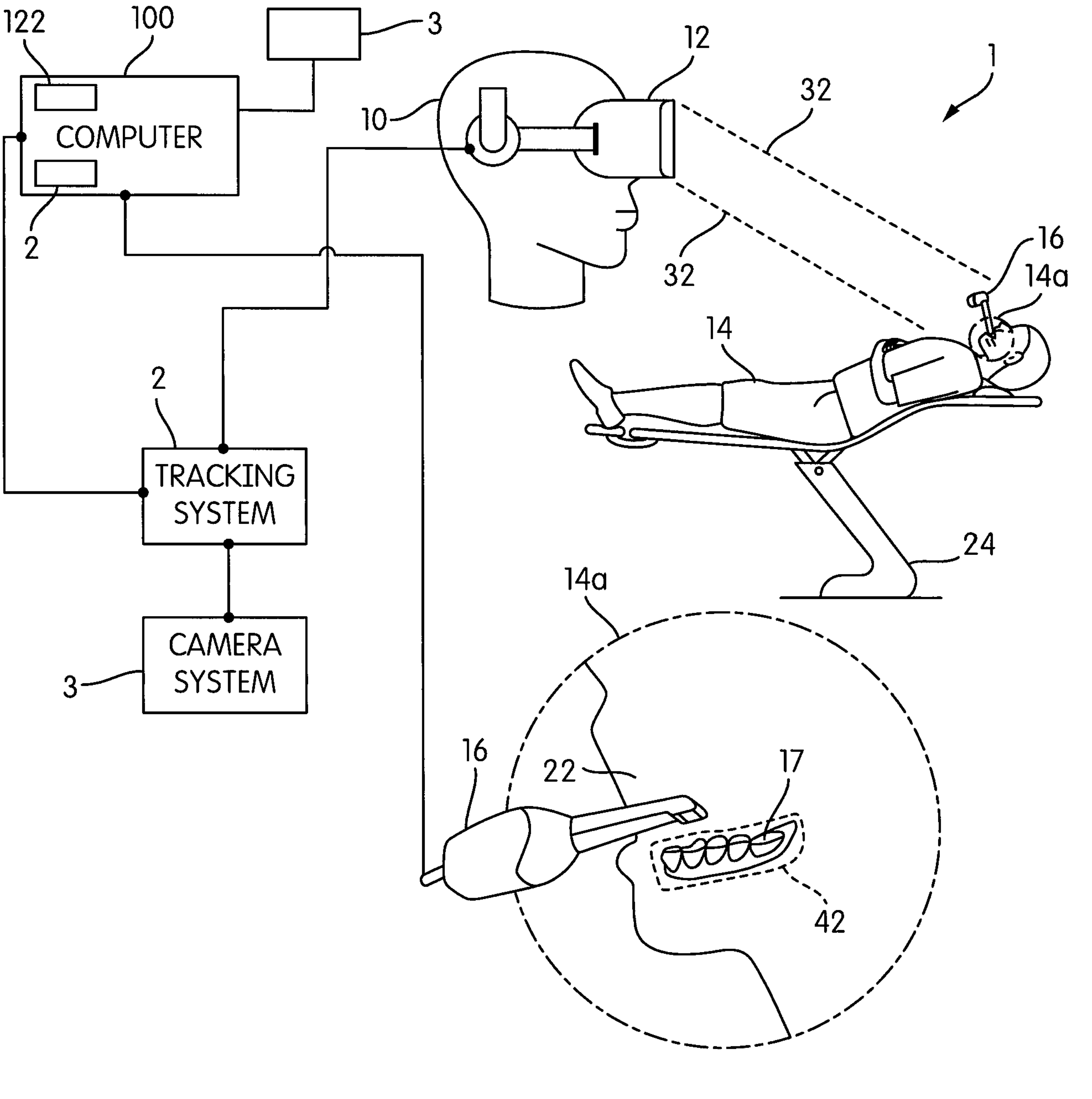


FIG. 13


122
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COMPUTER
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16
14a
14
2
TRACKING SYSTEM
24
14a
CAMERA SYSTEM
3
16
22
17
42

FIG. 2