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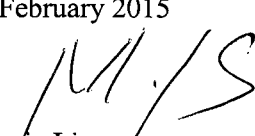
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Detecting tooth shade

Field of the invention

5 This invention generally relates to methods and a user interfaces for determining the shade of a patient's tooth or teeth and for utilizing the determined tooth shades for designing and manufacturing dental restorations.

10 **Summary**

Disclosed is a method for determining shade of a patient's tooth, wherein the method comprises:

- 15 - recording a series of sub-scans of the patient's set of teeth, where a plurality of said sub-scans comprises both texture information and geometry information for said tooth;
- generating a digital 3D representation of the tooth from said sub-scans, wherein the digital 3D representation comprises shape data expressing the shape of the tooth and texture data expressing a texture profile of the tooth; and
- 20 - determining a tooth shade value for a point on the tooth by comparing the texture data of the corresponding point of the digital 3D representation with a known texture value of one or more known tooth shade values.

25

Disclosed is a user interface for determining and displaying shade of a patient's tooth, wherein the user interface is configured for:

- obtaining a digital 3D representation of the tooth, said digital 3D representation comprising shape data expressing the shape of the tooth and texture data expressing a texture profile of the tooth;
- displaying at least the shape data of the digital 3D representation such that the shape of the tooth is visualized in the user interface;
- determining a tooth shade value for a point on the tooth by comparing the texture data of the corresponding point of the digital 3D representation with a known texture value of one or more known tooth shade values; and
- displaying the determined tooth shade value.

The digital 3D representation of the tooth is generated at least partly from the geometry information of the sub-scans. In some embodiments, the texture information of the sub-scans is also taken into account when generating the digital 3D representation of the tooth.

Sub-scans comprising texture information and geometry information may be recorded for more than said tooth, such that the generated digital 3D representation may comprise shade data expressing the shape and texture data expressing the texture profile of several of the patient's teeth.

In some embodiments the method comprises determining tooth shade values for a number of points on the tooth, and where a tooth shade distribution for the tooth is created from the tooth shade values determined in these points.

In some embodiments the user interface is configured for determining tooth shade values for a number of points on the tooth, and for creating a tooth shade distribution for the tooth from the tooth shade values determined in these points.

In some embodiments, the tooth shade distribution comprises a number of tooth shade regions on the tooth surface where an average tooth shade color is derived for each region from tooth shade values determined for a number
5 of points in the region.

In some embodiments, the tooth shade distribution comprises a tooth shade profile derived at least in part by interpolating tooth shade values determined for the number of points on the tooth.

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In some embodiments, tooth shade value are determined for a plurality of points the teeth, i.e. on parts of the digital 3D representation corresponding to two or more teeth, and where a tooth shade distribution for each of these teeth is created from the determined tooth shade values.

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The point on the tooth for which the tooth shade value is determined can be selected by an operator. This can be the case e.g. when the digital 3D representation of the tooth is visualized in a user interface and the operator uses a pointing tool, such as a computer mouse, to indicate where on the
20 digital 3D representation of the tooth, he wishes to determine the tooth shade value.

The point on the tooth for which the tooth shade value is determined can be selected by a computer implemented algorithm based on predetermined
25 positions on the digital 3D representation of the tooth, such as a point arranged at a certain distance to the incisal edge of the tooth.

When tooth shade values are determined for a number of points on the tooth, the points may be arranged in a grid over the part of the digital 3D
30 representation of the tooth.

In some embodiments, the texture data are at least partly derived by combining the texture information from corresponding parts in a number of overlapping sub-scans, i.e. the parts of the sub-scans which relate to the same region of the tooth.

5

In some embodiments, combining the texture information from the sub-scans comprises interpolating the texture information of the parts of the sub-scans corresponding to the point on the tooth.

In some cases this has the advantage that the derived texture data for a point
10 on the teeth are more precise.

In some embodiments, combining the texture information from the sub-scans comprises calculating an average value of the texture information of the parts of the sub-scans corresponding to the point on the tooth.

15

In some embodiments, the calculated average value is a weighted average of the texture information of the parts of the sub-scans corresponding to the point on the tooth.

In some cases this has the advantage that the derived texture data are not as
20 sensitive to errors in the textured information of a single sub-scan.

In some embodiments, the method comprises detecting saturated pixels in the recorded sub-scans and assigning a low weight to the texture information of the saturated pixels when combining the texture information from the sub-
25 scans.

In some embodiments, the method comprises deriving a certainty score describing an estimate of the certainty of the determined tooth shade value for at least one point on the tooth.

30

In some embodiments, the method comprises generating a visual representation of the certainty score and displaying this visual representation in a user interface optionally together with the digital 3D representation of the patient's set of teeth.

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In some embodiments, the method comprises comparing the derived certainty score with a threshold value and/or a range of acceptable certainty score values.

- 10 In some embodiments, the method comprises deciding based on the certainty score whether the determined tooth shade value or tooth shade distribution is acceptable. This may be based on the comparison of the derived certainty score and the threshold value and/or the range of acceptable certainty score values, e.g. where it is decided that the
- 15 determined tooth shade value is acceptable if the certainty score is above said threshold value.

- In some embodiments, the visual representation of the certainty score comprises a binary code, such as red for certainty scores outside a range of
- 20 acceptable certainty score values, and green for certainty scores within the range.

- In some embodiments, the visual representation of the certainty score comprises a certainty score indicator.
- 25 The certainty score indicator may comprise a bar structure with a color gradient going from a first color representing a low certainty score to a second color representing a high certainty score. The first color may be red and the second color green. The color gradient of the bar structure may be configured to have an intermediate color, e.g. yellow representing the
- 30 threshold value for the certainty score. The certainty score indicator may

comprise marker which is arranged relative to the color gradient of the bar structure such that it indicated the certainty score.

5 In some embodiments, the visual representation of the certainty score comprises a numerical value, such as a numerical value in an interval extending from a lower limit indicating a low certainty, i.e. a relatively uncertain tooth shade value, to a higher limit indicating a high certainty, i.e. a relatively certain tooth shade value.

10 In some embodiments, the method comprises determining an alternative tooth shade value for the point when said certainty score is outside said range of acceptable certainty score values and/or below said threshold value.

15 In some embodiments, the method displaying the alternative tooth shade value in the user interface optionally together with the digital 3D representation of the patient's set of teeth and/or the initially determined tooth shade value

20 In some embodiments, the texture information comprises at least one of tooth color or surface roughness.

25 When the texture information comprises tooth color information, the texture data expressing a texture profile of the tooth may be color data expressing a color profile of the tooth, and the tooth shade value for a point on the tooth may be derived by comparing the color data of the corresponding point of the digital 3D representation with a known color value of one or more known tooth shade values.

30 In some embodiments, the user interface is configured for deriving a certainty score describing an estimate of the certainty of the determined tooth shade value for said point.

In some embodiments, the user interface comprises a virtual tool which when activated on a point of the digital 3D representation of the tooth provides that

- the tooth shade value and/or
- 5 - a visual representation of a certainty score for the tooth shade value derived for this point and/or
- a visual representation of a comparison of the derived certainty score with a threshold value and/or a range of acceptable certainty score values
- 10 is visualized in the user interface. The user interface then provides an operator with an opportunity to decide based on the visualized certainty score and/or the virtual representations whether the determined tooth shade value or tooth shade distribution is acceptable. The visual representation of a comparison of the derived certainty score with a threshold value may be
- 15 configured to provide visualization of whether the certainty score is below or above said threshold value.

In some embodiments, the visual representation of the comparison of the derived certainty score with the threshold value and/or the range of acceptable certainty score values comprises a binary code, such as red for certainty scores outside a range of acceptable certainty score values, and

20 green for certainty scores within the range.

The visualized certainty score and/or the virtual representations of the certainty score or comparison of the certainty score with the threshold value and/or the range of acceptable certainty score values may be displayed at

25 the digital 3D representation in the user interface or in shade value region of the user interface.

In some embodiments, the user interface is configured for determining an alternative shade value for the point and for displaying the alternative shade value when the certainty score is below the threshold value or when the certainty scores outside a range of acceptable certainty score values.

5

Disclosed is a method for designing a dental restoration for a patient, wherein the method comprises:

- 10 - obtaining a digital 3D representation of at least one tooth, said digital 3D representation comprising shape data expressing the shape of the tooth and texture data expressing a texture profile of the tooth;
- determining a tooth shade value for a point on the tooth by comparing the texture data of the corresponding point of the digital 3D representation with a known texture value of one or more known tooth
15 shade values; and
- designing a virtual dental restoration for one or more of the patient's teeth; and
- selecting a restoration shade of the virtual dental restoration based on said tooth shade value.

20

In some embodiments, the method comprises suggesting a dental material for manufacturing the dental restoration from the virtual dental restoration based on the determined restoration shade.

- 25 In some cases the dental restoration is designed and manufactured for a tooth which either is damaged or has an undesired shade profile, such as for a broken or dead tooth. In such cases it can be advantageous to determine the tooth shade value or tooth shade distribution for one or more of the neighboring teeth and selecting the restoration shade of the virtual dental

restoration from e.g. an interpolation of the tooth shades of the neighboring teeth.

5 In cases where the dental restoration is designed and manufactured for an existing tooth which has an acceptable shade, the tooth shade value or tooth shade distribution can be determined for the existing tooth such that the restoration shade of the virtual dental restoration is based on the tooth shade value or tooth shade profile of the existing tooth.

10 This may e.g. be advantageous for the crown portions of a bridge restoration in the case where the tooth which is intended to accept the crown portion is a healthy tooth.

15 In some embodiments, the sub-scans comprise at least texture information and for the patient's soft tissue, and optionally also geometry information for said soft tissue. The generated digital 3D representation may then comprise shape data expressing the shape of the soft tissue and texture data expressing a texture profile of the soft tissue.

20 From this information, an aesthetical pleasing denture can be designed where the color of the soft tissue part of the denture is selected based on the texture profile of the corresponding part of the digital 3D representation.

25 Knowledge of the texture of the soft tissue, such as of the color of the soft tissue, can be used for diagnostics.

In some embodiments, the sub-scans are recorded using an intra-oral scanner, such as the 3Shape TRIOS intra-oral scanner.

30 The intra-oral scanner may be configured for utilizing focus scanning, where the sub-scans of the scanned teeth are reconstructed from in-focus images acquired at different focus depths. The focus scanning technique can be performed by generating a probe light and transmitting this probe light

towards the set of teeth such that at least a part of the set of teeth is illuminated. Light returning from the set of teeth is transmitted towards a camera and imaged onto an image sensor in the camera by means of an optical system, where the image sensor/camera comprises an array of sensor elements. The position of the focus plane on/relative to the set of teeth is varied by means of focusing optics while images are obtained from/by means of said array of sensor elements. Based on the images, the in-focus position(s) of each of a plurality of the sensor elements or each of a plurality of groups of the sensor elements may be determined for a sequence of focus plane positions.

The in-focus position can e.g. be calculated by determining the light oscillation amplitude for each of a plurality of the sensor elements or each of a plurality of groups of the sensor elements for a range of focus planes. From the in-focus positions, sub-scans of the set of teeth can be derived with geometry information relating to the shape of the scanned surface.

A digital 3D representation of the set of teeth can then be generated from the recorded sub-scans by e.g. the use of an Iterative Closest Point (ICP) algorithm. Iterative Closest Point (ICP) is an algorithm employed to minimize the difference between two clouds of points. ICP can be used to reconstruct 2D or 3D surfaces from different scans or sub-scans. The algorithm is conceptually simple and is commonly used in real-time. It iteratively revises the transformation, i.e. translation and rotation, needed to minimize the distance between the points of two raw scans or sub-scans. The inputs are: points from two raw scans or sub-scans, initial estimation of the transformation, criteria for stopping the iteration. The output is: refined transformation. Essentially the algorithm steps are:

1. Associate points by the nearest neighbor criteria.
2. Estimate transformation parameters using a mean square cost function.
3. Transform the points using the estimated parameters.
4. Iterate, i.e. re-associate the points and so on.

The present invention relates to different aspects including the method and user interface described above and in the following, and corresponding methods and user interface, each yielding one or more of the described advantage, and each having one or more embodiments corresponding to the
 5 embodiments described above and/or disclosed in the appended claims.

Disclosed is a method for designing a dental restoration for a first tooth, wherein the method comprises:

- 10 - obtaining a digital 3D representation of the patient's set of teeth, said digital 3D representation comprising shape data and texture data expressing the shape and texture profile, respectively, of at least one second tooth;
- designing a virtual dental restoration for the first tooth;
- 15 - derive a desired texture profile of the virtual dental restoration from the texture data of the at least one second tooth; and
- determining a restoration shade value or restoration shade distribution of the virtual dental restoration by comparing the desired texture profile with texture values for one or more known tooth shade values.

20

In some embodiments, the desired texture profile is derived by interpolation or averaging of the texture data of the digital 3D representation of the neighbor teeth.

- 25 Furthermore, the invention relates to a computer program product comprising program code means for causing a data processing system to perform the method according to any of the embodiments, when said program code means are executed on the data processing system, and a computer

program product, comprising a computer-readable medium having stored there on the program code means.

5 **Brief description of the drawings**

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

Figure 1 shows an example of a flow chart for an embodiment.

15 Figures 2 to 4 show parts of screen shots of user interfaces.

Figure 5 shows steps of a method for designing a dental restoration.

20 Figure 6 shows a schematic of a system for determining tooth shade values

Detailed description

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

25 Figure 1 shows an example of a flow chart 100 for an embodiment of the method for determining shade of a patient's tooth.

In step 102 a series of sub-scans of the patient's set of teeth is recorded, where a plurality of said sub-scans comprises both texture information and
30 geometry information for a tooth of the patient's set of teeth.

In step 103 a digital 3D representation of the tooth is generated from said sub-scans, where the digital 3D representation comprises texture data expressing a texture profile of the tooth. The digital 3D representation further comprises shape data expressing the shape of the tooth such that the shape of the tooth can be visualized by displaying when the shape data in a user interface.

In step 103 a tooth shade value for a point on the tooth is determined based on the texture data. This is done at least in part by comparing the texture data of the corresponding point of the digital 3D representation with a known texture value of one or more known tooth shade values. The known tooth shade values may be provided in the form of a library file and comprise tooth shade values and corresponding texture value ranges based on e.g. the VITA 3D-Master and/or the VITA Classic tooth shade systems.

Figures 2 to 4 show parts of screen shots of user interfaces in which derived tooth shade values and visual representation of the corresponding certainty scores for a number of regions are displayed together with the digital 3D representations of the patient's set of teeth.

The screen shot 210 seen in Fig. 2 shows determined tooth shade values for three regions 212, 213, 214 on the digital 3D representation of the patient's set of teeth. Two of these 212, 213, are selected at the part of the digital 3D representation corresponding to the tooth 211 while the third 214 is selected on the soft tissue part 215 of the digital 3D representation. Average tooth shade value for a region is calculated by averaging over tooth shade values derived for a number of points within the region or by calculating an average texture value for the region and determining the average tooth shade value therefrom. The average tooth shade values are displayed in tooth value sections 217, 218, 219 linked to the regions in the user interface. In the tooth

value sections 217, 218 relating to the regions 212, 213 two tooth shade values are displayed where the upper shade value is derived using known texture values corresponding to the tooth shade values of the VITA 3D-Master tooth shade system and the lower is relates to the VITA Classic tooth shade system. It is also seen that for the region 213 closest to the gingiva, the tooth shade is determined to be 2L1.5 in the VITA 3D-Master system and B1 in the VITA Classic system. In Fig. 2 the certainty scores for the derived tooth shade values are visualized as a certainty score indicator displayed next to the tooth shade values. In Fig. 2 the visualization of the certainty score indicator is in the form of a checkmark which indicates that the certainty score is sufficiently high to provide that the derived tooth shade values can be relied upon. The color of the checkmark may further provide further information to the certainty score, such as in cases where a green checkmark indicates a more certain tooth shade value than a yellow checkmark. The third region 214 is located at the patient's soft tissue. An anatomical correct tooth shade value can hence not be calculated from the texture data of that part of the digital 3D representation of the patient's teeth and the corresponding certainty scope is accordingly very low. The visualization of the certainty score in the tooth value section 219 is hence a cross indicating that the derived shade value was rejected. Further no shade value is indicated in the tooth value section 219.

The screen shot 310 seen in Fig. 3 shows determined tooth shade values for two regions 312, 314 on the digital 3D representation of the patient's set of teeth. One of these regions 312 is selected at the part of the digital 3D representation corresponding to the tooth 311 while the second region 314 is selected on the soft tissue part 315 of the digital 3D representation. Average tooth shade value for a region is calculated by averaging over tooth shade values derived for a number of points within the region or by calculating an average texture value for the region and determining the average tooth

shade value therefrom. Shade value sections 317, 319 are also displayed for the regions 312, 314. Two tooth shade values 321 are derived for the region 312 and displayed in the corresponding tooth value section 317, where the upper value is derived using known texture values corresponding to the tooth shade values of the VITA 3D-Master tooth shade system (derived tooth shade value is 1.5M1) and the lower value using the VITA Classic tooth shade system (derived tooth shade value is B1). In Fig. 3 the certainty score is visualized in the form of a certainty score indicator 322 comprising a vertical bar with a color gradient going from red representing a low certainty score to green representing a high certainty score. The certainty score indicator has a marker indicating the certainty score on the bar. It is seen that the tooth shade value 1.5M1 of the VITA 3D-Master system is more certain than the tooth shade value B1 of the VITA Classic system for this region. The second region 314 is located at the patient's soft tissue. An anatomical correct tooth shade value can hence not be calculated from the texture data of that part of the digital 3D representation of the patient's teeth and the corresponding certainty scope is accordingly very low as seen in the vertical bars of tooth value section 319.

20

Fig. 4 shows a screen shot 410 where determined tooth shade values are derived for a total of 15 regions 412, 413 on the digital 3D representation of the tooth 411. The tooth shade values are derived all derived using known texture values corresponding to the tooth shade values of the VITA 3D-Master tooth shade system and the certainty scores are visualized in the form of a certainty score indicator comprising a vertical bar with a color gradient going from red representing a low certainty score to green representing a high certainty score. As can be seen in the tooth value sections 417, 418 of the user interface there are large variations in the certainty scores. For example, the certainty score for the region 412 is almost

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at maximum while the certainty score of the region 413 is much close to a threshold for acceptable certainty score values.

- 5 Fig. 5 shows steps of a method for designing a dental restoration.
In step 531 a virtual dental restoration is designed e.g. based on the shape data of a digital 3D representation of the patient's set of teeth and/or on template virtual restoration loaded from a library. Template virtual restorations may e.g. be used when the tooth is broken.
- 10 In step 532 the tooth shade values of different points or regions of the teeth are derived from the texture data of the digital 3D representation of the patient's set of teeth. From the derived tooth shades or from tooth shade profiled created based on the derived tooth shades a desired shade profile for the dental restoration can be determined. This can be based on e.g.
- 15 feature extraction where shade values are extracted from the other teeth by e.g. Identifying shade zones on these teeth and copying these zones to the dental restoration. It can also be based on established shade rules for teeth, e.g. a rule describing a relation between the tooth shades values or profiles of the canines and the anterior teeth.
- 20 In step 533 the desired tooth shade value(s) for the dental restoration is merged into the virtual dental restoration.
When the dental restoration is to be drilled from a multicolored milling block it is important that the dental restoration is milled from the correct parts of the milling block. In step 534 a CAD model of the milling block is provided, where
- 25 the CAD model comprises information of the shade profile of the milling block material. The optimal position of the virtual restoration model relative to the CAD model of the milling block is then determined in 535, where different criteria can be apply to provide the best fit between the desired shade profile and what actually can be obtained as dictated by the shade profile of the
- 30 milling block.

In step 536 the dental restoration is manufactured from the milling block by removing milling block material until the dental restoration is shaped according to the virtual dental restoration.

5

Fig. 6 shows a schematic of a system for determining tooth shade values. The system 640 comprises a computer device 642 comprising a computer readable medium 643 and a processor 644. The system further comprises a visual display unit 647, a computer keyboard 645 and a computer mouse 646
10 for entering data and activating virtual buttons in a user interface visualized on the visual display unit 647. The visual display unit can be a computer screen. The computer device 642 is capable of receiving a digital 3D representation of the patient's set of teeth from a scanning device 641, such as the TRIOS intra-oral scanner manufactured by 3shape A/S, or capable of
15 receiving scan data from such a scanning device and forming a digital 3D representation of the patient's set of teeth based on such scan data. The received or formed digital 3D representation can be stored in the computer readable medium 643 and provided to the processor 644. The processor is configured for implementing the method according to any of the
20 embodiments. This may involve presenting one or more options to the operator, such as where to derive the tooth shade value and whether to accept a derived tooth shade value. The options can be presented in the user interface visualized on the visual display unit 647.

25 The system may further comprise a unit 648 for transmitting a virtual restoration and a CAD model of a milling block to e.g. a computer aided manufacturing (CAM) device 649 for manufacturing a shaded dental restoration or to another computer system e.g. located at a milling center where the dental restoration is manufactured. The unit for transmitting the
30 virtual 3D model can be a wired or a wireless connection.

The scanning of the patient's set of teeth using the scanning device 641 can be performed at a dentist while deriving the tooth shade values can be performed at a dental laboratory. In such cases the digital 3D representation of the patient's set of teeth can be provided via an internet connection
5 between the dentist and the dental laboratory.

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

15 In device claims enumerating several means, several of these means can be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims or described in different embodiments does not indicate that a combination of these measures cannot be used to advantage.

20 A claim may refer to any of the preceding claims, and "any" is understood to mean "any one or more" of the preceding claims.

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

The features of the method described above and in the following may be
30 implemented in software and carried out on a data processing system or other processing means caused by the execution of computer-executable

instructions. The instructions may be program code means loaded in a memory, such as a RAM, from a storage medium or from another computer via a computer network. Alternatively, the described features may be implemented by hardwired circuitry instead of software or in combination with

5 software.

Claims:

1. A method for determining shade of a patient's tooth, wherein the method comprises:
 - 5 - recording a series of sub-scans of the patient's set of teeth, where a plurality of said sub-scans comprises both texture information and geometry information for said tooth;
 - generating a digital 3D representation of the tooth from said sub-scans, wherein the digital 3D representation comprises shape data
10 expressing the shape of the tooth and texture data expressing a texture profile of the tooth; and
 - determining a tooth shade value for a point on the tooth by comparing the texture data of the corresponding point of the digital 3D
15 representation with a known texture value of one or more known tooth shade values.
2. The method according to the preceding claim, wherein the method comprises determining tooth shade values for a number of points on the
20 tooth, and where a tooth shade distribution for the tooth is created from the tooth shade values determined in these points.
3. The method according to claim 1 or 2, wherein the texture data are at least partly derived by combining the texture information from
25 corresponding parts in a number of overlapping sub-scans.
4. The method according to the preceding claim, wherein combining the texture information from the sub-scans comprises interpolating the
30 texture information and/or calculating an average value of the texture information of the parts of the sub-scans corresponding to the point on the tooth.

5. The method according to the preceding claim, wherein the calculated average value is a weighted average of the texture information of the parts of the sub-scans corresponding to the point on the tooth.
- 5
6. The method according to any of the preceding claims wherein the method comprises deriving a certainty score describing an estimate of the certainty of the determined tooth shade value for at least one point on the tooth.
- 10
7. The method according to the preceding claim, wherein the method comprises generating a visual representation of the certainty score and displaying this visual representation in a user interface optionally together with the digital 3D representation of the patient's set of teeth.
- 15
8. The method according to the preceding claim, wherein the method comprises comparing the derived certainty score with a threshold value and/or a range of acceptable certainty score values.
- 20
9. The method according to any of claims 7 or 8, wherein the method comprises determining an alternative tooth shade value for the point when said certainty score is outside said range of acceptable certainty score values and/or below said threshold value, and displaying the alternative tooth shade value in the user interface optionally together with
- 25
- the digital 3D representation of the patient's set of teeth and/or the initially determined tooth shade value
10. The method according to any of the previous claims, wherein the texture information comprises at least one of tooth color or surface roughness.
- 30

Abstract

Disclosed is method for determining shade of a patient's tooth, wherein the method comprises:

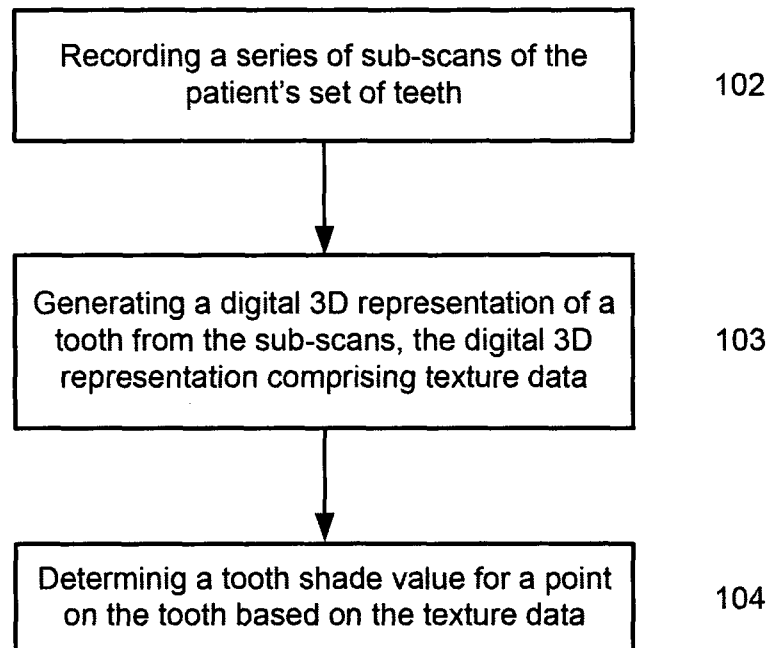
- 5 - recording a series of sub-scans of the patient's set of teeth, where a plurality of said sub-scans comprises both texture information and geometry information for said tooth;
- generating a digital 3D representation of the tooth from said sub-scans, wherein the digital 3D representation comprises shape data
- 10 expressing the shape of the tooth and texture data expressing a texture profile of the tooth; and

determining a tooth shade value for a point on the tooth by comparing the texture data of the corresponding point of the digital 3D representation with a known texture value of one or more known tooth shade values.

15

(fig. 3 should be published)

100

*Fig. 1*

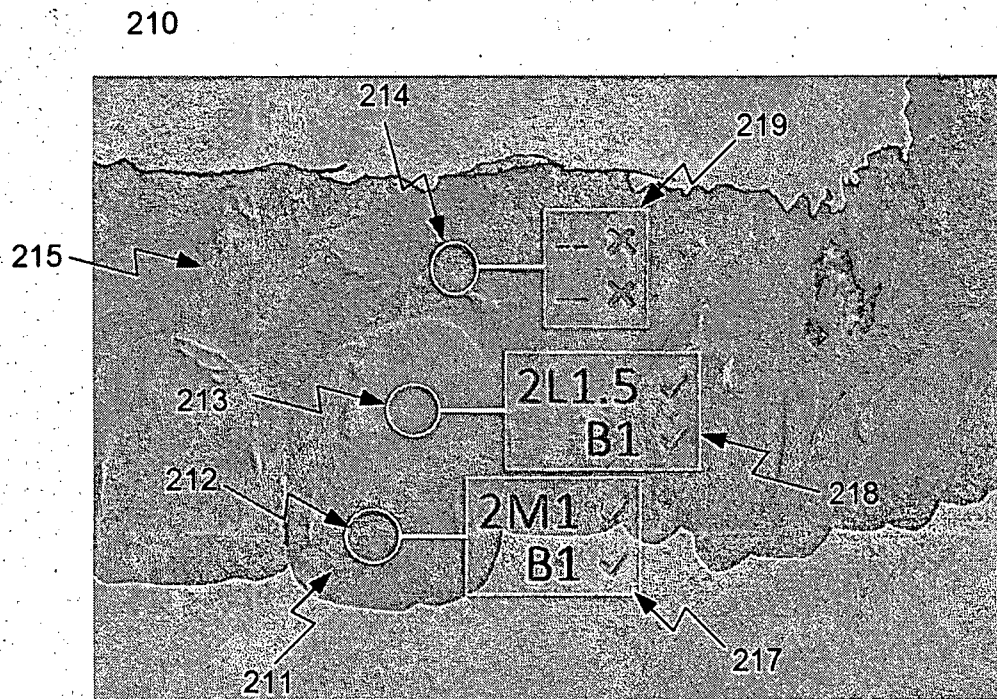


Fig. 2

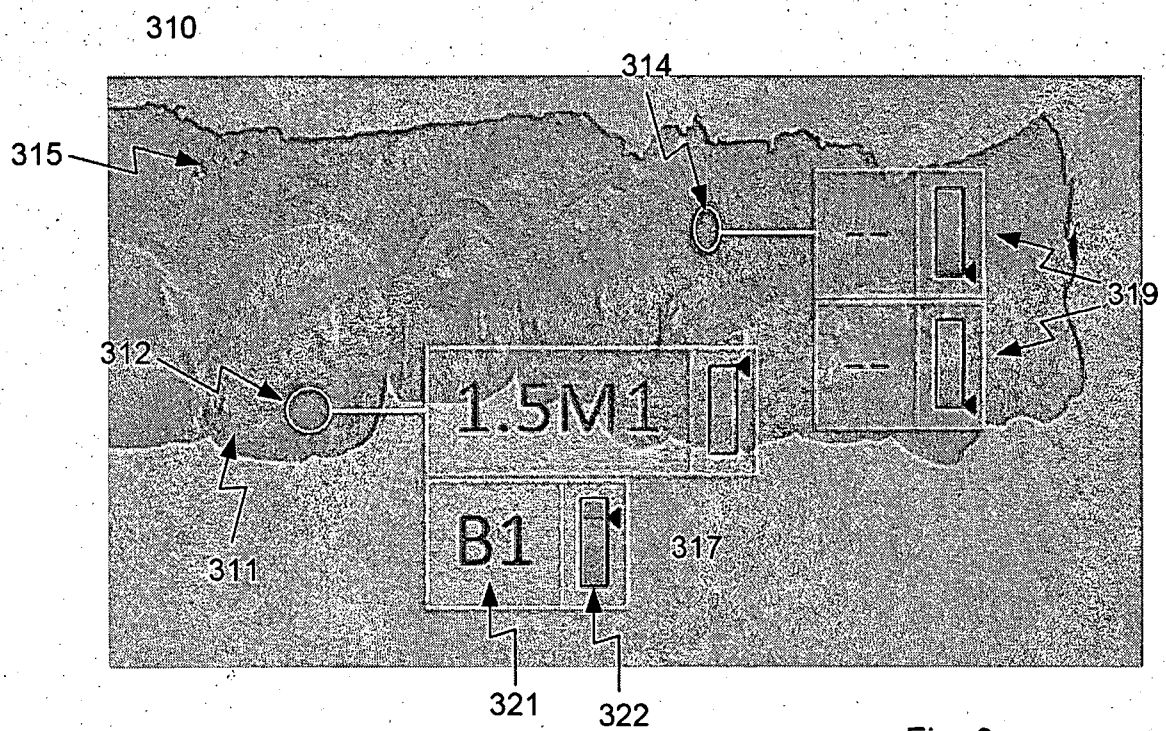


Fig. 3

410

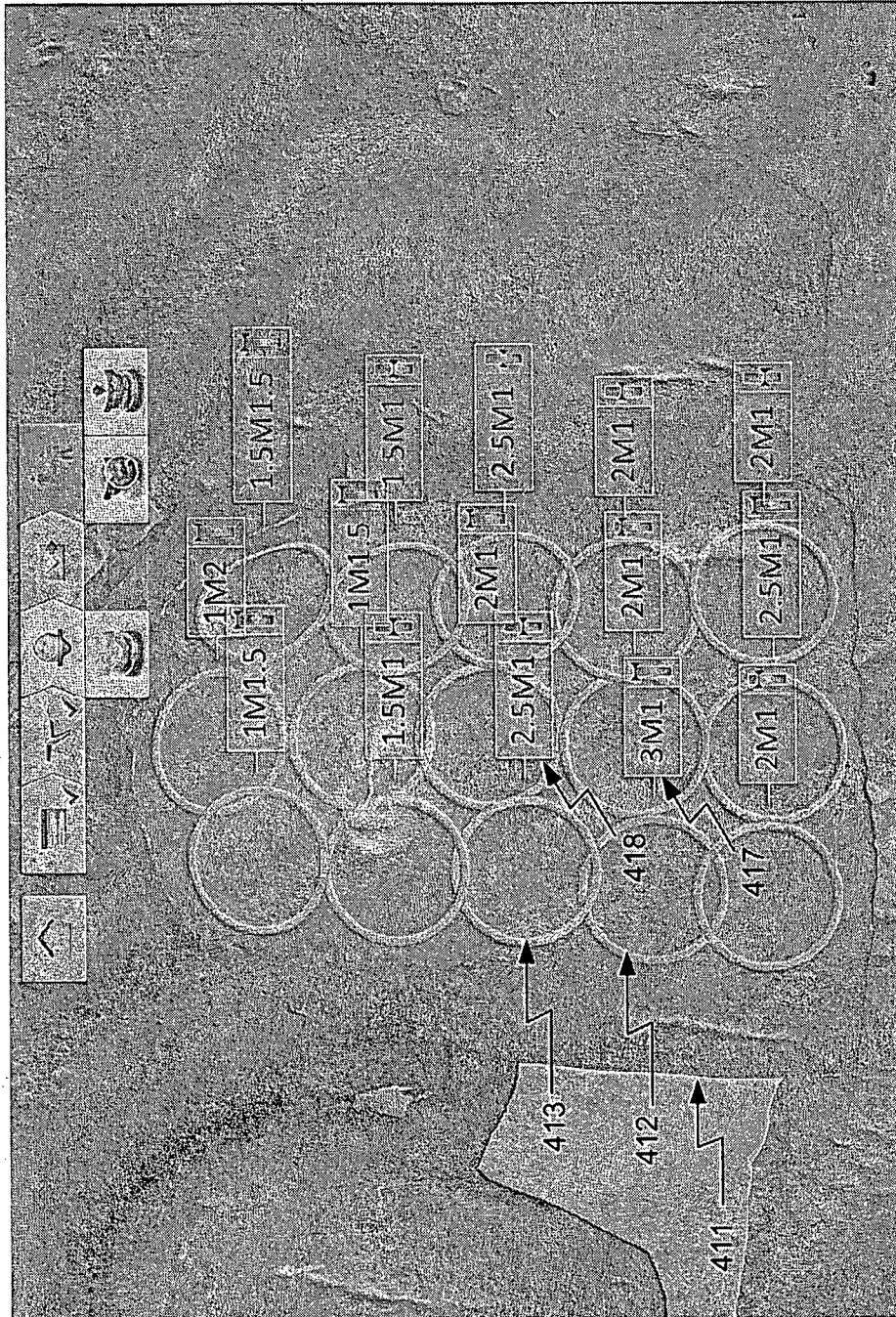


Fig. 4

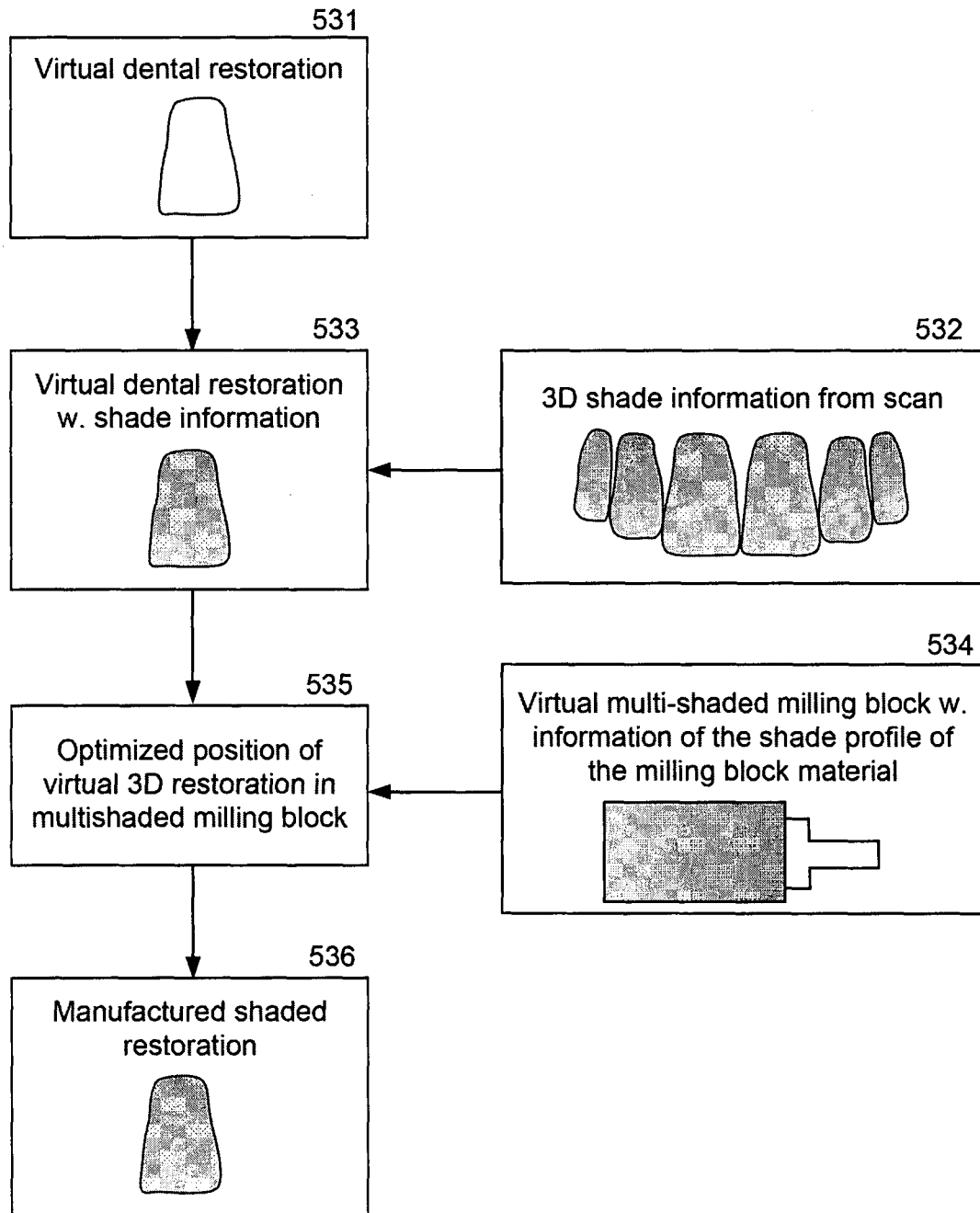


Fig. 6

