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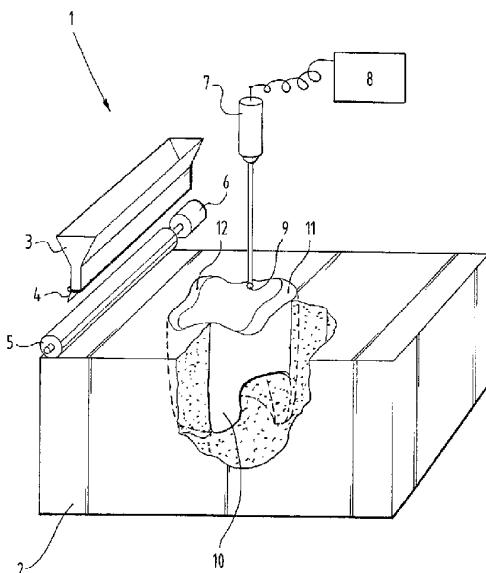
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(54) Title: METHOD FOR MANUFACTURING A DENTAL RESTORATION



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(57) Abstract: The invention relates to a method for manufacturing a dental restoration, comprising of: determining an external form and dimensions available for a completed restoration, for instance with a CAD-CAM system; obtaining an image of a natural tooth to be replaced with the restoration or a tooth corresponding therewith, wherein the image comprises at least the external surface visible in use of the to be replaced or corresponding tooth, with variations in the appearance therein; defining locally on and at least to visible depth below the surface of appearance-determining properties of at least one material to be applied for the restoration in accordance with the obtained image and the variations in the appearance therein; constructing the restoration, comprising of: providing at least one material to be applied in non-cohesive form; and providing cohesion to the material in accordance with the available form and dimensions.



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METHOD FOR MANUFACTURING A DENTAL RESTORATION

The present invention relates to a method for manufacturing a dental restoration.

Any discussion of the prior art throughout the specification should in no way be considered as an admission that such prior art is widely known or forms part of common 5 general knowledge in the field.

Different methods are known in the art for manufacturing a dental restoration, wherein these methods are mainly determined by the type of materials used.

10 Ceramic materials have been successfully applied for many years in dental restorations. The two most important functions of restorative ceramics are aesthetics and strength. However, most dental ceramics do not fulfil both functions. Different porcelains and glass ceramics are used for aesthetic applications. These have a natural tooth colour and translucence but have a relatively low three-point bending strength 15 (50-200MPa).

Higher-strength materials have been developed as basic core material. These materials have a three-point bending strength of 150 to 500 MPa, but are generally too 20 opaque and must be combined with translucent porcelain veneered thereon. The fracture toughness however remains low compared to metal alloys, whereby these ceramics are susceptible to production errors and stress concentrations, such as occur when there is a less than optimal fit between prepared tooth and the restorative ceramic.

25 Medically pure yttrium-stabilized tetragonal zirconium oxide (Y-TZP) is characterized by both aesthetics and a high three-point bending strength, higher than 1000 MPa, with a great toughness and an excellent resistance to slow crack development.

Zirconium oxide has heretofore been applied very

successfully in orthopaedics as hip-joint ball. It has also been very successfully introduced in dentistry for root pins. It has further been found to have a very low susceptibility to dental plaque. However, zirconium 5 oxide has a white colour not suitable for dental restorations and must be coloured with a colour corresponding with the tooth colours.

In DE 4207179 A1 (1992) Yoshida describes a method of colouring orthodontic zirconium oxide components by 10 adding a mixture of erbium-, praseodymium-, iron- and zinc oxides. Some additives, such as zinc, result in serious degradation of the physical properties of the sintered zirconium oxide. In DE 19938143 A1 erbium-, iron- and manganese oxide are mainly applied as 15 colouring oxides.

Effect of suitable colour additives to sintered Y-TZP zirconium oxide

20	Colour additive	Form	Effective colour	Note
Iron	Fe_2O_3	Brown		Concentration lower than 1% by weight
Erbium	Er_2O_3	Light violet		Forms solid solution with ZrO_2
Praseodymium	Pr_2O_3	Deep yellow		Forms solid solution with ZrO_2

25 These are first dissolved in hydrochloric acid and added to zirconium oxide and admixtures dissolved in hydrochloric acid. By hydrolysis with ammonia, annealing of the deposition and fine-grinding, an homogeneously coloured zirconium oxide powder is obtained which can be 30 further processed. This takes place by mixing the powder with binders (for instance 2% by weight polyvinyl alcohol and 0.15% by weight oleic acid), and making this

into a geometrical shape by pressing. The binder is burnt out for 0.5 to 2 hours at a temperature of 850-1000 °C. A dental restoration, enlarged by the sintering shrinkage factor, is then cut out by means of a CAD/CAM system and the product is sintered to increase density at 1300-1500 °C for 2-4 hours. The result is a monochrome coloured

5 restoration.

It is however desired in dentistry to colour the restoration locally. The base structure of a crown, in the form of a cap, is thus coloured slightly browner at the bottom, the so-called shoulder portion, and lighter yellow in the sections in the cutting

10 edge area.

At the moment the restorations are further produced in automatic manner with fairly traditional cutting technique, with proportionately high material loss. With the use of zirconium oxide the price of the material is considerable and a net-shape production

15 method would be desirable. Accurate colouring with locally occurring variations is complex here, if not impossible.

Up to the present there has been no possibility of making restorations using rapid prototyping or even in automated manner which have locally different properties or

20 colours. In addition to the absence of an experimental configuration, there has also been no possibility of locally colouring product files.

According to the first aspect of the invention, there is provided a method for manufacturing a dental restoration, comprising of:

25 - determining an external form and dimensions available for a completed restoration;

- obtaining an image of a natural tooth to be replaced with the restoration or a tooth corresponding therewith, wherein the image comprises at least the external surface visible in use of the tooth to be replaced or corresponding tooth, with variations in the

30 appearance therein;

- defining locally on and at least to visible depth below the surface of appearance-determining properties of at least one material to be applied for the restoration in accordance with the obtained image and the variations in the appearance therein;

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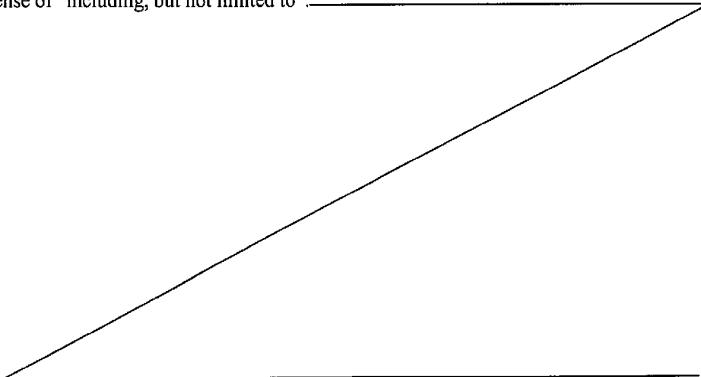
- constructing the restoration, comprising of: repeatedly providing layers of at least one material to be applied in non-cohesive form; and for each layer providing cohesion to the layer of at least one material with previous layers in accordance with the available form and dimensions, wherein the step of providing at least one material to be applied comprises: varying the at least one material to be applied in accordance with variations in the image in a plane defined by each of the layers around the periphery of the surface of a cross section of a dental restoration to be formed.

With a method according to the invention it is possible to manufacture a restoration with a very natural appearance, in respect of both colour, translucence and so on and the shape thereof.

According to a second aspect of the invention, there is provided a dental restoration obtained by the first aspect of the invention.

15 Preferably, the step of determining an external form and dimensions available for a completed restoration is with a CAD-CAM system.

Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise", "comprising", and the like are to be construed in an 20 inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to".



A possible embodiment of a method according to the invention can be designated as 3D printing. Experimental configurations have recently been constructed, particularly at the Massachusetts Institute of

5 Technology (MIT, Boston, USA), with which it is possible using software to determine the colours of the STL files (input files for rapid prototyping machines). Owing to the development of new materials and machines, the possibilities in the field of 3D printing have recently

10 been greatly expanded, although there is still no application known for using this technology for dental restorations. The printer is used to apply an organic binder to a powder compacted using a roller, whereby complex shapes can be produced.

15 The principle of 3D printing (3DP) is known. The method was developed by the institute of technology of Boston, MIT. Market developments of the principle have since taken place. Zcorporation for instance has however used starch, which has little environmental impact and

20 is freely available, as binder.

A drawback to the use of starch as binder is that it increases the shrinkage of the bound ceramic powder and that the shrinkage can moreover not be predicted in all directions. This makes starch less useful for the

25 accuracy desired in dentistry. This in contrast to cold isostatic pressed (more than 2000 bar) ceramic, which after cutting and sintering results in a sufficiently accurate restoration. A new material, ZP100, was developed as an alternative, with which thin-walled and

30 complex products such as dental restorations can indeed be printed in 3D with sufficient accuracy.

It is furthermore possible to "build in" a natural colour layer by layer by adding Pr-oxide (yellow), Fe-oxide (brown) and Er-oxide (violet) as pigment to the

35 binder. The quantities to be applied amount for each of

these colour additives to between for instance 0.05% and 2.0% of the weight.

In a preferred embodiment a method according to the invention comprises of providing layer by layer in non-cohesive form at least one material to be applied ; and

5 providing cohesion to the material in each of the layers in accordance with the available form and dimensions as well as providing adhesion to a preceding layer before providing a subsequent layer. By providing the material layer by layer, the depth to which this material must be processed to provide it with cohesion remains limited. The production process hereby remains readily manageable and leads to good results.

10

Particularly good results are achieved in respect of the appearance of the restoration to be produced (colour, translucence and so on), if the measures as provided in the preceding paragraph are herein also applied. Colour variations can thus be realized in a three-dimensional direction over the outer surface of the restoration to be

15 produced, while colour variations could only be realized in the direction in which the layers are successively provided on each other when layers to be provided separately have a homogenous composition. In the preferred embodiment, a variation resulting in colour variation can also be realized in the layers, so that even more natural variations can be obtained.

20

In yet another preferred embodiment the non-cohesive form of the material to be applied can be one of powder form, liquid, thin slices and so on. This is related to the method to be applied for providing cohesion therein. In a powder form the cohesion can for instance be given by selectively adding binder to the powder or by subjecting the

25 powder to the action of at least one laser. Particularly in the case of liquid forms of the material to be applied, an arrangement with two lasers can be used depending on the capacity of this liquid material to transmit laser light, where the intended effect of providing cohesion, for instance solidifying, only occurs where the laser beams coming from the lasers cross each other. In an embodiment with thin slices colour variations can

30 be realized per slice

around the periphery thereof, or the slices can be manufactured from homogenous material.

The material to be applied in the method is for instance ceramic material, porcelain, glass ceramic, and 5 so on, but preferably yttrium-stabilized tetragonal zirconium oxide, to which the invention is however not limited. This has properties which are very advantageous in respect of the invention.

In order to allow variation in the appearance over 10 the outer surface of the restoration to be manufactured, for instance in respect of the colour thereof, many materials can be used, such as erbium oxide, iron oxide and praseodymium oxide, manganese oxide and so on. Such materials can be combined well with the materials to be 15 applied in the restoration to be manufactured, particularly zirconium oxide.

The present invention will be elucidated on the basis of an embodiment hereinbelow and a description of the one annexed drawing, which shows schematically a 20 partly cut-away perspective view of an embodiment of the invention.

The figure shows a possible embodiment of an installation as implementation of the present invention. Installation 1 comprises a holder (not shown) in which 25 layers of powder-form yttrium-stabilized tetragonal zirconium oxide (Y-TZP) can be placed one over another. The zirconium oxide is in powder form so that a body 2 of this powder is formed as the stacking of said layers onto each other progresses.

30 The layers are arranged using a powder holder 3, which in this embodiment is funnel-shaped and adapted to pour a measured quantity. Powder holder 3 is provided for this purpose with a flap 4 with which the pouring opening of powder holder 3 can be closed.

If a quantity of powder-form zirconium oxide from powder holder 3 is poured, either at one location or spread over the upper surface of the body 2 formed so far, the upper surface is levelled using a driven roller 5 which is coupled to a motor 6. The powder-form zirconium oxide is not only levelled, but also compressed and compacted to the desired extent.

The installation further comprises a laser generator 7 connected to a control 8. The focal point 9 of the laser generator acts on the upper surface of body 2 to give the powder-form zirconium oxide cohesion in the upper layer, which has just been poured from powder holder 3 and levelled and compacted by roller 5. Under the influence of the action of the focal point of laser generator 7 there also occurs adhesion to the material lying beneath the last poured layer. Any random shape can thus be generated in a layered structure, precisely this being advantageous in the case of dental restorations because of the usually erratic shapes thereof.

The figure shows such a dental restoration 10. The method for manufacture hereof is being performed, so that the dental restoration 10 is only partly shown. A part of the body 2 of loose powder is further cut away in the view in order to show the dental restoration 10.

The focal point 9 of laser generator 7 follows a pattern in the material of the last spread layer such that, after processing a number of layers in this manner, a desired three-dimensional form of the dental restoration can be obtained.

In the areas 11 and 12 of the dental restoration 10 material is added to the powder-form zirconium oxide prior to the action of focal point 9. This may be for instance iron oxide, erbium oxide or praseodymium oxide. These materials have an effect on the colour, wherein

iron oxide produces a brown discolouration and erbium oxide a light violet discolouration, while praseodymium oxide has a deep yellow colouring effect.

It is shown clearly in the figure that, round the 5 periphery on the upper side of the dental restoration 10 formed so far in fig. 1, variations are arranged in the depth in internal direction of layers 11 and 12, which can otherwise also be doped with colouring agents differing from those stated above. Colour variation is 10 thus possible in all directions over the outer surface of the dental restoration 10 to be formed. The properties of the material for doping in areas 11 and 12 can be varied from the bottom to the top, just as around 15 the surface shown in fig. 1 of a cross-section of a dental restoration 10 to be formed.

The installation 1 as shown in fig. 1 is also referred to as a colour printer.

As an alternative within the scope of the present invention to the laser generator 7 shown in fig. 1, it 20 is also possible to work with a binder which gives the non-cohesive powder-form zirconium oxide cohesion locally and where desired. As shown in fig. 1, this can also take place in a structure with layers. The binder is active up to a depth to which the binder is able to 25 give cohesion to the powder-form zirconium oxide. In such an application this active depth is of course greater than the thickness of a layer of powder-form zirconium oxide which has been applied or is to be applied, so that the adhesion to underlying parts of the 30 restoration 10 to be formed is also brought about.

Dental restorations are manufactured with colour printer 1 from a loose, dry zirconium oxide powder with 3% yttrium oxide. The geometry for the restorations originates from a scan-design system such as a CAD-CAM 35 system. Printer 1 is used to apply an organic binder to

powder compacted with the roller, whereby complex shapes can be produced. A solution of 4% by weight 4AC (Hercules, USA) is made as binder. Three print suspensions are made herefrom by adding respectively

5 0.05% Pr-oxide, 0.05% Fe-oxide and 0.05% Er-oxide. The pigment is added to the binder as micronized powder and mixed in a turbine agitator. In a colour printer a bridge is printed with an STL data file, with differentiated colouring, obtained from a CAD system for

10 dental restorations. After construction the bridge is heated to 650°C at 5°C/min. The restoration is then heated to 1500°C at 10°C/min and held there for 2 hours. The bridge exhibits the designed local differentiated colouring.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:-

1. Method for manufacturing a dental restoration, comprising of:
 - determining an external form and dimensions available for a completed
- 5 restoration;
 - obtaining an image of a natural tooth to be replaced with the restoration or a tooth corresponding therewith, wherein the image comprises at least the external surface visible in use of the tooth to be replaced or corresponding tooth, with variations in the appearance therein;
- 10 - defining locally on and at least to visible depth below the surface of appearance- determining properties of at least one material to be applied for the restoration in accordance with the obtained image and the variations in the appearance therein;
 - constructing the restoration, comprising of: repeatedly providing layers of at least one material to be applied in non-cohesive form; and for each layer providing
- 15 cohesion to the layer of at least one material with previous layers in accordance with the available form and dimensions, wherein the step of providing at least one material to be applied comprises: varying the at least one material to be applied in accordance with variations in the image in a plane defined by each of the layers around the periphery of the surface of a cross section of a dental restoration to be formed.

20

2. Method according to claim 1 wherein the step of determining an external form and dimensions available for a completed restoration is with a CAD-CAM system.

25

3. Method as claimed in claim 1 or claim 2, comprising of providing layer by layer in non-cohesive form at least one material to be applied ; and providing cohesion to the material in each of the layers in accordance with the available form and dimensions as well as providing adhesion to a preceding layer before providing a subsequent layer.

30

4. Method as claimed in any one of claims 1, 2 or 3, wherein the non-cohesive form is at least one of the forms from the group comprising: powder form, liquid, thin slices.

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5. Method as claimed in any one of the preceding claims, comprising of providing as the material to be applied at least one of the materials from the group comprising:

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ceramic material, porcelain, glass ceramic, yttrium-stabilized tetragonal zirconium oxide (Y-TZP).

6. Method as claimed in claims 1 and 5, comprising of adding an additive to the
5 material in order to bring the appearance of the restoration to be thus formed into
accordance with the image.

7. Method as claimed in claim 6, wherein the additive is at least one of the materials
from the group comprising: erbium oxide (Er₂O₃), iron oxide (Fe₂O₃) ; and
10 praseodymium oxide (Pr₂O₃), manganese oxide (Mg₂O₃).

8. Method as claimed in any one of the preceding claims, wherein the providing of
cohesion to the material comprises of: applying a binder, such as the action of at least
one laser and/or the addition of a binding additive.

15 9. Method as claimed in claim 8, followed by sintering out of binding additive.

10. Method as claimed in claim 3, further comprising of: levelling a provided layer of
material, prior to providing the material with cohesion.

20 11. Method as claimed in claim 10 wherein said layer of material is in powder form.

12. Dental restoration obtained by the method of any one of the preceding claims.

13. Method for manufacturing a dental restoration, substantially as herein described
with reference to any one of the embodiments of the invention illustrated in the
accompanying drawings and/or examples.

25 14. Dental restoration, substantially as herein described with reference to any one of
the embodiments of the invention illustrated in the accompanying drawings and/or
examples.

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