ENDODONTIC INSTRUMENT FOR DRILLING ROOT CANALS

Technical field

The present invention concerns an endodontic instrument for preparing a patient's tooth, in particular an instrument for cleaning the root canal which follows the natural geometry of said canal, the instrument being made of a shape memory material which has a static state and a dynamic state, the said static state corresponding to a substantially straight geometry to enable the instrument to be inserted partially into the canal and the said dynamic state corresponding to a structured geometry, a supple flexible form in which it is set rotating to clean the inside wall of the said root canal, following its natural geometry, the said instrument having a rigid tip arranged to be mounted on a rotating support and a working sector made to be engaged in said root canal.

Prior art

Cleaning and preparing the root canals of a tooth to receive fillings is usually made using drilling instruments having an active section, known as the working section, the purpose of which is to machine, trim and clean the inside walls of the root canal to prepare it to take treatment materials then a filling to prevent any oxygen being allowed in which could be liable to allow bacteria to grow inside the tooth and close to the root in particular.

Root canal drilling equipment of this kind usually comprises an active section, known as cutting section, having a conical shell and one or more cutting blades arranged in a helix along the said active section. These instruments tend to 'trim' the canal walls, that is, cut into the dentine without really following the natural shape of the canal, following the canal line. Now, recent studies have shown that it is inadvisable to cut into the dentine as this weakens the tooth. The best endodontists try to follow these directives by trying to find rotary instruments which are designed to enable them to follow the root canal and clean all its walls whatever the shape and morphology of the said canal may be, knowing that this varies from one individual to another. It is known on the one hand that the shape of root canals varies considerably from one patient to

another, that these canals often have an irregular oval cross-section over their length and one or more recesses and curved sectors.

Now practically all current endodontic instruments for drilling root canals are *a priori* straight, even if some are flexible to some extent which enables them to adapt more or less to the longitudinal profile of the root canal. This suppleness does not, however, guarantee they will clean all the wall if it is of variable curve and section; and the envelope described by the area which a conventional instrument sweeps as it rotates around its longitudinal axis is more or less cylindrical or conical due to the axially symmetrical geometry of that instrument, such that the walls of an oval section root canal cannot be swept by a single instrument, but have to be swept by a series of instruments of progressive sections. The practitioner is therefore obliged to change instruments during treatment, starting with small diameters and using progressively larger ones, which is complex and also does not guarantee that the walls will actually be cleaned effectively without harming the dentine.

Almost none of the root canal drilling instruments currently available on the market provide many practitioners with what they need, first, because they do not match the morphology of the canal and, second, because they have a number of cutting heads which cut into and grind the dentine in the walls of the canal instead of simply following its profile to clean its surface; and their relative rigidity means they can only be used to grind the cylindrical or conical openings with each passage and even moving along the instrument's axis of rotation parallel to itself cannot be used to clean all the surfaces of the walls if the latter are oval with irregular sections and have recesses over their length.

There is therefore a need for a new type of instrument which meets practitioners' requirements, that is, instruments flexible enough to follow the canal profile, press onto all the roughnesses and unevennesses of the canal wall and brush them to remove the internal biofilm without damaging the dentine.

International application WO 2012/079183 A1 describes an endodontic instrument which has a retracted straight geometrical form when in what is known as its martensitic phase, in the resting position or in the static state and a structured form when it is in the austenitic phase, in the working position or in the dynamic position, the transition from the 'martensitic' to the 'austenitic' phase being due to a change of temperature. In its dynamic state, the instrument has a coiled, twisted shape coiled a number of times over its length: these coils can slow down and brake the rotation of the instrument which is subject to some considerable mechanical stresses.

Summary of invention

The purpose of the present invention is to create an instrument which meets all the requirements which practitioners state in preparing root canals. To this end, this instrument, which satisfies the constraints imposed effectively in preparing such a canal following its profile precisely and cleaning its walls without rubbing away the dentine in which it is located, that is, by scraping its walls to remove the soft materials which make up the biofilm without harming the harder bony matter called the dentine. The instrument according to the invention is designed to handle these operations well, whether it be the morphology of the canal, in particular if some or all of that canal is oval in section, whether there are recesses over its width or not, whether it is substantially straight or curved with angular variations over its length and if its walls are regular or rough.

This purpose is achieved by the endodontic instrument according to the invention as defined in the preamble and characterised in that, when the instrument is in its dynamic state, the said working sector comprises a first substantially straight active segment arranged in the extension of the said rigid tip, this first active segment being extended by a second active segment having a free end and a curved shape between the point where it meets the said first active segment and a free end, the said curved second active segment having a deflection the length of which is comprised between the largest half cross-

section of the said root canal and the smallest half cross-section of the said root canal.

Different embodiments are envisaged, particularly with a free end having a bevelled tip having an angle between 30° and 60° and preferably at least approximately equal to 90°, a free end having a swallow-tailed tip with an opening angle of between 60° and 30° and preferably close to 45°, a free end having a bell-mouthed tip, having an enlargement is defined by a radius (R1) or presenting an enlargement is defined by an angle substantially between 120° and 150°.

According to another embodiment, it is made of a shape memory metal alloy in which the transition from the martensitic phase to the austenitic phase occurs naturally at body temperatures between 32 °C and 37 °C.

According to one variant, it is made of a shape memory metal alloy in which the transition from the martensitic phase to the austenitic phase is made by increasing the temperature by injecting a hot liquid or by applying ultrasound-induced vibrations.

It may advantageously be made of a metal alloy having super-elastic properties from being heat-treated.

Brief description of drawings

The present invention and its advantages will be better understood by reading the detailed description of the preferred embodiments of the instrument, referring to the drawings attached, which are indicative and non-limitative, in which:

Fig. 1 shows the instrument as in the invention shown in a static state and inserted in the root canal of a tooth to be treated,

Fig. 2 shows the instrument as in the invention shown in a dynamic state and inserted in the root canal of a tooth to be treated,

Figs. 2A and 2B are cross-section views of the patient's tooth in a plane A-A and in a plane B-B parallel to plane A-A but at different levels,

Fig. 3 shows a view similar to that in Fig. 2, showing the instrument as in the invention in the dynamic state inserted inside a root canal in the course of the second phase of treatment,

Fig. 4 shows a view similar to that in Fig. 3, showing the instrument as in the invention in the dynamic state, inserted inside a root canal in the course of the third phase of treatment,

Figs. 5 and 6 show an initial embodiment of the instrument as in the invention in its static and dynamic states respectively,

Fig. 7 shows a second embodiment as in the invention in its dynamic state,

Fig. 7A shows a detailed view of the end of the instrument in Fig. 7,

Fig. 8 shows a third embodiment of the instrument as in the invention in its dynamic state,

Fig. 8A shows a detailed view of the end of the instrument in Fig. 8,

Fig. 9 shows a second embodiment of the instrument as in the invention in its dynamic state, and

Fig. 9A shows a detailed view of the end of the instrument in Fig. 9.

Best Modes for Carrying out the InventionReferring to the figures, endodontic instrument 10, which is designed to prepare a tooth 100 of a patient as part of a root treatment, is an instrument for cleaning the or a root canal 101 of tooth 100. Unlike the instruments known to make such preparations, this instrument 10 is made to clean the inside walls of the cavity without 'grinding' or 'damaging' the canal but to follow the natural trajectory without cutting into the hard part of the tooth. It is designed to have at least one static state as shown by Fig. 1 in particular and a dynamic state as shown in Fig. 2. It will be noted that, in its static state, the instrument has a substantially straight profile and that it is also highly supple or flexible, enabling it to be introduced easily into the root canal 101 of tooth 100. It its dynamic state, the instrument has a curved profile with at least one curve, enabling it to perform its task of cleaning the walls of the said root canal by sweeping the inside surface of the root canal walls.

Endodontic instrument 10 has a rigid tip 11 arranged to be mounted on a rotating mounting 102 of an apparatus 103 called a contra-angle and a working sector 12. The said working sector comprises an free end section 13, and is arranged to be inserted in the said root canal 101. Working sector 12 comprises a first active segment 14 which is substantially straight arranged in the extension of the rigid tip 11 and a second active segment 15 comprising the said free end section 13. In the static state (see Fig. 1), the said second active segment 15 is substantially straight, and in the said dynamic state (see Fig. 2), the said second active segment 15 has a curved shape between the point where it meets the said first active segment 14 and the said free end 13. The curved shape of active segment 15 may correspond to the arc of a circle or to any other profile approaching the shape of the arc of a circle (see Figs. 2 and 6 in particular) of which the deflection d is the distance between the summit S of the arc on the right which links its two ends M and N. In the present invention, the deflection d of this arc has a length which is substantially comprised between half the smallest average cross-section a of a root canal 101 and half the largest section b of this root canal when the said instrument 10 is in its dynamic state.

Fig. 2 shows the instrument in its dynamic state in the first phase of treatment, with the end section 13 is inserted as far as the end of the root canal 101. When the instrument is set rotating, its end section sweeps the deepest area of the canal and cleans the walls in this area to lift the soft parts lining it without cutting into the dentine. While they are rotated, these parts are pushed to the top of the canal to be removed. It will be noted that this is done irrespective of how wide the canal may be, what its geometry is, its transverse dimensions and whether there is any roughness or not, thanks to the flexible end section 13 and its curved shape which whips the surface of the walls.

Figs. 2A and 2B are sections on planes A-A and B-B of tooth 100 respectively, showing oval sections 101a and 101b of a root canal 101 and sections of the active segment 15 of the working sector 12. Canal 101 could of course be more complex in shape such as a cross section in the shape of a C or an S. As the working sector is flexible, it can treat all types of canal, whatever their geometry, such that it is possible to imagine a canal profile which could be regarded as a reference, having a more or less oval cross-section and a length which is substantially between one and ten times the cross-section concerned.

Instrument 10 is specially designed to treat this type of non-circular section root canals over a part of their course at least or complex profile canals presenting at least one fracture or angular deviation over their length. For these rather difficult canals, in fact, it is possible to insert the instrument into the canal over its full length no matter how geometrically complex the canal is, start the active sector working and clean the walls effectively because the working sector is now rotating freely and is not slowed down or braked. It has been found that the form described with a single curved section fitted as an extension of a straight section provides a maximum of benefits to do the task set.

Figs. 3 and 4 show two views of instrument 10 showing it in the course of the different phases of treatment, the instrument having moved along the canal

between the two operations. By moving the instrument in this way, the operator can sweep all the wall areas of the canal over its whole length.

Instrument 10 may be advantageously made of a metal alloy of the memory retaining type, such that it passes from its static state as shown in Fig. 1 to its dynamic state as shown in Fig. 2 due to an increase in temperature. It may also have super-elasticity characteristics obtained by the choice of alloy and by using specific treatments and heat treatment in particular.

What is particularly advantageous is that, if the instrument is of the shape memory type, it reaches its static state at ambient temperatures, i.e. around 20 C and its dynamic state at body temperature, i.e. around 32 °C to 37 °C. This increase in temperature may be attained naturally having inserted working sector 12 in root canal 101 or by applying heat from outside, e.g. by injecting a hot liquid, radiated heat or heating by the Joule effect.

In its static state, instrument 10, at rest as shown in Fig. 5 or at the start of the working procedure as shown in Fig. 1 has a substantially straight profile. When it starts rotating, as shown in Fig. 2, for example, accompanied by being irrigated with a liquid which assumes body temperature, which triggers the shape memory effect, the instrument resumes its predefined shape as shown in Fig. 6. It is in this state that working sector 12 and, to be more precise, the second active segment 15 of instrument 10 rest on the canal walls. The second active segment 15 has a span or deflection d of the arc made by the said active segment 15. The deflection d is the distance between summit S of the arc of segment MN which links the two ends of the arc, corresponding to the curve of active segment 15. The length of this deflection is comprised between half the smallest section a of root canal 101 and half the widest section b of that canal. In this way, by rotating the instrument, the said active segment 15 acts like a whip, brushing against the canal walls and removing the soft parts which may be lining their surface. Its function is to clean the surface of the walls, whatever their geometry.

Instrument 10, if it is of the shape memory type, when it is in its dynamic state is in its austenitic phase, that is, highly flexible and elastic, enabling it to scratch the surface of the walls of root canal 101. The transition from one of these states to another may be connected to a temperature variation or using vibration which may be induced by ultrasound. It will be noted that the second active segment 15 of instrument 10 touches the canal wall whatever the canal geometry is. This characteristic is shown in particular by Figs. 3 and 4, which show instrument 10 working at different levels in the canal. However narrow the canal, restricted passage or the cross-section of canal 101 may be, second active segment 15 can do its work cleaning the surface of the canal walls.

It will be noted that the second active segment 15 of instrument 10, comprising part of the working sector 12, advantageously has a single curved element in the shape of an arc only when the instrument is in its active state. In its passive state, the second active segment 15 is substantially straight.

While using the instrument, i.e. when active segment 15 is fulfilling its purpose of cleaning the canal walls, the 'scratching' force may be adapted, even reduced, by injecting irrigation liquid at ambient temperature via a syringe. The cooling effect of this action has the effect of transforming the NiTi from the austenitic to the martensitic phase which reduces the 'scratching' force on the canal walls.

After being used for some time, the super-elastic effect will resume as the temperature of the irrigation fluid increases due to the body temperature or the heating due to the frictional forces of the instrument.

Fig. 7 and detail Fig. 7A show another embodiment of instrument 10 in which end section 13 has a tip 16 cut with a bevel profile between 60° and 30° preferably close to 45°. This angular section is advantageously sharp and makes it possible to cut material at the extreme end of the canal if need be.

Fig. 8 and detail Fig. 8A show another embodiment of instrument 10 in which end section 13 has a tip 16 which has a round swallow tail profile arranged transversely relative to the axis of tip 16. The swallow tail profile has an angle of opening between 60° and 30° and preferably close to 45°. As before, the section, which has two cutting edges, can be used to cut the material at the end of the root canal if necessary.

Fig. 9 and detail Fig. 9 A show an embodiment of instrument 10, the end section 13 of which has a tip 16 with a funnel-shaped profile. The funnel-shaped profile end has an enlargement defined by a radius of curvature R1, the angle of opening being substantially between 120° and 150°. The funnel-shaped profile edge is cutting to provide a cutting edge which is intended to cut material along the root canal walls as the case may be.

The various forms described above are designed to improve the action of the instrument, i.e. cleaning the walls. The end sections may be adapted to suit specific uses in certain cases to remove material along the root canal walls or remove filler used in a prior intervention.

The present invention is not limited to the embodiments as described, but may undergo various modifications or versions which would be obvious to an expert skilled in the art. In particular, other materials may be used, such as certain plastics or compositions of synthetic materials, fibres, carbon fibres in particular.

Claims

1. Endodontic instrument for preparing a patient's tooth, in particular an instrument for cleaning the root canal that follows the natural geometry of said canal, the said instrument being made of a shape memory material having a static state and a dynamic state, the said static state corresponding to a substantially straight geometry to allow the instrument to be inserted partially into the canal and the said dynamic state corresponding to a structured geometry, a supple flexible behaviour, in which it is set rotating to clean the said root canal following its natural geometry, the said instrument having a rigid tip arranged to be mounted on a rotating support and a working sector arranged to be engaged in said root canal, **characterised in that,** when the instrument is in its dynamic state, the said working sector consists of a first substantially straight active segment disposed in the extension of the said rigid tip, this first active segment being prolonged by a second active segment having a free end and having a curved shape between the point where the said first active segment and a free end meet, the said second active segment having a deflection (d) the length of which is comprised between the largest half cross-section (a) of the said root canal and the smallest half cross-section (b) of the said root canal.

2. Endodontic instrument as in claim 1, characterised in that the said free end has a bevelled tip.

3. Endodontic instrument as in claim 2, characterised in that said bevel is angled between 30° and 60° and preferably approximately equal to 45°.

4. Endodontic instrument as in claim 1, characterised in that said free end has a swallow-tail-shaped tip.

5. Endodontic instrument as in claim 4, characterised in that the said swallow-tail has an angle of opening of between 60° and 30° preferably close to 45°.

6. Endodontic instrument as in claim 1, characterised in that the said free end has a funnel-shaped tip.

7. Endodontic instrument as in claim 6, characterised in that that the end is funnel-shaped defined by a radius of curvature (R1).

8. Endodontic instrument as in claim 6, characterised in that the end presents an enlargement defined by an angle substantially between 120° and 150°.

9. Endodontic instrument as in claim 1, characterised in that it is made of a shape memory metal alloy in which the transition from the martensitic phase to the austenitic phase occurs naturally at a body temperature between 32 °C and 37 °C.

10. Endodontic instrument as in claim 1, characterised in that it is made of a shape memory metal alloy in which the transition from the martensitic phase to the austenitic phase can be made by increasing the temperature by injecting a hot liquid.

11. Endodontic instrument as in claim 1, characterised in that it is made of a metal alloy which has super-elasticity properties acquired through being heat-treated.

12. Endodontic instrument as in claim 1, characterised in that it is made of a shape memory metal alloy in which the transition from the martensitic phase to the austenitic phase is made by applying ultrasound induced vibrations.

ENDODONTIC INSTRUMENT FOR DRILLING ROOT CANALS

Technical field

The present invention concerns an endodontic instrument for preparing a tooth of a patient, in particular an instrument for cleaning the root canal which follows the natural geometry of that canal, the said instrument being made of a shape memory material and having a first static state and a second dynamic state, the said first static state corresponding to a substantially straight geometry to facilitate the partial introduction of the instrument in the said root canal and the second dynamic state corresponding to a structured geometry, a supple and flexible form, the said endodontic instrument being set rotating to clean the inside wall of the said root canal, following its natural geometry, and having a rigid tip arranged to be mounted on a rotating support and a working sector arranged to be engaged in the said root canal.

Prior art

Cleaning and preparing the root canals of a tooth to receive fillings is usually made using drilling instruments having an active section, known as the working section, the purpose of which is to machine, trim and clean the inside walls of the root canal to prepare it to take treatment materials then a filling to prevent any oxygen being allowed in which could be liable to allow bacteria to grow inside the tooth and close to the root in particular.

Root canal drilling equipment of this kind usually comprises an active section, known as cutting section, having a conical shell and one or more cutting blades arranged in a helix along the said active section. These instruments tend to 'trim' the canal walls, that is, cut into the dentine without really following the natural shape of the canal, following the canal line. Now, recent studies have shown that it is inadvisable to cut into the dentine as this weakens the tooth. The best endodontists try to follow these directives by trying to find rotary instruments which are designed to enable them to follow the root canal and clean all its walls whatever the shape and morphology of the said canal may be, knowing that this varies from one individual to another. It is known on the one

hand that the shape of root canals varies considerably from one patient to another, that these canals often have an irregular oval cross-section over their length and one or more recesses and curved sectors.

Now practically all current endodontic instruments for drilling root canals are *a priori* straight, even if some are flexible to some extent which enables them to adapt more or less to the longitudinal profile of the root canal. This suppleness does not, however, guarantee they will clean all the wall if it is of variable curve and section; and the envelope described by the area which a conventional instrument sweeps as it rotates around its longitudinal axis is more or less cylindrical or conical due to the axially symmetrical geometry of that instrument, such that the walls of an oval section root canal cannot be swept by a single instrument, but have to be swept by a series of instruments of progressive sections. The practitioner is therefore obliged to change instruments during treatment, starting with small diameters and using progressively larger ones, which is complex and also does not guarantee that the walls will actually be cleaned effectively without harming the dentine.

Almost none of the root canal drilling instruments currently available on the market provide many practitioners with what they need, first, because they do not match the morphology of the canal and, second, because they have a number of cutting heads which cut into and grind the dentine in the walls of the canal instead of simply following its profile to clean its surface; and their relative rigidity means they can only be used to grind the cylindrical or conical openings with each passage and even moving along the instrument's axis of rotation parallel to itself cannot be used to clean all the surfaces of the walls if the latter are oval with irregular sections and have recesses over their length.

There is therefore a need for a new type of instrument which meets practitioners' requirements, that is, instruments flexible enough to follow the canal profile, press onto all the roughnesses and unevennesses of the canal

wall and brush them to remove the internal biofilm without damaging the dentine.

International application WO 2012/079183 A1 describes an endodontic instrument which has a retracted straight geometrical form when in what is known as its martensitic phase, in the resting position or in the static state and a structured form when it is in the austenitic phase, in the working position or in the dynamic position, the transition from the 'martensitic' to the 'austenitic' phase being due to a change of temperature. In its dynamic state, the instrument has a coiled, twisted shape coiled a number of times over its length: these coils can slow down and brake the rotation of the instrument which is subject to some considerable mechanical stresses.

US patent 5,836,764 describes an endodontic instrument having a pre-curved end zone which is intended to facilitate inserting the instrument in a curved root canal; but it does not resolve the problem of inserting the tip of the instrument into canals whose shapes are complex, and cannot in any case adapt itself to such shapes by changing shape while it is being used, as is the case with instruments made of shape-changing material.

Summary of invention

The purpose of the present invention is to create an instrument which meets all the requirements which practitioners state in preparing root canals. To this end, this instrument, which satisfies the constraints imposed effectively in preparing such a canal following its profile precisely and cleaning its walls without rubbing away the dentine in which it is located, that is, by scraping its walls to remove the soft materials which make up the biofilm without harming the harder bony matter called the dentine. The instrument according to the invention is designed to handle these operations well, whether it be the morphology of the canal, in particular if some or all of that canal is oval in section, whether there are

recesses over its width or not, whether it is substantially straight or curved with angular variations over its length and if its walls are regular or rough.

This purpose is achieved by the endodontic instrument according to the invention as defined in the preamble in the dynamic state of the instrument, the said working sector consists of a first active segment which is substantially straight and at least one second active segment disposed in the extension of the first active segment, the said at least one second segment having a free end tip having a curved form between the point where the first active segment and the said free end meet, the said second curved active segment having a deflection (d) the length of which is comprised between the largest half cross-section (a) of the said root canal and the smallest half cross-section (b) of the said root canal..

Different embodiments are envisaged. The said free end tip may have a structured geometric form.

The said free end tip may be bevelled in shape, the said bevel having advantageously an angle comprised between 30° and 60° and preferably approximately equal to 45°.

The said free end tip may be swallow-tailed in shape, the said swallow-tail preferably having an opening angle between 30° and 60° and preferably approximately close to 45°.

The said free end tip may carry a tip with a flared mouth, the said flared mouth being advantageously flared defined by a radius of curvature (R1).

The said free end tip may advantageously be enlarged at an angle defined by a radius of curvature between 120° and 150°.

According to another embodiment, it is made of a shape memory metal alloy in which the transition from the martensitic phase to the austenitic phase occurs naturally at body temperatures between 32 °C and 37 °C.

According to one variant, it is made of a shape memory metal alloy in which the transition from the martensitic phase to the austenitic phase is made by increasing the temperature by injecting a hot liquid or by applying ultrasound-induced vibrations.

It may advantageously be made of a metal alloy having super-elastic properties from being heat-treated.

Brief description of drawings

The present invention and its advantages will be better understood by reading the detailed description of the preferred embodiments of the instrument, referring to the drawings attached, which are indicative and non-limitative, in which:

Fig. 1 shows the instrument as in the invention shown in a static state and inserted in the root canal of a tooth to be treated,

Fig. 2 shows the instrument as in the invention shown in a dynamic state and inserted in the root canal of a tooth to be treated,

Figs. 2A and 2B are cross-section views of the patient's tooth in a plane A-A and in a plane B-B parallel to plane A-A but at different levels,

Fig. 3 shows a view similar to that in Fig. 2, showing the instrument as in the invention in the dynamic state inserted inside a root canal in the course of the second phase of treatment,

Fig. 4 shows a view similar to that in Fig. 3, showing the instrument as in the invention in the dynamic state, inserted inside a root canal in the course of the third phase of treatment,

Figs. 5 and 6 show an initial embodiment of the instrument as in the invention in its static and dynamic states respectively,

Fig. 7 shows a second embodiment as in the invention in its dynamic state,

Fig. 7A shows a detailed view of the end of the instrument in Fig. 7,

Fig. 8 shows a third embodiment of the instrument as in the invention in its dynamic state,

Fig. 8A shows a detailed view of the end of the instrument in Fig. 8,

Fig. 9 shows a second embodiment of the instrument as in the invention in its dynamic state, and

Fig. 9A shows a detailed view of the end of the instrument in Fig. 9.

Best Modes for Carrying out the Invention

Referring to the figures, endodontic instrument 10, which is designed to prepare a tooth 100 of a patient as part of a root treatment, is an instrument for cleaning the or a root canal 101 of tooth 100. Unlike the instruments known to make such preparations, this instrument 10 is made to clean the inside walls of the cavity without 'grinding' or 'damaging' the canal but to follow the natural trajectory without cutting into the hard part of the tooth. It is designed to have at least one static state as shown by Fig. 1 in particular and a dynamic state as shown in Fig. 2. It will be noted that, in its static state, the instrument has a substantially straight profile and that it is also highly supple or flexible, enabling it to be introduced easily into the root canal 101 of tooth 100. It its dynamic state, the

instrument has a curved profile with at least one curve, enabling it to perform its task of cleaning the walls of the said root canal by sweeping the inside surface of the root canal walls.

Endodontic instrument 10 has a rigid tip 11 arranged to be mounted on a rotating mounting 102 of an apparatus 103 called a contra-angle and a working sector 12. The said working sector comprises an free end section 13, and is arranged to be inserted in the said root canal 101. Working sector 12 comprises a first active segment 14 which is substantially straight arranged in the extension of the rigid tip 11 and a second active segment 15 comprising the said free end section 13. In the static state (see Fig. 1), the said second active segment 15 is substantially straight, and in the said dynamic state (see Fig. 2), the said second active segment 15 has a curved shape between the point where it meets the said first active segment 14 and the said free end 13. The curved shape of active segment 15 may correspond to the arc of a circle or to any other profile approaching the shape of the arc of a circle (see Figs. 2 and 6 in particular) of which the deflection d is the distance between the summit S of the arc on the right which links its two ends M and N. In the present invention, the deflection d of this arc has a length which is substantially comprised between half the smallest average cross-section a of a root canal 101 and half the largest section b of this root canal when the said instrument 10 is in its dynamic state.

Fig. 2 shows the instrument in its dynamic state in the first phase of treatment, with the end section 13 is inserted as far as the end of the root canal 101. When the instrument is set rotating, its end section sweeps the deepest area of the canal and cleans the walls in this area to lift the soft parts lining it without cutting into the dentine. While they are rotated, these parts are pushed to the top of the canal to be removed. It will be noted that this is done irrespective of how wide the canal may be, what its geometry is, its cross dimensions and whether there is any roughness or not, thanks to the flexible end section 13 and its curved shape which whips the surface of the walls.

Figs. 2 A and 2 B are sections on planes A-A and B-B of tooth 100 respectively, showing oval sections 101a and 101b of a root canal 101 and sections of the active segment 15 of the working sector 12. Canal 101 could of course be more complex in shape such as a cross section in the shape of a C or an S. As the working sector is flexible, it can treat all types of canal, whatever their geometry, such that it is possible to imagine a canal profile which could be regarded as a reference, having a more or less oval cross-section and a length which is substantially between one and ten times the cross-section concerned.

Instrument 10 is specially designed to treat this type of non-circular section root canals over a part of their course at least or complex profile canals presenting at least one fracture or angular deviation over their length. For these rather difficult canals, in fact, it is possible to insert the instrument into the canal over its full length no matter how geometrically complex the canal is, start the active sector working and clean the walls effectively because the working sector is now rotating freely and is not slowed down or braked. It has been found that the form described with a single curved section fitted as an extension of a straight section provides a maximum of benefits to do the task set.

Figs. 3 and 4 show two views of instrument 10 showing it in the course of the different phases of treatment, the instrument having moved along the canal between the two operations. By moving the instrument in this way, the operator can sweep all the wall areas of the canal over its whole length.

Instrument 10 may be advantageously made of a metal alloy of the memory retaining type, such that it passes from its static state as shown in Fig. 1 to its dynamic state as shown in Fig. 2 due to an increase in temperature. It may also have super-elasticity characteristics obtained by the choice of alloy and by using specific treatments and heat treatment in particular.

What is particularly advantageous is that, if the instrument is of the shape memory type, it reaches its static state at ambient temperatures, i.e. around 20 C and its dynamic state at body temperature, i.e. around 32 °C to 37 °C. This increase in temperature may be attained naturally having inserted working sector 12 in root canal 101 or by applying heat from outside, e.g. by injecting a hot liquid, radiated heat or heating by the Joule effect.

In its static state, instrument 10, at rest as shown in Fig. 5 or at the start of the working procedure as shown in Fig. 1 has a substantially straight profile. When it starts rotating, as shown in Fig. 2, for example, accompanied by being irrigated with a liquid which assumes body temperature, which triggers the shape memory effect, the instrument resumes its predefined shape as shown in Fig. 6. It is in this state that working sector 12 and, to be more precise, the second active segment 15 of instrument 10 rest on the canal walls. The second active segment 15 has a span or deflection d of the arc made by the said active segment 15. The deflection d is the distance between summit S of the arc of segment MN which links the two ends of the arc, corresponding to the curve of active segment 15. The length of this deflection is comprised between half the smallest section a of root canal 101 and half the widest section b of that canal. In this way, by rotating the instrument, the said active segment 15 acts like a whip, brushing against the canal walls and removing the soft parts which may be lining their surface. Its function is to clean the surface of the walls, whatever their geometry.

Instrument 10, if it is of the shape memory type, when it is in its dynamic state is in its austenitic phase, that is, highly flexible and elastic, enabling it to scratch the surface of the walls of root canal 101. The transition from one of these states to another may be connected to a temperature variation or using vibration which may be induced by ultrasound. It will be noted that the second active segment 15 of instrument 10 touches the canal wall whatever the canal geometry is. This characteristic is shown in particular by Figs. 3 and 4, which

show instrument 10 working at different levels in the canal. However narrow the canal, restricted passage or the cross-section of canal 101 may be, second active segment 15 can do its work cleaning the surface of the canal walls.

It will be noted that the second active segment 15 of instrument 10, comprising part of the working sector 12, advantageously has a single curved element in the shape of an arc only when the instrument is in its active state. In its passive state, the second active segment 15 is substantially straight.

While using the instrument, i.e. when active segment 15 is fulfilling its purpose of cleaning the canal walls, the 'scratching' force may be adapted, even reduced, by injecting irrigation liquid at ambient temperature via a syringe. The cooling effect of this action has the effect of transforming the NiTi from the austenitic to the martensitic phase which reduces the 'scratching' force on the canal walls.

After being used for some time, the super-elastic effect will resume as the temperature of the irrigation fluid increases due to the body temperature or the heating due to the frictional forces of the instrument.

Fig. 7 and detail Fig. 7A show another embodiment of instrument 10 in which end section 13 has a tip 16 cut with a bevelled profile between 60° and 30° preferably close to 45°. This angular section is advantageously cutting and makes it possible to cut material at the extreme end of the canal if need be.

Fig. 8 and detail Fig. 8A show another embodiment of instrument 10 in which end section 13 has a tip 16 which has a round swallow tail profile arranged transversely relative to the axis of tip 16. The swallow tail profile has an angle of opening between 60° and 30° and preferably close to 45°. As before, the section, which has two cutting edges, can be used to cut the material at the end of the root canal if necessary.

Fig. 9 and detail Fig. 9 A show an embodiment of instrument 10, the end section 13 of which has a tip 16 with a flared profile. The flared profile end has an enlargement defined by a radius of curvature R1, the angle of opening being

substantially between 120° and 150°. The flared profile edge is cutting to provide a cutting edge which is intended to cut material along the root canal walls as the case may be.

The various forms described above are designed to improve the action of the instrument, i.e. cleaning the walls. The end sections may be adapted to suit specific uses in certain cases to remove material along the root canal walls or remove filler used in a prior intervention.

The present invention is not limited to the embodiments as described, but may undergo various modifications or versions which would be obvious to an expert skilled in the art. In particular, other materials may be used, such as certain plastics or compositions of synthetic materials, fibres, carbon fibres in particular.

Claims

1. Endodontic instrument for preparing a patient's tooth, in particular an instrument for cleaning the root canal that follows the natural geometry of said canal, the said instrument being made of a shape memory material having a first static state and a second dynamic state, the said first static state corresponding to a substantially straight geometry to facilitate the instrument being inserted partially into the said root canal and the said second dynamic state corresponding to a structured geometry, a supple flexible behaviour, the said endodontic instrument being set rotating to clean the said root canal following its natural geometry, the said instrument having a rigid tip arranged to be mounted on a rotating support and a working sector arranged to be engaged in said root canal, **characterised in that,** when the instrument is in its dynamic state, the said working sector consists of a first substantially straight active segment and at least one second active segment disposed in the extension of the said rigid tip, the said at least one second active segment having a free end tip and having a curved shape between the point where the said first active segment and the said free end tip meet, the said second active segment having a deflection (d) the length of which is comprised between the largest half cross-section (a) of the said root canal and the smallest half cross-section (b) of the said root canal.

2. Endodontic instrument as in claim 1, characterised in that the said free end tip has a structured geometrical shape.

3. Endodontic instrument as in claim 2, characterised in that the said free end tip is of bevelled form.

4. Endodontic instrument as in claim 3, characterised in that said bevel is angled between 30° and 60° and preferably approximately equal to 45°.

5. Endodontic instrument as in claim 4, characterised in that said free end tip has a swallow-tail-shaped tip.

6. Endodontic instrument as in claim 5, characterised in that the said swallow-tail has an angle of opening of between 60° and 30° preferably close to 45°.

7. Endodontic instrument as in claim 2, characterised in that the said free end tip has a flared tip.

8. Endodontic instrument as in claim 7, characterised in that the free end tip is flared defined by a radius of curvature (R1).

9. Endodontic instrument as in claim 6, characterised in that the free end tip presents an enlargement defined by an angle substantially between 120° and 150°.

10. Endodontic instrument as in claim 1, characterised in that it is made of a shape memory metal alloy in which the transition from the martensitic phase to the austenitic phase occurs naturally at a body temperature between 32 °C and 37 °C.

11. Endodontic instrument as in claim 1, characterised in that it is made of a shape memory metal alloy in which the transition from the martensitic phase to the austenitic phase can be made by increasing the temperature by injecting a hot liquid.

12. Endodontic instrument as in claim 1, characterised in that it is made of a metal alloy which has super-elasticity properties acquired through being heat-treated.

13. Endodontic instrument as in claim 1, characterised in that it is made of a shape memory metal alloy in which the transition from the martensitic phase to the austenitic phase is made by applying ultrasound induced vibrations.