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(71) Applicant: ULAB SYSTEMS INC. [US/US]; 101 Jefferson Drive, Suite 212A, Menlo Park, California 94025 (US).

(72) Inventor: WEN, Huafeng; 2117 Gossamer Avenue, Redwood Shores, California 94065 (US).

(74) Agents: HAN, Johnney U. et al.; Levine Bagade Han LLP, 2400 Geng Road, Suite 120, Palo Alto, California 94303 (US).

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(54) Title: SYSTEMS AND METHODS FOR FABRICATING DENTAL APPLIANCES OR SHELLS

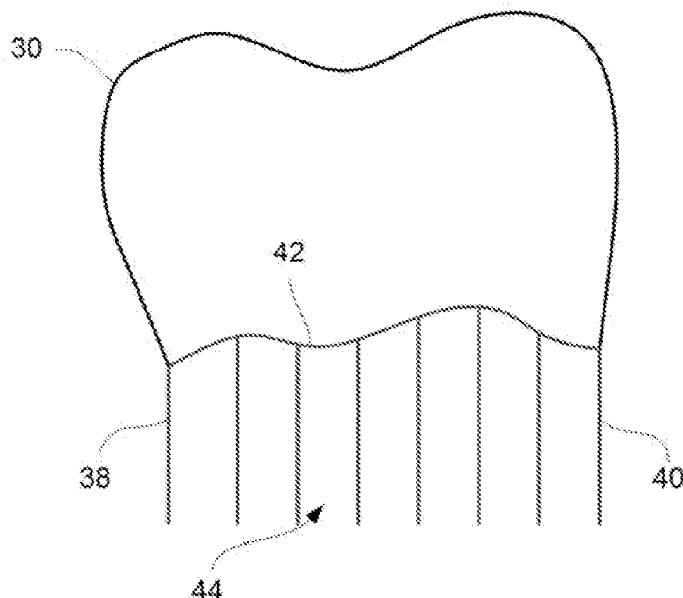


FIG. 3

(57) Abstract: Systems and methods are disclosed for cutting and trimming dental molds and oral appliances by receiving a digital model of teeth, determining a cutting loop path and applying a drape wall to the cutting loop to generate a simplified tooth base in a dental mold having an inner arch curve and an outer arch curve. The oral appliance may be formed on the dental mold and a cutter may be applied using a sweeping motion across the inner and outer arch curves.



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SYSTEMS AND METHODS FOR FABRICATING DENTAL APPLIANCES OR SHELLS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. Patent Application No. 15/230,251 filed August 5, 2016, which claims the benefit of priority to U.S. Provisional Application No. 62/238,539 filed October 7, 2015; and also claims the benefit of priority to U.S. Provisional Application No. 62/238,539 filed October 7, 2015, both of which are incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates to methods and apparatus for fabricating dental appliances. More particularly, the present invention relates to methods and apparatus for forming and cutting of molds used in fabricating oral appliances in an automated process and with a single machine.

BACKGROUND OF THE INVENTION

[0003] Conventionally, braces use brackets connected by wires to encourage teeth to move but more people are having success with clear orthodontic devices called aligners which are a series of tight-fitting custom-made retainers that slip over the teeth. Once a dentist or orthodontist decides how to correct a patient's bite, they make a plan for moving teeth. Patients are then fitted for several versions that make slight adjustments to move the teeth over the treatment time. Aligners made from a clear plastic or acrylic material and fit tightly over the teeth, but can be removed for eating, brushing, and flossing. Patients wear a new aligner every few weeks to continue moving the teeth into the desired position.

[0004] Treatment time with invisible teeth aligners is based on how much the teeth need to be moved or rotated. The more the patient bite is off or the more crooked the teeth, the longer it will take. Treatment usually takes between 10 and 24 months. An adult who had braces as a child may need teeth aligners for as little as 10 weeks.

[0005] Conventional aligners are typically fabricated at a central lab remote from the dental offices and such systems cause delays and fail to offer real-time, instant treatment for patients. Moreover, the manufacturing of the aligners are time-consuming and require multiple steps in fabricating the molds used to create the aligners as well as the aligners themselves.

[0006] Therefore, there remains a need for cost-effective systems which enable the modeling and fabrication of the molds and aligners directly at the dental office locations for providing real-time, instant treatment.

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SUMMARY OF THE INVENTION

[0007] Systems and methods are disclosed for cutting and trimming dental molds and oral appliances by receiving a digital model of teeth, determining a cutting loop path and applying a drape wall to the cutting loop to generate a simplified tooth base in a dental mold having an inner arch curve and an outer arch curve. The oral appliance may be formed on the dental mold and a cutter may be applied using a single sweeping motion across the inner and outer arch curves.

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[0008] The system enables an easy way to cut and trim tooth models. The system allows close control by the treating professional at each stage by allowing specific movements from one stage to the next stage. The system can form aligners quickly and efficiently due to the drape wall simplification. The CNC machines can manufacture each shell as a custom device for many stages of tooth movement. The mold can be cut/trimmed using inexpensive 2D cutting machines, if needed. Additionally, the resulting oral appliances (aligners, shells, etc.) can be removed from the positive mold with minimal force, reducing risk of shell tear from excessive removal force.

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[0009] Generally, one embodiment for a method of forming an oral appliance may comprise receiving a digital model of a patient's dentition, calculating a rule-based cutting loop path on the model for determining a path for trimming a mold replicating the patient's dentition, applying a drape wall from the cutting loop on the model to reduce a complexity of the model, determining a position of a cutting instrument relative to the mold for trimming the mold, generating a computer numerical control code based on the drape wall and position of the cutting instrument, and fabricating the mold based on the generated computer numerical control code.

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[0010] Another embodiment for a method of forming an oral appliance may generally comprise receiving a digital model of a patient's dentition, calculating a rule-based cutting loop path on the model for determining a path for trimming a mold replicating the patient's dentition, applying a drape wall from the cutting loop on the model to reduce a complexity of the model, determining a predetermined height of a base of the model, generating a computer numerical control code of the model, and fabricating the mold based on the generated computer numerical control code.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The following description of the figures of specific embodiments of the invention is merely exemplary in nature and is not intended to limit the present teachings,
5 their application or uses. Throughout the drawings, corresponding reference numerals indicate like or corresponding parts and features.

[0012] FIG. 1 shows an exemplary process for fabricating an oral appliance.

[0013] FIGS. 2 and 3 show side views of an exemplary process of defining a trim line between opposed dots on a digital model of the oral appliance.

10 [0014] FIG. 4 shows a top view of an oral appliance formed with one or more slots to facilitate manufacturing.

[0015] FIG. 5 shows a side view of an oral appliance mounted on a base for manufacturing.

15 [0016] FIG. 6 shows a side view of the oral appliance and some of the directions that the appliance may be translated and/or rotated to facilitate trimming of the appliance.

[0017] FIG. 7 shows a top view of a cutting device which may be used to trim the oral appliance and some of the directions that the cutting device may be articulated.

[0018] FIG. 8 shows a top view of an oral appliance and a cutting device for manufacturing.

20 [0019] FIG. 9 shows a side view of an oral appliance secured to a base for processing.

[0020] FIG. 10 shows an exemplary process for laser cutting a physical mold for the oral appliance.

25 [0021] FIG. 11 shows a side view of an oral appliance formed with a tooling cavity to facilitate articulation of the oral appliance.

[0022] FIG. 12 shows a side view of another oral appliance having a region formed to facilitate removal of the appliance via a stream of air or gas.

[0023] FIG. 13 shows an exemplary process for facilitating removal of the oral appliance.

30 [0024] FIG. 14 shows a side view of another oral appliance having a cavity formed to facilitate its removal via a wedged removal member.

[0025] FIG. 15 shows an exemplary process for facilitating removal of the oral appliance via the wedged removal member.

DETAILED DESCRIPTION OF THE INVENTION

[0026] The present invention will be described with respect to particular embodiments but the invention is not limited thereto but only by the claims. Any reference signs in the claims shall not be construed as limiting the scope thereof.

5 [0027] As used herein, the singular forms “a”, “an”, and “the” include both singular and plural referents unless the context clearly dictates otherwise.

[0028] The terms “comprising”, “comprises” and “comprised of” as used herein are synonymous with “including”, “includes” or “containing”, “contains”, and are inclusive or open-ended and do not exclude additional, non-recited members, elements or method steps. The terms “comprising”, “comprises” and “comprised of” when referring to recited members, elements or method steps also include embodiments which “consist of” said recited members, elements or method steps.

[0029] Furthermore, the terms first, second, third and the like in the description and in the claims, are used for distinguishing between similar elements and not necessarily for describing a sequential or chronological order, unless specified. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein.

[0030] The term “about” as used herein when referring to a measurable value such as a parameter, an amount, a temporal duration, and the like, is meant to encompass variations of $\pm 10\%$ or less, preferably $\pm 5\%$ or less, more preferably $\pm 1\%$ or less, and still more preferably $\pm 0.1\%$ or less of and from the specified value, insofar such variations are appropriate to perform in the disclosed invention. It is to be understood that the value to which the modifier “about” refers is itself also specifically, and preferably, disclosed.

[0031] The recitation of numerical ranges by endpoints includes all numbers and fractions subsumed within the respective ranges, as well as the recited endpoints.

[0032] All documents cited in the present specification are hereby incorporated by reference in their entirety.

30 [0033] Unless otherwise defined, all terms used in disclosing the invention, including technical and scientific terms, have the meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. By means of further guidance, definitions for the terms used in the description are included to better appreciate

the teaching of the present invention. The terms or definitions used herein are provided solely to aid in the understanding of the invention.

[0034] Reference throughout this specification to “one embodiment” or “an embodiment” means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment, but may. Furthermore, the particular features, structures or characteristics may be combined in any suitable manner, as would be apparent to a person skilled in the art from this disclosure, in one or more embodiments. Furthermore, while some embodiments described herein include some but not other features included in other embodiments, combinations of features of different embodiments are meant to be within the scope of the invention, and form different embodiments, as would be understood by those in the art. For example, in the following claims, any of the claimed embodiments can be used in any combination.

[0035] In fabricating oral or dental appliances which are used to treat malocclusions in a patient’s dentition, the oral appliance may be initially formed via, e.g., thermal forming or three-dimensional (3D) printing techniques. Once formed, the oral appliance may require further processing to trim excess material for ensuring a good fit on the patient. However, trimming this excess is typically a time-consuming process which requires a separate step after forming the appliance.

[0036] In one embodiment, the forming and cutting of the oral appliance may be accomplished in an automated process and with a single machine. Generally, a patient’s scanned dentition may be used to create one or more molds of the dentition where each subsequent mold is configured to subsequently follow a corrective path for one or more teeth for correcting malocclusions in the dentition. Each of the one or more molds may be used as a mold for thermal forming or 3D printing a corresponding oral appliance upon the molds. The resulting oral appliances may be used in sequence to move the dentition for correcting the malocclusions.

[0037] FIG. 1 shows an exemplary process for utilizing computerized or computer numerical control (CNC) for fabricating the oral appliances. Typical CNC systems and end-to-end component design is highly automated using computer-aided design (CAD) and computer-aided manufacturing (CAM) dental software. The process begins by loading digital models of the lower and upper arches 10 of the subject’s dentition into a

computer system having a processor. This may involve capturing the 3D representation of the surfaces, e.g. external contours, of a patient's dentition for correcting one or more malocclusions. For this purpose, the subject may be scanned using a 3D scanner, e.g. a hand-held laser scanner, and the collected data can then be used to construct a digital, three dimensional model of the body part of the subject. Alternatively, the patient-specific images can be provided by a technician or medical practitioner by scanning the subject or part thereof. Such images can then be used as or converted into a three-dimensional representation of the subject, or part thereof.

[0038] With the digital model of the subject's dentition loaded into the computer system, the process then calculates a rule-based cutting loop path **12** on the digital model for determining a path along which the CNC machine may follow for trimming the mold upon which the oral appliance is fabricated. Once the cutting loop path has been determined, the process may then reduce the model complexity by applying a drape wall **14** (as described in further detail below) which digitally extends from the cutting loop path towards a bottom of the mold model (e.g., away from the portion of the appliance which contacts the teeth and towards the portion of the appliance which extends towards the gums). The drape wall functions by defining a region of the oral appliance which can be ignored since this portion is to be removed or trimmed.

[0039] The digital model may then be rotated around its center in relation to a reference plane in order to calculate a cutting blade tilt angle and blade height **16** (relative to the reference plane) which may be applied during the actual trimming procedure. With this information, the code to be sent to the CNC machine may be generated based on the stage configuration to be utilized **18**. A physical mold base to be used in the processing procedure may be trimmed and one or more anchoring features may be incorporated into the mold base for securing a holding jig which may be used to secure the oral appliance **20** to the mold base. The completed digital model may then be exported as, e.g., a 3D printer acceptable model **22**, for printing the oral appliance or mold upon which an oral appliance may be formed.

[0040] FIGS. 2 and 3 show side views of a portion of a digital model of a patient's dentition showing a tooth **30** and gums **32**, as an example. In calculating a rule-based cutting loop path **12**, as shown in FIG. 1 above, the scanned image of the patient's dentition may be processed to identify the interface areas between the teeth and gums **32**. One or more markers **34**, **36** may be digitally placed on the model at these interface regions such that the markers **34**, **36** are opposed to one another on the model. A

boundary or trim line **42** may then be defined to extend between the markers **34**, **36** such that the trim line **42** follows the border between the teeth and gums. With the trim line **42** identified on the model, a series of drop lines **38**, **40** which are parallel to one another and spaced apart, e.g., uniformly, relative to one another may be formed to begin from the trim line **42** and extend away from the trim line **42** and away from the dentition in a straight path. This base region **44** formed by the drop lines **38**, **40** below the trim line **42**, i.e., away from or opposite to the dentition, may be identified and demarcated as a region to be removed from the mold.

[0041] To ensure that the height of the mold including the base region **44** does not excessively stretch the material forming the oral appliance, the system may be used to determine the lowest point (relative to the trim line **42** and appliance **30**) for trimming the entire mold just above this identified lowest point. In one embodiment, the trimming may be done with a predetermined margin, e.g., 2 mm, above the lowest identified point. The base region wall can also be tapered slightly based on the height of the base region wall so that the width of the base region **44** tapers from a larger width adjacent to the trim line **42** down to a relatively smaller width away from the trim line **42**. The resulting mold formed from the dentition (or corrected dentition) is shown in the side view of FIG. 3 where the base region **44** has a minimum height of the predetermined margin, e.g., 2 mm.

[0042] Once the mold has been formed with the base region **44**, the mold may be further processed. A bottom view of a formed mold **50** is shown in FIG. 4 with slots **52**, **54** formed into a surface **56** of the mold **50** into which tools or anchors can be inserted for securing the mold **50** in place during further processing procedures. FIG. 5, for example, shows a side view of the fabricated mold **50** secured along its interface surface **56** and anchored via slots **52**, **54** to a surface **62** of a platform **60**. FIG. 6 shows one configuration where the platform **60** holding the physical mold **50** for pressure-forming the oral aligner may be positioned upside down, i.e., such that the mold **50** is held in an inverted position as shown. The platform **60** may be fixed or secured upon a stage **68** which may be actuated to move the platform **60** and mold **50** in a vertical direction **64** (up/down) or linearly **66** within a plane defined by the stage **68** and platform **60**, as shown in FIG. 6, to facilitate cutting or trimming processes for the mold **50**. The stage **68** may also be actuated to rotate **70** the platform **60** and mold **50** within the plane defined by the stage **68** such that the stage **68** rotates about an axis which may be aligned to be collinear with a central axis **72** of the mold **50**, as shown in FIG. 7.

[0043] Another configuration may position the stage 68 relative to a blade which may be translated and/or rotated relative to mold 50 and stage 68. The system may calculate each motion stage parameters and while the mold 50 is moved rotationally, the blade may be used to cut or trim the mold 50, as needed. This may involve rotating the model 50 around its center and calculating the blade tilt angle and blade height 16, as described above.

[0044] Yet another configuration may involve moving the stage 68 and mold 50 relative to a stationary blade such that the mold 50 is rotated, tilted, and/or translated by the stage 68 while the position of the blade remains unchanged. The system then adjusts different tools to trim the mold 50 at the pre-designated cutting path. In this or any other variation, the blade can include a mechanical blade or a laser cutting tool and software may be used to calculate the laser focus to easier move the source back and force or attenuate its power to focus and cut the mold 50 at designated locations.

[0045] In one implementation for processing the mold, FIG. 8 shows a top view of a mold 50 positioned upon a stage and rotated relative to a stationary cutting blade 80. The mold 50 may be secured to the underlying platform and stage and rotated within the plane of the platform in the direction 70 about its central axis 72 which may be coincident with the axis of rotation defined by the stage. The cutting blade 80 having a cutting edge 82 may be positioned relative to the mold at the predetermined height and angle relative to the mold 50, as described herein, to trim the mold 50 as it rotates.

[0046] In this variation, instead of generating a complex 3D cutting curve, the system simply uses a 2D flat curve by optionally setting a water mark cutting plane. The advantage is that no numerical controller is needed to cut the molds. Instead, the mold 50 can be simply placed by hand and rotated (e.g., manually or automatically), as shown, to push it through or past the cutting blade 80. The action may be similar to cutting a wood board with a circular motion rather than a straight or linear motion.

[0047] Another advantage of this configuration is the ability to utilize a separate fixture which can be used to sandwich the material forming the oral appliance after placement upon the mold, e.g., when thermal forming the oral appliance. The material from which the oral appliance is thermal formed, if used for fabrication, may be secured directly removing the need for yet another fixture on the mold itself. One implementation uses a two-dimensional (2D) laser cutting tool that can be used to cut along a flat curve formed by a horizontal silhouette line generated by a projection to the base surface.

[0048] FIG. 9 shows a side view of one embodiment where the mold 50 is positioned above a platform 60 with the plastic shell mold 92 after thermal forming upon the mold 50. The entire assembly of the mold 50, platform 60, and shell mold 92 rests on a flat bottom fixture base 90 having a clamping fixture with one or more clamping plates 94, 96 on either side to secure the mold 50 and shell mold 92. The fixture assembly may be used to secure the shell mold 92 for further processing such as trimming. Once the processing has been completed, the clamping plates 94, 96 may be released and the shell mold 92 and/or mold 50 may be removed from the fixture base 90.

[0049] In the event that the physical mold is processed by laser cutting, the steps shown in the flow diagram of FIG. 10 may be implemented in another embodiment. Initially, a digital model of the lower and upper arches may be loaded in the system 100, as described previously. The system may then calculate a rule based cutting loop path for the 2D cutting system 102, as discussed above. Model complexity may be reduced by applying the drape wall from the cutting loop 104, as also discussed above. The process trims the mold base above a water mark 106 which may be imprinted upon the mold to demarcate a boundary. For laser cutters, the system may generate a 2D laser cutting path using vertical projects 108 and determine the border of the shadow as the cutting path 110. The system may then export the 3D printer model 112 for fabrication. The process may be repeated for each subsequent mold used for fabricating one or more of the corresponding oral appliances.

[0050] Regardless of how the mold is trimmed or how the oral appliance is processed upon the mold, the separation and release of the shell (aligner or oral appliance) from the mold can be generally difficult due to the lack of any features for grabbing the mold. To address this, one or more holes or cavities 122 may be drilled or otherwise defined at various locations within the mold 120 and optionally at an angle 126 relative to a normal direction of the mold, as shown in the end view of FIG. 11. The angling of the hole or cavity 122 enables the insertion of a tool 124 which may be positioned within to provide a counterforce for releasing and removing an oral appliance 128 formed upon the mold 120.

[0051] Another embodiment shown in the end view of FIG. 12 which illustrates an end view of a mold 130 formed to have a hole or cavity 132 which extends through the bottom of the mold 130 and into proximity of the top of the mold, i.e., where the model of the patient's dentition is located. A thin layer 134 of the mold may extend over the hole 132 to provide a surface upon which the oral appliance 128 may be fabricated, as

described herein. However, once fabrication of the oral appliance **128** has been completed and trimmed suitably, the tip **138** of a tool **136** appropriately sized may be inserted into the opening **132** and pushed through the thin layer **134** of the mold **130** and into contact against an inner surface of the oral appliance such that the oral appliance **128** may be urged to release from the mold **130**. Alternatively, the tool **136** may comprise an air blower so that the tip **138** may be positioned within the opening **132** into proximity of the layer **134**, as shown by the detail view **D**, where a jet of air introduced through tip **138** may be break through the layer **134** and urge the oral appliance **128** to release from the mold **130**.

[0052] To ensure that the mold **130** retains its strength during fabrication of the mold, oral appliance, or release of the oral appliance from the mold, the mold **130** may be optionally fabricated to include a honeycomb, mesh, or other porous feature underlying the surface of the mold **130**. With the added structural strength provided by a honeycomb or mesh, the layer **134** may be broken or punctured and still allow of the passage of the air but the mold **130** may have the structural resilience to withstand the pressures generated by the shell formation upon the mold **130** surface.

[0053] FIG. 13 illustrates a flow diagram for removing the oral appliance fabricated upon a mold, as described above. As previously described, the digital model of the lower and upper arches may be loaded into the computer system **140**. The system may then identify an appropriate area along the model for tool insertion **142**. Such an area may be located away from the dentition model and so as not to interfere with the fabrication of the oral appliance upon the mold. The system may trim the model by defining a through-hole from insertion **144** and to strengthen the through-hole, the system may then remodel the hole area by forming the region of the hole adjacent to where the dentition is modeled as a mesh or honeycomb configuration **146** to provide strength to the model when fabricated but which still allows for air to pass through the openings defined by the mesh or honeycomb. The model may incorporate a receiving fixture to allow for the insertion of tools and/or allows for the securement of the mold during removal of the oral appliance from the mold **148**. Once the model has been completed, a 3D printer acceptable model may be exported **150**.

[0054] FIG. 14 shows yet another exemplary embodiment for facilitating removal of the fabricated oral appliance from the mold in the end view of mold **160**. The mold **160** may be formed to define an opening or channel **162** which extends through the mold **160** from a bottom (e.g., opposite to the portion of the mold replicating the dentition) towards a

top (e.g., portion of the mold replicating the dentition such as the occlusal surfaces). In this embodiment, a tapered structure 164 may be formed to be part of the oral appliance 172 which is formed upon the mold 160. The tapered structure 164 may remain attached to an internal surface of the oral appliance while being formed with a tapered surface 166 which tapers to a larger diameter structure within the opening or channel 162 away from the oral appliance 172.

[0055] The tapered structure 164, once formed, may present a cork-like structure which helps to secure the oral appliance upon the mold 160 during fabrication and processing. Once the oral appliance 172 is completed and ready for release and removal from the mold 160, a tool may be inserted into the opening or channel 162, in the direction 170 as indicated, and used to gently push against the bottom surface of the tapered structure 164 to urge the release of the oral appliance 172 from the mold 160 until the tapered structure 164 is removed entirely from the opening or channel 162, in the direction 168 as indicated. Once the oral appliance 172 has been removed entirely, the tapered structure 164 may be removed from the oral appliance 172 as well.

[0056] FIG. 15 illustrates a flow diagram for removing the oral appliance fabricated upon a mold using the tapered structure 164, as described above. As previously described, the digital model of the lower and upper arches may be loaded into the computer system 180. The system may then identify an appropriate area along the model for tool insertion 182. Such an area may be located away from the dentition model and so as not to interfere with the fabrication of the oral appliance upon the mold. The system may trim the model by defining a through-hole from insertion 184 and to strengthen the through-hole, the system may then remodel the hole area by forming or inserting the tapered structure 164 (e.g., reverse cork-type structure) 186. The model may incorporate a receiving fixture to allow for the insertion of tools and/or allows for the securement of the mold during removal 188 of the oral appliance from the mold. Once the model has been completed, a 3D printer acceptable model may be exported 190.

[0057] The system or method described herein may be deployed in part or in whole through a computer system or machine having one or more processors that execute software programs with the methods as described herein. The software programs may be executed on computer systems such as a server, domain server, Internet server, intranet server, and other variants such as secondary server, host server, distributed server, or other such computer or networking hardware on a processor. The processor may be a part of a server, client, network infrastructure, mobile computing platform, stationary computing

platform, or other computing platform. The processor may be any kind of computational or processing device capable of executing program instructions, codes, binary instructions or the like that may directly or indirectly facilitate execution of program code or program instructions stored thereon. In addition, other devices required for execution of methods as described in this application may be considered as a part of the infrastructure associated with the computer system or server.

[0058] The system or method described herein may be deployed in part or in whole through network infrastructures. The network infrastructure may include elements such as computing devices, servers, routers, hubs, firewalls, clients, wireless communication devices, personal computers, communication devices, routing devices, and other active and passive devices, modules or components as known in the art. The computing or non-computing device(s) associated with the network infrastructure may include, apart from other components, a storage medium such as flash memory, buffer, stack, RAM, ROM, or the like. The processes, methods, program codes, and instructions described herein and elsewhere may be executed by the one or more network infrastructural elements.

[0059] The elements described and depicted herein, including flow charts, sequence diagrams, and other diagrams throughout the figures, imply logical boundaries between the elements. However, according to software or hardware engineering practices, the depicted elements and the functions thereof may be implemented on machines through the computer executable media having a processor capable of executing program instructions stored thereon and all such implementations may be within the scope of this document. Thus, while the foregoing drawings and descriptions set forth functional aspects of the disclosed methods, no particular arrangement of software for implementing these functional aspects should be inferred from these descriptions unless explicitly stated or otherwise clear from the context. Similarly, it will be appreciated that the various steps identified and described above may be varied, and that the order of steps may be adapted to particular applications of the techniques disclosed herein. All such variations and modifications are intended to fall within the scope of this document. As such, the depiction or description of an order for various steps should not be understood to require a particular order of execution for those steps, unless required by a particular application, or explicitly stated or otherwise clear from the context.

[0060] Thus, in one aspect, each method described above and combinations thereof may be embodied in computer executable code that, when executing on one or

more computing devices, performs the steps thereof. In another aspect, the methods may be embodied in systems that perform the steps thereof, and may be distributed across devices in a number of ways, or all of the functionality may be integrated into a dedicated, standalone device, or other hardware. All such permutations and combinations are

5 intended to fall within the scope of the present disclosure.

[0061] The applications of the devices and methods discussed above are not limited to the dental applications but may include any number of further treatment applications. Moreover, such devices and methods may be applied to other treatment sites within the body. Modification of the above-described assemblies and methods for

10 carrying out the invention, combinations between different variations as practicable, and variations of aspects of the invention that are obvious to those of skill in the art are intended to be within the scope of the claims.

CLAIMS

What is claimed is:

1. A method of forming an oral appliance, comprising:
receiving a digital model of a patient's dentition;
5 calculating a rule-based cutting loop path on the model for determining a path for trimming a mold replicating the patient's dentition;
applying a drape wall from the cutting loop on the model to reduce a complexity of the model;
determining a position of a cutting instrument relative to the mold for trimming the
10 mold;
generating a computer numerical control code based on the drape wall and position of the cutting instrument; and
fabricating the mold based on the generated computer numerical control code.
- 15 2. The method of claim 1 wherein calculating a rule-based cutting loop path comprises identifying a first location and a second location opposite to the first location on the model at corresponding interface regions and extending a trim line between the first location and second location.
- 20 3. The method of claim 2 wherein applying a drape wall comprises identifying the trim line and replacing a volume below the trim line with a base region.
4. The method of claim 1 wherein the drape wall comprises a base region having
straightened lines.
- 25 5. The method of claim 1 wherein the drape wall comprises a base region having a tapered surface.
6. The method of claim 1 wherein applying a drape wall comprises limiting a
30 height of the drape wall to avoid stretching an oral appliance formed upon the mold.
7. The method of claim 1 wherein fabricating the mold comprises securing the mold to a platform.

8. The method of claim 7 further comprising securing the mold and platform upon one or more stages.

5 9. The method of claim 8 further comprising rotating the mold relative to the cutting instrument.

10 10. The method of claim 8 further comprising rotating the cutting instrument relative to the mold.

11. The method of claim 1 wherein determining a position of a cutting instrument further comprises generating a 2D cutting path by setting a water mark cutting plane.

12. The method of claim 1 wherein fabricating the mold further comprises placing an opening or hole on a base of the mold for receiving a tool to facilitate removal of an
15 oral appliance from the mold.

13. The method of claim 12 wherein placing an opening or hole comprises placing the opening or hole at an angle.

20 14. The method of claim 12 further comprising applying a stream of air to the opening or hole such that the oral appliance is released from the mold.

15. The method of claim 12 further comprising forming a tapered structure within the opening or hole to facilitate removal of the oral appliance from the mold.

25 16. The method of claim 1 wherein fabricating the mold further comprises applying the cutting instrument across an inner and outer arch curve of the mold.

17. A method of forming an oral appliance, comprising:
30 receiving a digital model of a patient's dentition;
calculating a rule-based cutting loop path on the model for determining a path for trimming a mold replicating the patient's dentition;
applying a drape wall from the cutting loop on the model to reduce a complexity of the model;

determining a predetermined height of a base of the model;
generating a computer numerical control code of the model; and
fabricating the mold based on the generated computer numerical control code.

5 18. The method of claim 17 further comprising determining a position of a cutting instrument relative to the mold for trimming the mold prior to fabricating the mold.

10 19. The method of claim 18 wherein generating a computer numerical control code further comprises generating the computer numerical control code based on the drape wall and position of the cutting instrument.

15 20. The method of claim 17 wherein calculating a rule-based cutting loop path comprises identifying a first location and a second location opposite to the first location on the model at corresponding interface regions and extending a trim line between the first location and second location.

21. The method of claim 20 wherein applying a drape wall comprises identifying the trim line and replacing a volume below the trim line with a base region.

20 22. The method of claim 17 wherein fabricating the mold comprises securing the mold to a platform.

23. The method of claim 22 further comprising securing the mold and platform upon one or more stages.

25 24. The method of claim 23 further comprising rotating the mold relative to the cutting instrument.

30 25. The method of claim 17 wherein fabricating the mold further comprises placing an opening or hole on a base of the mold for receiving a tool to facilitate removal of an oral appliance from the mold.

26. The method of claim 25 further comprising forming a tapered structure within the opening or hole to facilitate removal of the oral appliance from the mold.

27. The method of claim 17 wherein fabricating the mold further comprises applying the cutting instrument across an inner and outer arch curve of the mold.

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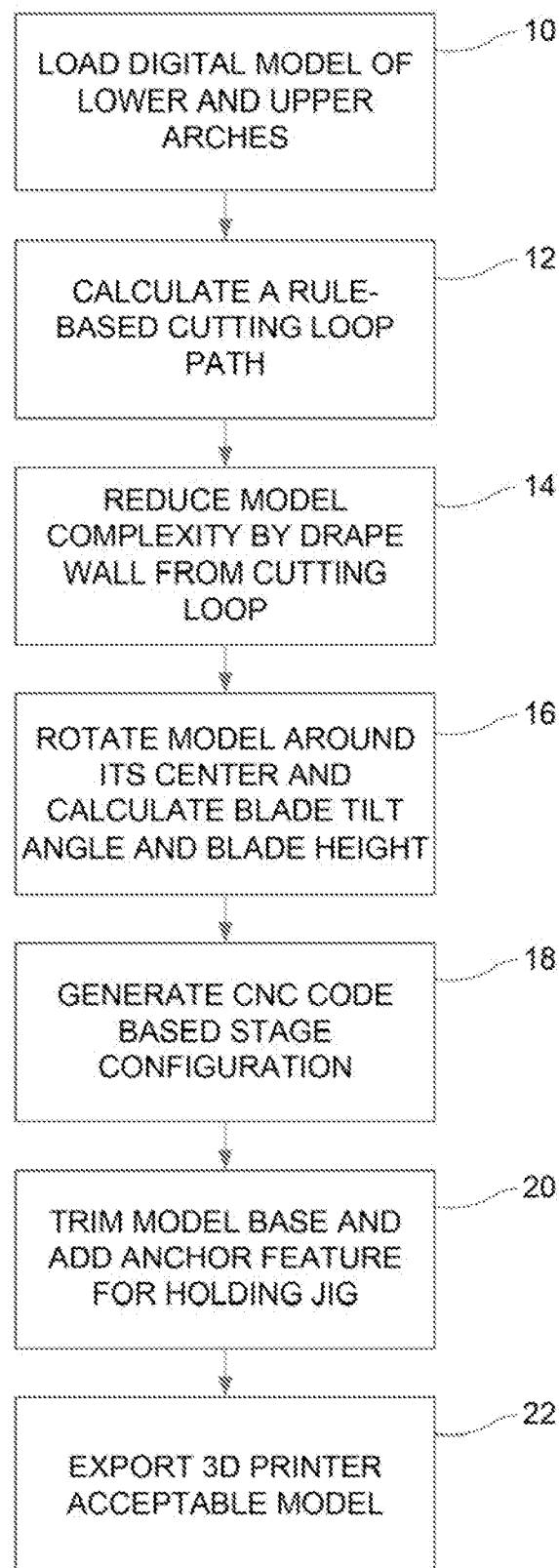


FIG. 1

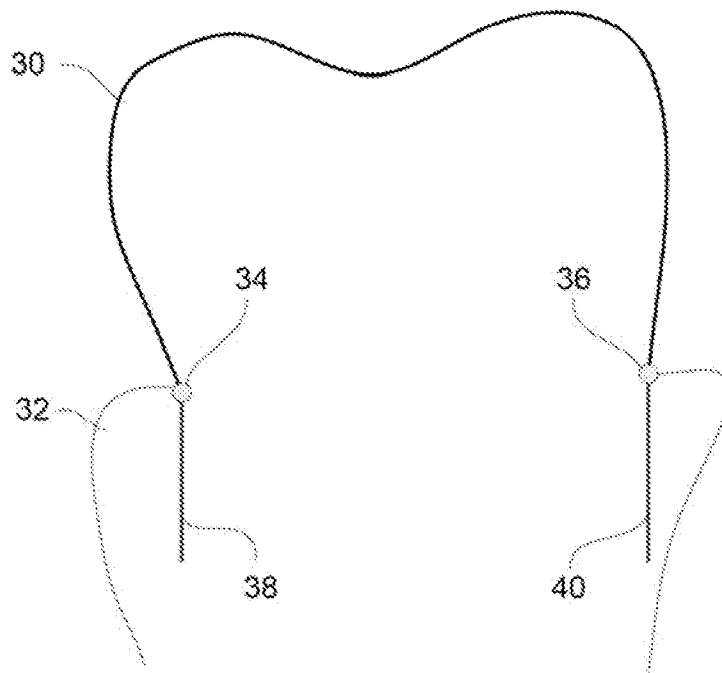


FIG. 2

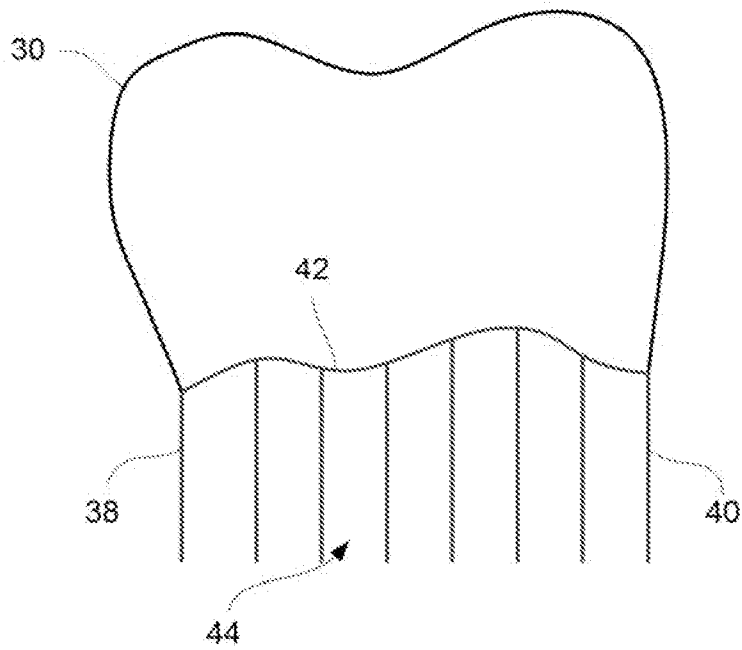


FIG. 3

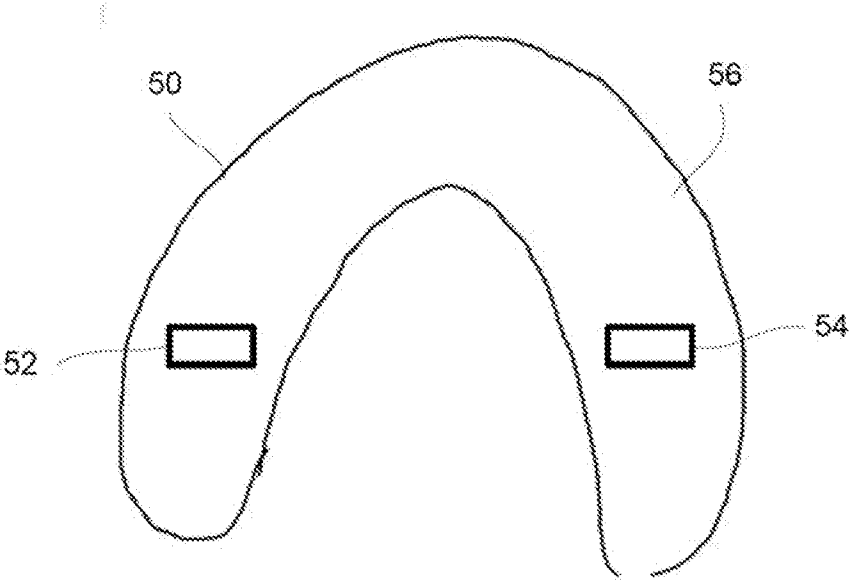


FIG. 4

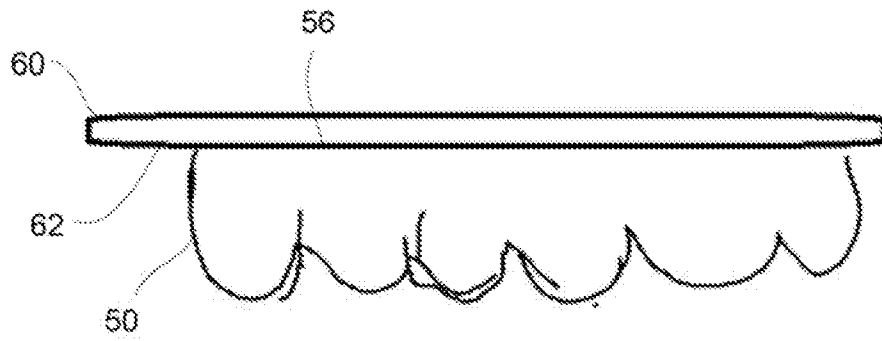


FIG. 5

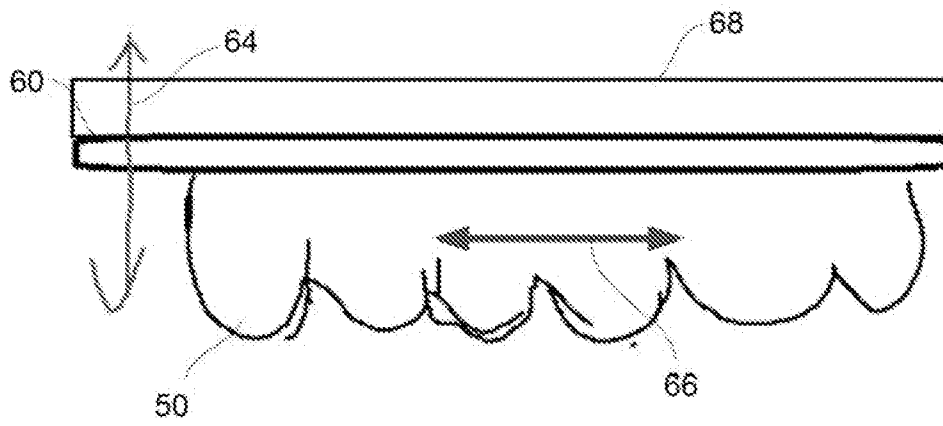


FIG. 6

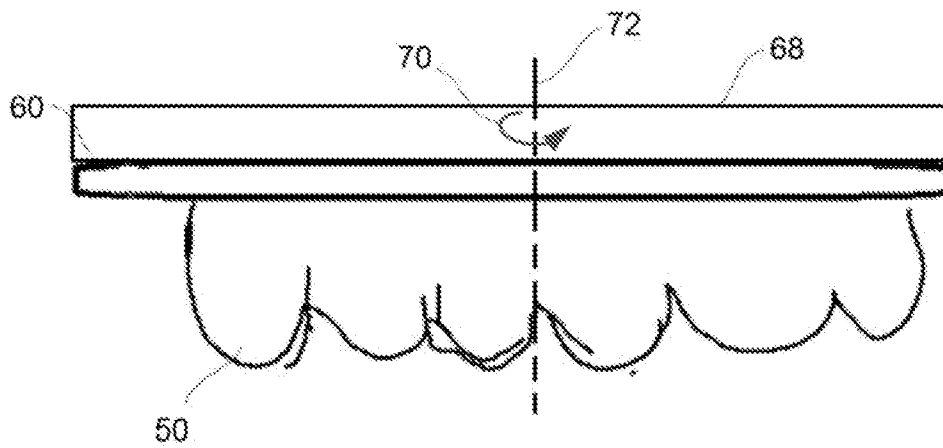


FIG. 7

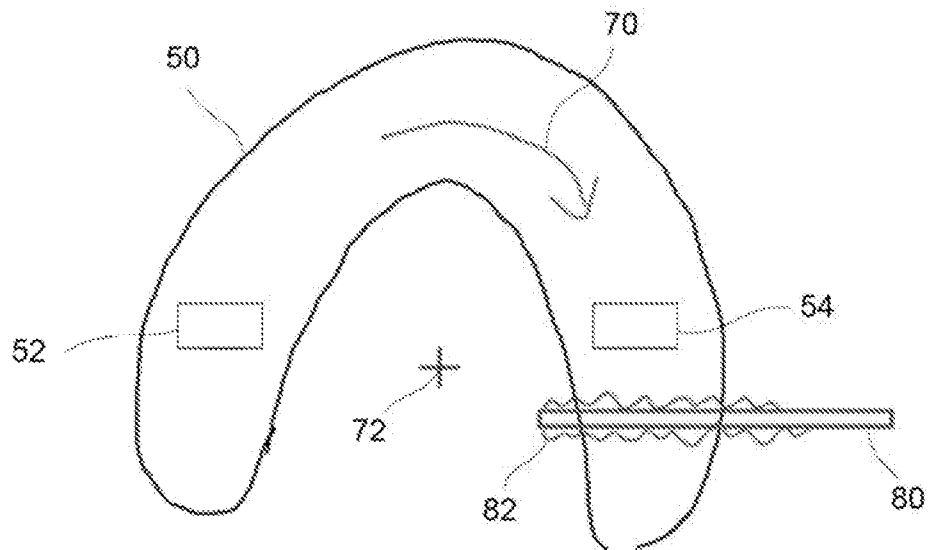


FIG. 8

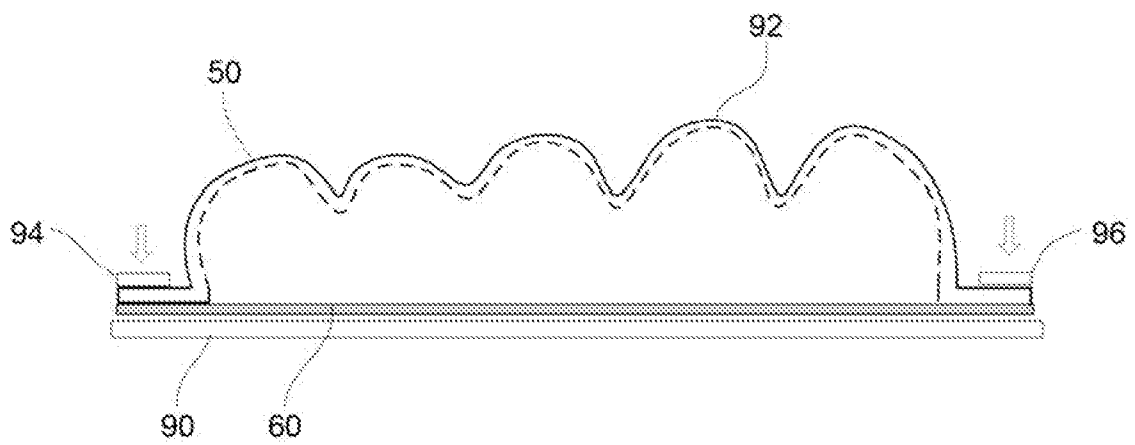


FIG. 9

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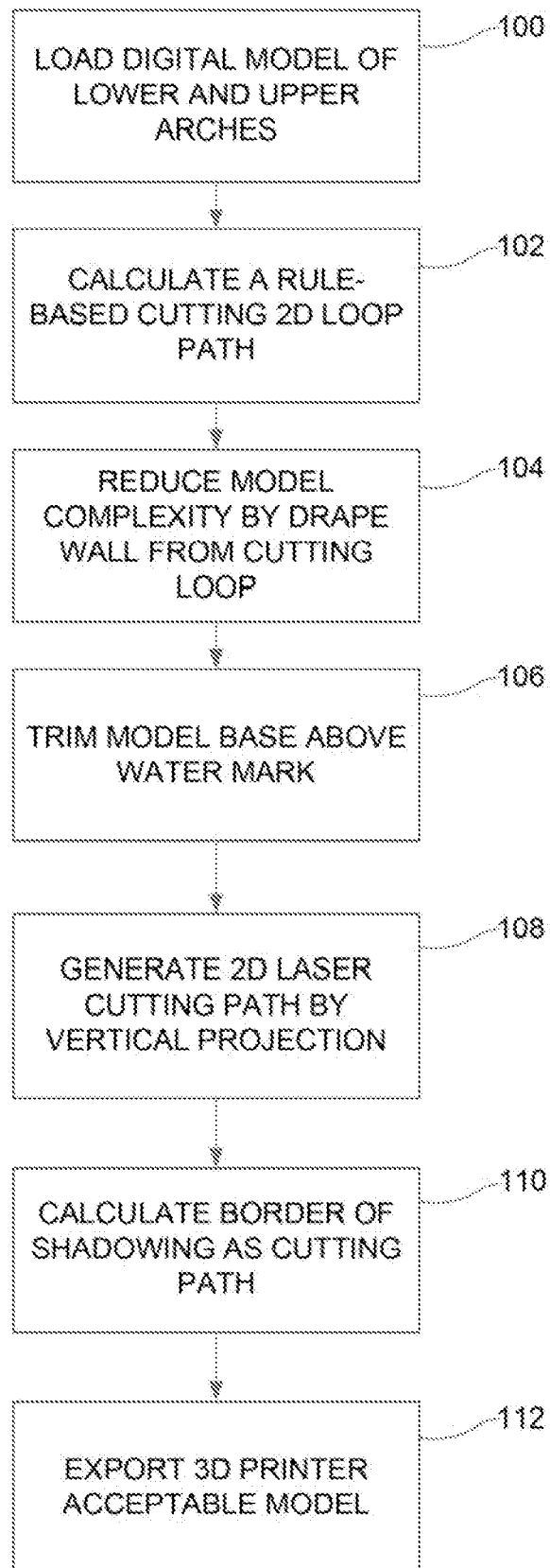


FIG. 10

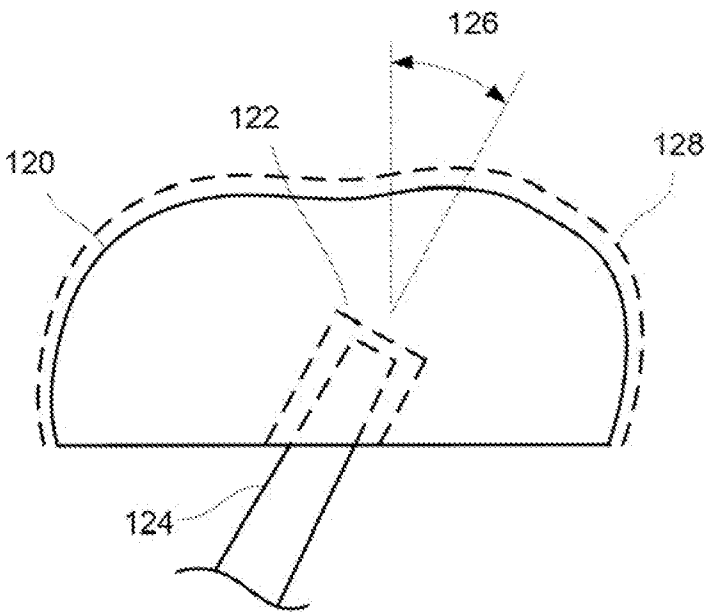


FIG. 11

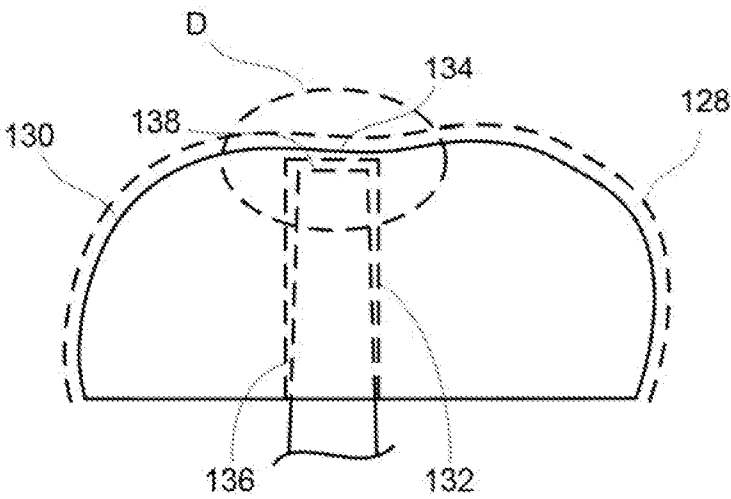


FIG. 12

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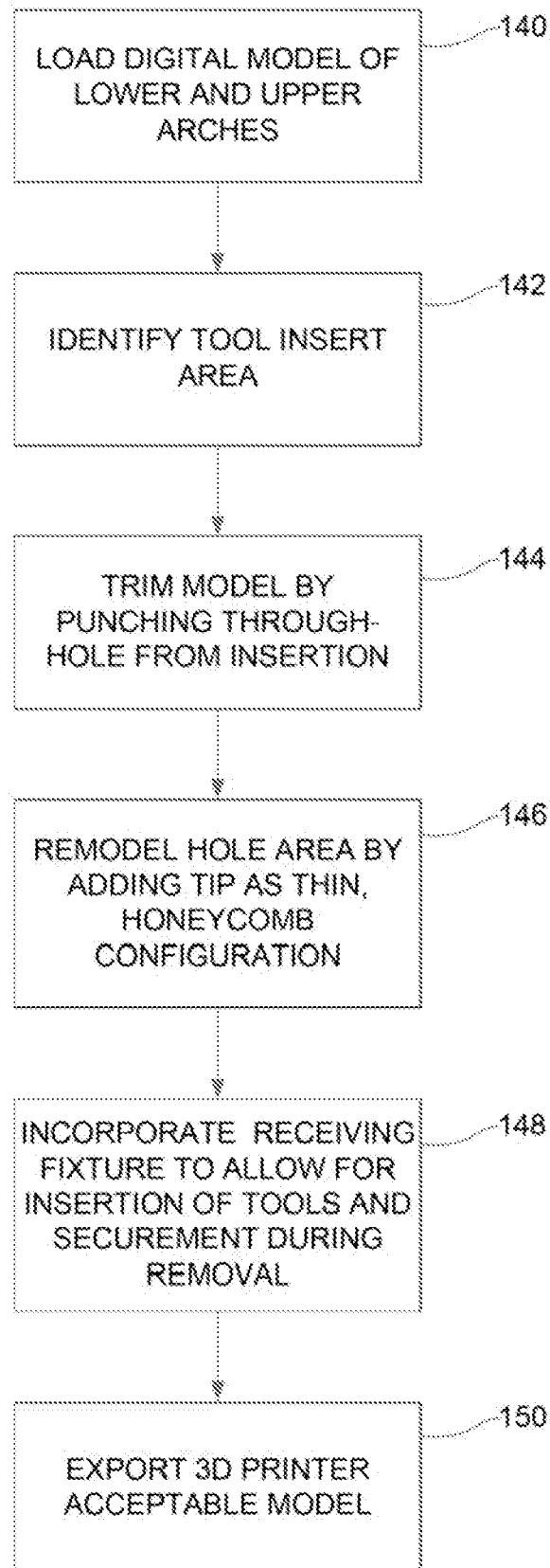


FIG. 13

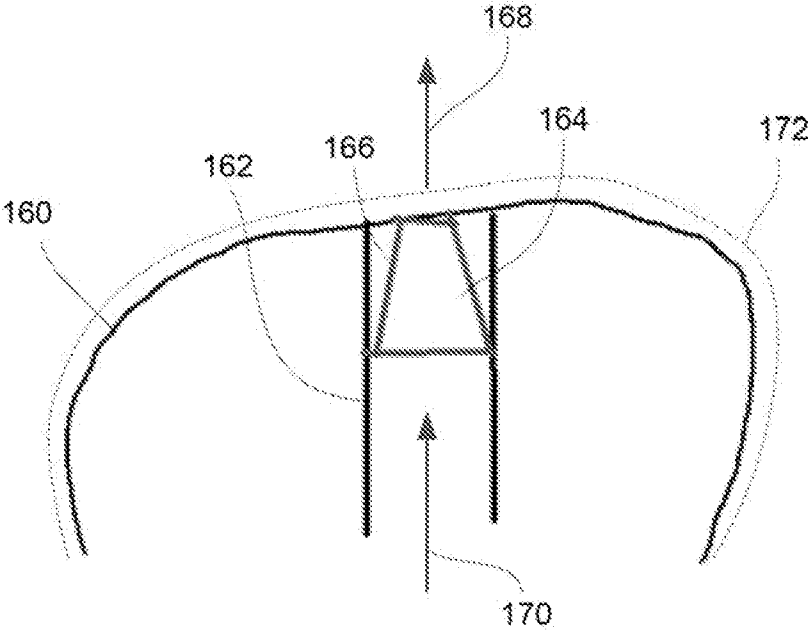


FIG. 14

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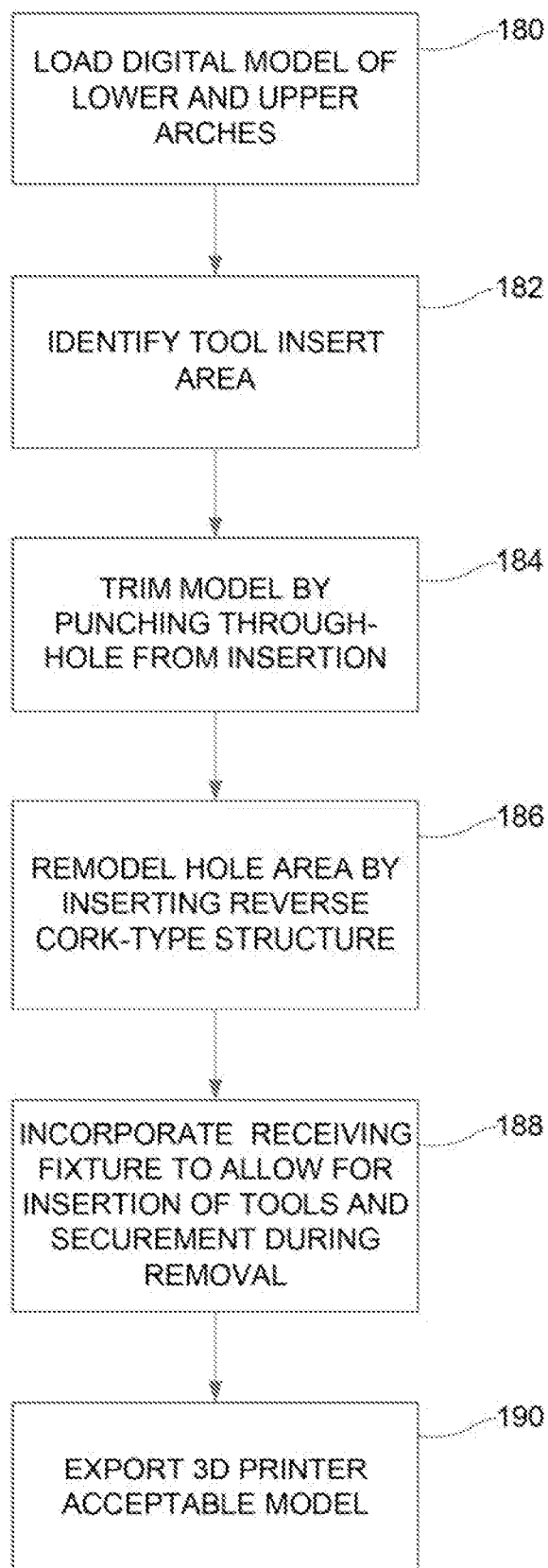


FIG. 15

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2016/053803

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61C 7/00; A61C 7/08; A61C 9/00; A61C 13/00; A61C 13/34; A61C 19/04; G06F 17/50 (2016.01)

CPC - A61C 7/00; A61C 7/002; A61C 7/08; A61C 9/002; A61C 9/0046; A61C 13/0004 (2016.08)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC - A61C 7/00; A61C 7/08; A61C 9/00; A61C 13/00; A61C 13/34; A61C 19/04; G06F 17/50

CPC - A61C 7/00; A61C 7/002; A61C 7/08; A61C 9/002; A61C 9/0046; A61C 13/0004; A61C 13/34; A61F 2/30942; G06F 19/3437

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

USPC - 433/6; 433/24; 433/201.1; 433/213; 433/223; 700/98; 700/118 (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Patbase, Google Patents, Google Scholar

Search terms used: dental model drape cutting loop control code rule path pattern digital aligner mold retainer

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.:
A	US 2008/0141534 A1 (HILLIARD) 19 June 2008 (19.06.2008) entire document	1-27
A	US 2014/0229878 A1 (ALIGN TECHNOLOGY INC) 14 August 2014 (14.08.2014) entire document	1-27
A	US 2014/0315154 A1 (B & D DENTAL CORPORATION) 23 October 2014 (23.10.2014) entire document	1-27
A	US 5,691,905 A (DEHOFF et al) 25 November 1997 (25.11.1997) entire document	1-27
A	US 2008/0206702 A1 (HEDGE et al) 28 August 2008 (28.08.2008) entire document	1-27

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

14 November 2016

Date of mailing of the international search report

26 JAN 2017

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, VA 22313-1450

Facsimile No. 571-273-8300

Authorized officer

Blaine R. Copenheaver

PCT Helpdesk: 571-272-4300

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