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(54) Title: A METHOD OF MAKING CUSTOMIZED ORTHODONTIC BRACKETS

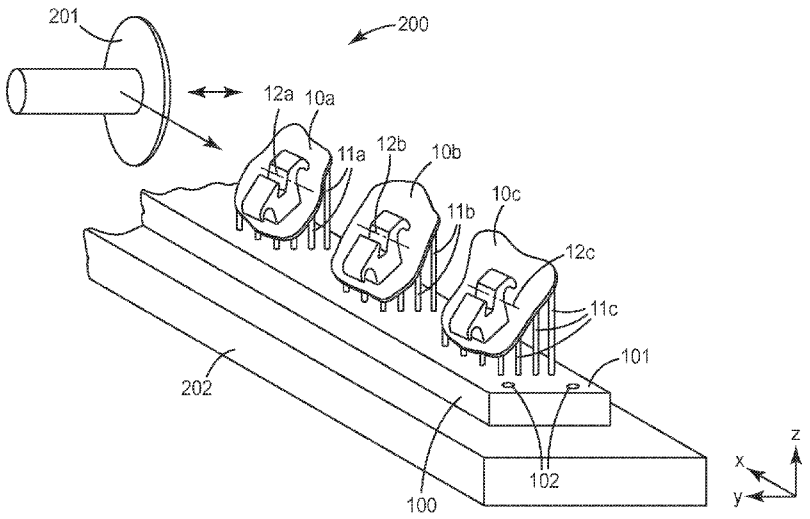

FIG. 1

(57) Abstract: A method of making customized orthodontic brackets. The method has steps of providing a plurality of customized orthodontic bracket precursors, providing one or more support structures, positioning the bracket precursors by means of the support structure(s) in a machining device and using the machining device to provide an archwire slot in each bracket precursor by material removal with the archwire slots aligned along a common path with each other. The invention helps minimizing efforts in the manufacturing and provides the brackets with a precise archwire slot.

WO 2015/085030 A1

A METHOD OF MAKING CUSTOMIZED ORTHODONTIC BRACKETS

Field of the Invention

The invention relates to a method of making a customized orthodontic bracket, and in particular to a method in which a plurality of customized orthodontic bracket precursors are provided by a build-up process, and which by help of support structures provided in the build-up process are jointly provided with archwire slots by material removal. The invention further relates to a customized orthodontic bracket obtained by the method of the invention.

Background Art

Orthodontic brackets are generally used in orthodontic treatments for moving one or more teeth from an initial position to a desired position in a patient's dentition. The initial position typically refers to a position at the beginning of an orthodontic treatment, for example a position in which the labial faces of the teeth are misaligned to each other, whereas in the desired position the labial faces of the same teeth may be generally aligned. For example the patient's teeth may be aligned relative to each other to provide the dentition with a more aesthetically pleasant appearance. Further one or more teeth may be moved within the dentition to compensate for a malocclusion. Such a movement of a tooth or teeth can be typically achieved by using one or more brackets attached to one or more teeth. The brackets are typically connected to an elastic archwire for applying a force to the teeth toward the desired position over a longer term.

Often orthodontic brackets are off-the-shelf products which are designed to for use with clinical situations of different patients. Further there are customized orthodontic brackets which are typically made to fit with an individual clinical situation of one particular patient.

For example US 2012/0015315 A1 discloses a customized orthodontic bracket system which includes a bracket having a customized bracket bonding pad for bonding the bracket to a tooth of a patient and a bracket slot adapted to receive a customized archwire. The customized archwire is adapted to be positioned in the bracket slot to form a precise bracket slot-archwire interface.

Although a variety of different brackets and bracket systems are on the market there is still a desire to provide brackets which on the one hand match an individual clinical situation and on the other hand are minimized in costs for manufacturing and costs for application to a patient's teeth. Typically the minimization of costs in the manufacturing must be balanced relative to the desired accuracy of the customized brackets. For example, brackets should be placeable easily and precisely to a patients teeth, and should have a geometry allowing an orthodontic archwire to be attached precisely at desired positions

relative to the teeth. Further customized brackets should be sufficiently durable over the time period of an orthodontic treatment. On the other hand available manufacturing methods for mass production of customized brackets may not be compatible with such precision and quality requirements, whereas available sufficiently precise and high quality manufacturing methods may not satisfy or fully satisfy requirements for mass production at minimized costs.

Summary of the Invention

In one aspect the invention relates to a method of making customized orthodontic brackets. The method comprising the steps of:

- providing a plurality of individually shaped customized orthodontic bracket precursors;
- providing one or more support structures;
- positioning the bracket precursors by means of the support structure(s) in a machining device;
- using the machining device to provide an archwire slot in each bracket precursor by material removal with the archwire slots aligned along a common path with each other, and thereby provide a plurality of brackets; and
- separating the support structure(s) and the brackets from each other.

The invention provides advantages in the manufacturing of customized orthodontic brackets. In particular the invention helps minimizing efforts in the making of the brackets and also specifically helps maximizing the precision of the archwire slot of the bracket. The invention allows for example building up the brackets using a rapid prototyping technique at minimized costs, sufficient overall precision and using a relatively inexpensive material (for example steel), and nevertheless allows providing the bracket with an archwire slot having a maximized precision. It has been found that the precision of the archwire slot is important for a successful and rapid orthodontic treatment. In particular a customized bracket system using a rectangular archwire, allowing not only a movement by lateral forces but also a rotation of teeth by torque, the brackets should be dimensioned so that there is neither too much play between the archwire and the archwire slots nor should the archwire sit overly tight in the archwire slots. The invention helps providing brackets which meet such requirements and further help achieving minimized costs in manufacturing.

For the purpose of the present specification a “bracket precursor” relates to a semi-finished bracket having no archwire slot or a preliminary archwire slot being undersized relative to the archwire slot at its desired final geometry. Further a “bracket” as referred to in this specification relates to a bracket having an archwire slot at its desired final geometry. Such a bracket has a bracket bonding pad and a bracket body and the archwire slot is provided in the bracket body.

In an embodiment the method comprises the step of providing a support structure for each bracket precursor. The method may further comprise the step of providing a plurality of support structures for each bracket precursor. The bracket precursor and the support structure are preferably monolithically formed. A support structure as referred to in this specification may be in the form of a protrusion extending from the bracket. In one embodiment the protrusion is a pin, for example a pin extending at a generally uniform cross-section (for example circular or rectangular) along a linear axis. Several support structures preferably end on a common virtual plane or surface. Preferably at least three such pins may be used as support structures for one bracket precursor. Thus the support structures allow a defined positioning and orientation of the bracket precursor on a (planar) surface.

In a further embodiment the method comprises the step of providing a predetermined breaking point between the bracket precursor and the support structure. Thus the bracket precursor (or bracket) and the support structure are adapted for separation from each other by breaking the predetermined breaking point. The predetermined breaking point may be formed for example by a constriction in the pin or pins located adjacent the bracket.

In one embodiment the bracket precursors are positioned in the machining device consecutively in a row. The bracket precursors thereby are preferably positioned and oriented by means of the respective support structures such that the position and orientation of the archwire slot intended to be provided in the bracket precursor are aligned relative to each other.

In a further embodiment the archwire slot in each bracket precursor is provided by grinding. Grinding is preferably performed based on a linear relative movement between a grinding tool and the bracket precursors along the row. For example a grinding wheel may be used to cut the slots straight though all bracket precursors.

In a further embodiment the archwire slot in each bracket precursor is provided by electrical discharge machining of multiple or all bracket precursors at a time. For electrical discharge machining a generally linear structure or wire which extends along the row may be used, for example to cut the slots straight though all bracket precursors.

In a further embodiment the method comprises the steps of:

- building up the (or one of the) support structure using additive material manufacturing; and
- building up the bracket precursor on the support structure using additive material manufacturing.

In case a bracket precursor comprises a plurality of support structures the method may comprise the steps of:

- building up the support structures using additive material manufacturing; and
- building up one of the bracket precursors on the support structures using additive material manufacturing.

Preferably building up the support structure(s) and building up the bracket precursor(s) are performed using the same using additive material manufacturing, like for example selective laser melting.

In one embodiment the step of building up the bracket precursor(s) comprises building up a bracket bonding pad on the support structure and a bracket body precursor on the bonding pad. The bracket bonding pad preferably comprises a tooth facing surface oriented toward the support structure and an opposite rear surface supporting the bracket body precursor. The bracket body precursor may comprise an undersized (preliminary) slot forming a basis for providing the archwire slot by material removal from the bracket precursor, particularly from the bracket body precursor.

In a further embodiment the method comprising the steps of:

- providing at least one virtual tooth surface of a patient;
- providing a virtual bracket comprising a virtual bracket bonding pad and a virtual bracket body, the virtual bracket bonding pad having a virtual tooth facing surface being associated to the virtual tooth surface;
- determining a geometric relationship between at least two of:
  - o an archwire position (or archwire slot position),
  - o the bracket position and
  - o a reference surface; and
- determining a geometry of a support structure based on the determined geometric relationship.

In a further embodiment the method comprising the step of creating the support structure between the reference surface and the virtual bracket bonding pad.

A computer based method of designing a customized orthodontic bracket as may be used also with present invention is for example disclosed in US 2012/0015315 A1. Such a method is based on capturing the shape of a patient's dentition, for example using a scanner. The dentition may for example be scanned intra-orally or from a plaster model obtained via a dental impression taken from the patient's dentition. The captured shape of the patient's dentition may be stored in the form of a three-dimensional computer representation in a computer that is equipped with computer aided design (CAD) software. The CAD software may be used to simulate the orthodontic treatment, for example the CAD software may store the patient's virtual dentition in an initial position (for example in malocclusion) and may further store the patient's virtual dentition in a desired position (after the treatment). The patient's virtual dentition in the

desired position may be obtained by computer aid based on the patient's virtual dentition in the initial position or may be scanned from a so-called set-up model (a physical model in which the teeth have been repositioned manually toward the desired position). Based on the patient's virtual dentition in the initial and the desired position an archwire shape may be designed in relation the virtual dentition.

Further the virtual dentition may be used to define bonding areas for brackets on individual teeth. This may be done by an operator by manually marking such area on individual teeth of the virtual dentition. Each marked area on a tooth of the virtual dentition may be used to create a correspondingly shaped virtual tooth facing surface for a bracket intended to be attached to that tooth. A virtual bracket bonding pad may be provided by creating a three-dimensional virtual object based on the virtual tooth facing surface an offset of the virtual tooth facing surface.

Finally a virtual bracket body may be created as a three-dimensional connector object between the archwire and the boding pad. Because the shape and position of the archwire is defined relative to the virtual dentition a position and orientation of a virtual archwire slot for receiving the archwire can be determined in the virtual bracket body.

A so created virtual bracket precursor comprises at least the bracket bonding pad and the bracket body, and may be provided to a build-up machine, for example a selective laser melting device, for building up the bracket precursor. According to the invention one or more support structures may be included in the design of the bracket precursor so that the bracket precursor may be built up including the support structures.

A virtual structure as used in this specification preferably refers to a mathematic model representing such structure. For example the terms "virtual dentition", "virtual tooth surface", "virtual bracket", "virtual bracket bonding pad" and "virtual bracket body" preferably further refer to a computer representation of a physical "dentition", "tooth surface", "bracket", "bracket bonding pad" and "bracket body", respectively.

In an embodiment the step of providing the bracket precursors involves three-dimensionally building up the bracket precursors in a three-dimensional build-up device which is based on Selective Laser Melting (SLM) or Stereo Lithography (STL).

In one embodiment the bracket precursors are built up from a cobalt-chrome steel or gold.

In a further embodiment the method comprises the steps of:

- providing a support plate which forms the reference surface;
- positioning the support plate in the build-up device; and

- building up the support structure and the bracket precursor.

The support plate may be formed as a common support plate for a plurality of bracket precursors and corresponding support structures, or as individual support plates for a single bracket precursor and corresponding support structure(s). The individual support plates may be configured for combination with each other to form one composed common support plate.

In one embodiment the method further comprises the steps of:

- placing the support plate with the bracket precursors built up thereon in the machining device; and
- providing the bracket precursors with the archwire slot.

In a further aspect the invention relates to a customized orthodontic bracket, obtained by the method of the invention. Such a customized orthodontic bracket preferably is obtained from three-dimensionally building-up or casting and has an archwire slot obtained from material removal.

Brief Description of the Figures

Fig. 1 is a perspective view illustrating a situation in a method according to an embodiment of the invention;

Fig. 2 is a perspective view of a bracket precursor with support structures according to an embodiment of the invention; and

Fig. 3 is a cross-sectional detail view based on the bracket precursor with support structures shown in Fig. 2.

Detailed Description of the Invention

Fig. 1 shows a grinding machine 200. The grinding machine 200 has a rotatable grinding wheel 201 and a machine table 202. The grinding machine 200 is configured such that the grinding wheel 201 and the machine table 202 are linearly movable relative to each other. A similar grinding machine is also known in the field of tool making as “surface grinding machine”. However the grinding machine 200 according to the invention is equipped with grinding wheel 201, for example with an ultrathin grinding wheel. The thickness of the grinding wheel 201 is between about 0.1 mm and about 0.4 mm. Such grinding wheel preferably has a polymeric binder to prevent breaking during grinding. A suitable grinding wheel is for example available under the designation type 34 from Finzler, Schrock & Kimmel GmbH, Germany.

A support plate 100 is positioned in the grinding machine 200. A plurality of bracket precursors 10a, 10b, 10c are arranged on a top surface 101 of the support plate 100. Each of the bracket precursors 10a, 10b, 10c are positioned and supported on the support plate 100 by support structures 11a, 11b, 11c. In the example the support structures 11a, 11b, 11c are in the form of pins extending between the top surface 101 of the support plate 100 and the bracket precursors 10a, 10b, 10c.

The bracket precursors 10a, 10b, 10c, by means of the support structures, are positioned and oriented on the support plate 100 at a predetermined position and orientation relative to the top surface 101 of the support plate 200. The position and orientation is predetermined such that the position and orientation of desired archwire slots in each of the bracket precursors 10a, 10b, 10c are in line with each other. In particular the bracket precursors 10a, 10b, 10c are arranged such that axes 12a, 12b, 12c of the desired archwire slots are coaxial. Thus the archwire slots can be ground in all bracket precursors 10a, 10b, 10c in one and the same grinding cycle. During such grinding cycle the bracket precursors 10a, 10b, 10c and the grinding wheel 201 are moved linearly relative to each other such that the grinding wheel 201 grinds portions from the bracket precursors 10a, 10b, 10c to successively form the archwire slots in all bracket precursors 10a, 10b, 10c. The skilled person will understand that although the overall movement between the bracket precursors 10a, 10b, 10c and the grinding wheel 201 is linear, infeed movements are included in the grinding cycle to provide the archwire slot with desired dimensions.

In another example (not illustrated) the archwire slot is provided by Electrical Discharge Machining. In this example a wire, or other appropriate straight structure, is used to machine the archwire slots in multiple bracket precursors at a time.

The support plate 100 preferably has a reference structure for positioning the support plate 100 at a known position and orientation in the grinding machine. Such a reference structure may for example comprise one or more holes 102 in the support plate which are engageable by appropriately fitting alignment pins (not visible) of the grinding device. Further the bracket precursors 10a, 10b, 10c are preferably arranged on the support plate at a predetermined position and orientation relative to the reference structure. Thus – because the position and orientation of the bracket precursors relative to the grinding machine may be known - the grinding wheel 201 of the grinding machine 200 may be easily positioned for grinding the archwire slots at the desired position and orientation in the bracket precursors 10a, 10b, 10c.

In another example (not shown) two or more support plates each carrying one or more bracket precursors may be used instead of a common support plate 100 as shown. Such multiple support plates may be adapted such that they can be combined in a predetermined alignment with each other, for example to form a composed common support plate. Further the support structures may be configured such that a plurality of bracket precursors can be directly aligned with each other. In this case a support plate may not be necessary. In still another example (not shown) the support plate may comprise the support structure(s) for supporting one or more bracket precursors. Such a support plate may carry support structures built up from a relatively inexpensive material, for example a wax or polymer, whereas the bracket precursors may be made of a metal (for example gold or steel) or ceramics.

Fig. 2 shows a bracket precursor 10 which has a plurality of support structures 11. The bracket precursor 10 in the example has a preliminary slot 13, although such preliminary slot may not be present in other examples. The preliminary slot 13 is undersized with respect to a final archwire slot and may help reducing the time for machining or grinding the archwire slot toward its desired dimensions. Further the bracket precursor 10 has a bonding pad 14 from which the support structures 11 protrude. In particular the support structures 11 protrude from a tooth facing surface 16 of the bracket precursor 10. Each of the support structures 11 has a free end 11a on a common virtual reference surface (in the example a virtual reference plane) 20. Thus the plurality of support structures 11 in combination form an overall planar support allowing the bracket precursor to be positioned on a planar surface (for example on the support plate 100 in Fig. 1). The bracket precursor 10 and the support structures 11 in the example are obtained from building up by a Selective Laser Melting process, for example using a chrome-cobalt steel or gold. Accordingly the bracket precursor 10 and the support structures 11 are monolithically formed in one piece.

Fig. 3 shows a portion of the bonding pad 14 of the bracket precursor 10 and a support structure 11 separated (broken off) from the bracket precursor 10. The tooth facing surface 16 has cavities 17 (one of which is shown in detail). The support structures 11 originally (before separation) protrude from a surface portion of the cavities 17 and preferably have a predetermined breaking point adjacent that cavity surface portion. In the example the predetermined breaking point is formed by a narrowed portion in the support structure 11. As schematically illustrated, therefore a remaining fracture portion 18 residing after breaking off the support structure 11 preferably does not protrude outside the opening of the cavity 17. Therefore the bracket bonding pad 14 is configured such that any fracture portion 18 of the support structures 11 do not collide or substantially collide with a tooth surface to which the bracket bonding pad may be adhered. And thus any residing fracture portion 18 may not affect mounting the finished bracket to a patient's tooth. The cavities and breaking points may further provide additional surface and structure to improve bond strength after bonding the bracket with the tooth facing surface to a patient's tooth.

Claims

1. A method of making customized orthodontic brackets, the method comprising the steps of:
   - providing a plurality of individually shaped customized orthodontic bracket precursors;
   - providing one or more support structures;
   - positioning the bracket precursors with the support structure(s) in a machining device;
   - using the machining device to provide an archwire slot in each bracket precursor by material removal with the archwire slots aligned along a common path with each other, and thereby provide a plurality of brackets; and
   - separating the support structure(s) and the brackets from each other.

2. The method of claim 1, comprising the step of providing a support structure for each bracket precursor.

3. The method of claim 2, wherein the bracket precursor and the support structure are monolithically formed , and wherein the method further comprises the step of providing a predetermined breaking point between the bracket precursor and the support structure.

4. The method of any of the preceding claims, wherein the bracket precursors are positioned in the machining device consecutively in a row.

5. The method of claim 4, wherein the archwire slot in each bracket precursor is provided by grinding, and wherein grinding is performed based on a linear relative movement between a grinding tool and the bracket precursors along the row.

6. The method of claim 4, wherein the archwire slot in each bracket precursor being provided by electrical discharge machining of multiple or all bracket precursors at a time using a generally linear structure or wire which extends along the row.

7. The method of any of the preceding claims, further comprising the steps of:
   - building up the (or one of the) support structure(s) using additive material manufacturing; and
   - building up the (or one of the) bracket precursor(s) on the support structure using additive material manufacturing.

8. The method of claim 7, wherein the step of building up the bracket precursor(s) comprises building up a bracket bonding pad on the support structure and a bracket body precursor on the bonding pad.

9. The method of claim 8, wherein the bracket body precursor comprises an undersized slot forming a basis for providing the archwire slot by material removal from the bracket body precursor.

10. The method of any of the preceding claims, comprising the steps of:
    - providing at least one virtual tooth surface of a patient;
    - providing a virtual bracket comprising a virtual bracket bonding pad and a virtual bracket body, the virtual bracket bonding pad having a virtual tooth facing surface being associated to the virtual tooth surface;
    - determining a geometric relationship between at least two of:
        - an archwire position (or archwire slot position),
        - the bracket position and
        - a reference surface; and
    - determining a geometry of a support structure based on the determined geometric relationship.

11. The method of claim 10, further comprising the step of creating the support structure between the reference surface and the virtual bracket bonding pad.

12. The method of any of the preceding claims, wherein the step of providing the bracket precursors involves three-dimensionally building up the bracket precursors in a three-dimensional build-up device which is based on Selective Laser Melting (SLM) or Stereo Lithography (STL).

13. The method of claim 10 and 12 or 11 and 12, further comprising the steps of:
    - providing a support plate which forms the reference surface;
    - positioning the support plate in the build-up device; and
    - building up the support structure and the bracket precursor.

14. The method of claim 13, further comprising the steps of:
    - placing the support plate with the bracket precursors built up thereon in the machining device; and
    - providing the bracket precursors with the archwire slot.

15. A customized orthodontic bracket, obtained from three-dimensionally building-up or casting and having an archwire slot obtained from material removal.

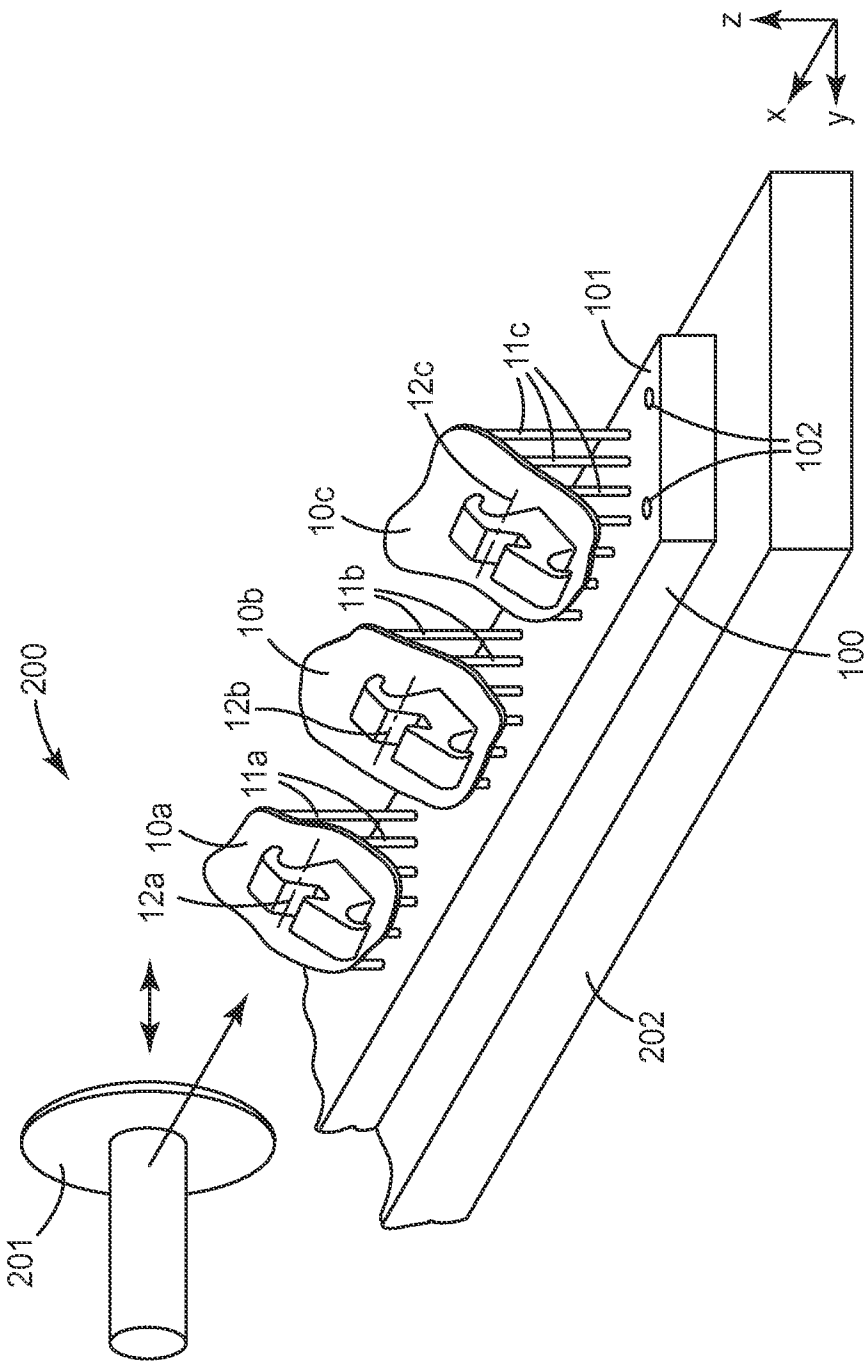

FIG. 1

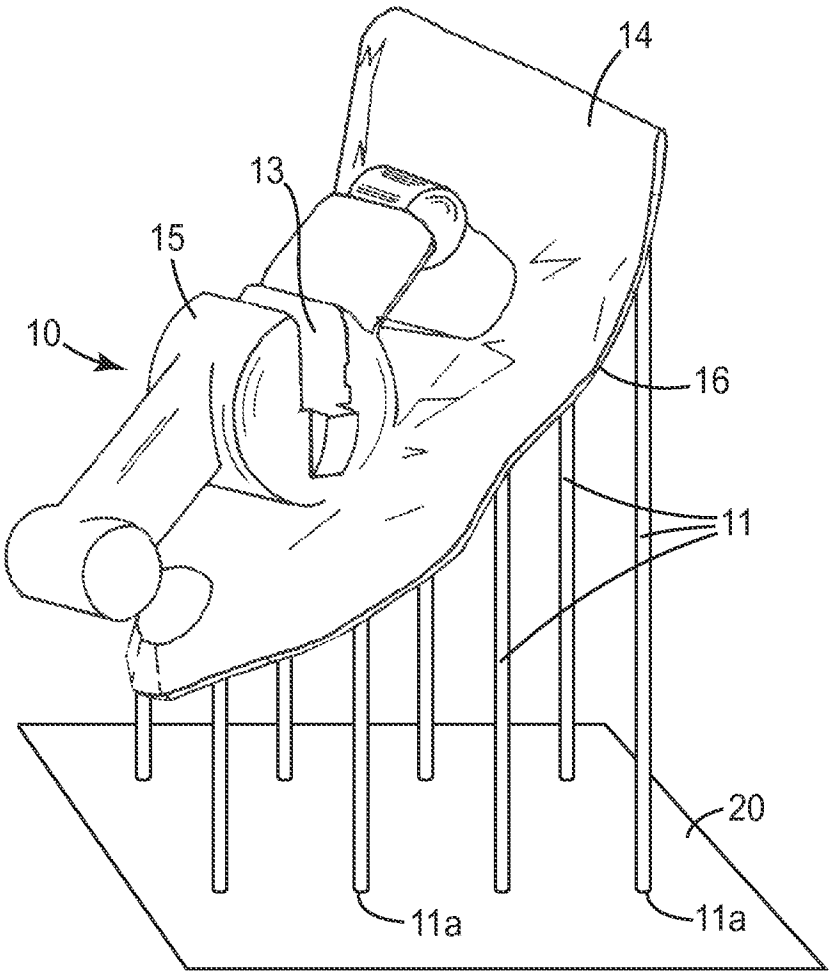

FIG. 2

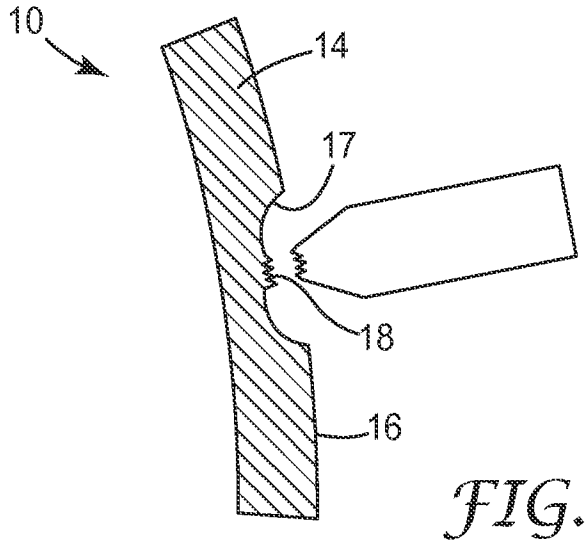

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/068496

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61C7/14
ADD.

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)
A61C

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 2011 003894 A1 (VU HOANG VIET-HA JULIUS [DE]; WIECHMANN DIRK [DE]) 9 August 2012 (2012-08-09)	1,2,4-7, 12
A	paragraphs [0001], [0005], [0009], [0013], [0047], [0048], [0050], [0056] figures 6, 6a	3,8-11, 13,14

A	EP 1 728 485 A2 (SIRONA DENTAL SYSTEMS GMBH [DE]) 6 December 2006 (2006-12-06) abstract figures 1-8	1-14

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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	Date of mailing of the international search report
16 March 2015	13/05/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Kerner, Bodo

1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/068496

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-14

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-14

   Method of making a plurality of customized orthodontic brackets

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2. claim: 15

   A single customized orthodontic bracket

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2014/068496

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