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(54) MECHANISM FOR USE IN DEVELOPING PANORAMIC IMAGES OF CURVED BODIES

(71) We, SYNTEX (U.S.A.) INC., organised and existing under the Laws of the State of Delaware, United States of America, of 5401 Hillview Avenue, Palo Alto, California 94304, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, andthe method by which it it is to be performed to be particluraly described in and by the following statement:

The present invention relates to a mechanism for use in developing panoramic images of curved objects.

More particularly, the present invention relates to a mechanism for moving an X-ray source in order to obtain, on an X-ray film, panoramic radiographs of an object having at least partly the shape of the dental arch. The mechanism preferably includes a stationary frame, a movable support arm with the source of radiation and the receiver or film holder attached at its opposite end, and means for effecting a rotational movement of the support arm around the object.

In panoramatomagraphic radiography technique, an image of a layer of the object, the layer being of a certain depth, is formed on the film. The shape, location and thickness of this image layer can be effected by a suitable arrangement of the geometry relating to the forming of an image of the object. Normally in this technique, the X-ray source and the film move in relation to the patient, who is therefore immobile during the radiographing. A precise image of the desired spot of the object is formed on the film, if the velocity of the film is selected equal to the velocity of the projected image of the spot being radiographed on the film surface.

The following factors among others, affect the results obtained in panoramatomographic radiography: the distance of the center of rotation of the X-ray source from the object being radiographed, the film and the X-ray source, the velocity of the film in relation to the velocities of the image spots of the object projected onto the film surface, the width of the X-ray beam on the film surface, the size of the focal spot of the X-ray source, the type of X-ray film used, the properties of the intensifying screens, and the quality and amount of radiation emitted by the source. The significance of these factors is explained in more detail in, for example, J. van Aken's article: Panoramic X-ray equipment, Reports of Councils and Bureaus/ Joda, Vol. 86, May 1973. The most important equipment available on the market and the principles of operation of the same are also described in the said publication.

There are currently available several panoramic X-ray apparatus, developed by different manufacturers. One of the basic models is the Finnish Orthopantomograph, developed by T. Nieminen on the basis of Professor Y. Paatero's idea and manufactured by Palomex Oy. In the said apparatus, the patient is in a standing position during the radiographing; the X-ray source and the film holder move around the patient's head while the patient remains immobile. In the apparatus, the rotational movement of the X-ray source has three different fixed rotation centers; change from one rotation center to another is through a cycloidal movement.

In the apparatus marketed by S.S. White (U.S. Patent 3,045,118), the patient is in a sitting position the X-ray source has during the radiographing two different rotation centers in relation to the patient, but the X-ray source rotates around one point at a time throughout the procedure, in which case the change from one rotation center to another takes place by shifting the patient laterally over a suitable distance with the aid of the chair. This system has a disadvantage in that radiographing is not possible during the shifting, in which case the central area in the X-ray film must be left unexposed and thus the front teeth, which are in the middle of the dental arch, are not radiographed.

In GE-3000 manufactured by General Electric (German (FRG) Patent Application 1,955,294), the movement of the rotation center of the source of X-ray

radiation is based on a pair of eliptic gears and takes place along a curved path in a manner determined by the dimensioning of the gear pair.

Japanese Panex-"E" of Morita Corporation is a kind of application of the ellipsograph. Its principle of operation is disclosed in German (FRG) Patent Applications 2,057,135, 2,252,578 and 2,252,579. In this apparatus also, the rotation center of the X-ray source moves along a curved path.

There are also other similar apparatus on the market, but the mechanisms moving the X-ray source in these systems do not deviate substantially from the basic types mentioned above.

The point of departure in planning the mechanisms of all the apparatus currently on the market is some geometric curve close to the shape of the object i.e. the jawbone, either an ellipse or a combination of two or three arcs of a circle, since thereby rather simple mechanisms can be constructed for moving the source of radiation.

However, if the planning is based on a shape as close to the jaw bone shape as possible and the optimal movement of the rotation center of the X-ray source in that case is determined thereafter, it is observed that the shape does not follow precisely any definitive simple geometric shape. From this it follows that the movement used in current radiographic equipment is always to a certain extent an imprecise approximation of the ideal.

The aim of the present invention is to eliminate the above disadvantages of known equipment and to provide a panoramic imaging apparatus for radiographing curved objects, more especially those having the same shape as the dental arch, in which the movement of the radiation source has been implemented in a generally ideal manner, corresponding to a general jaw bone shape. To achieve this desired movement, the motion of the X-ray source is divided into linear and rotational components and the desired movement is produced as a synchronization of these two partial components.

When the movement of the source is divided into rotational and linear components, there are primarily two alternatives: the linear component is either parallel to the axis of symmetry of the dental arch, or it is perpendicular to it. An apparatus according to the first alternative, however, involves certain technical problems. If the rectilinear movement takes place parallel to the axis of symmetry of the dental arch, the movement changes its direction half-way through the radiographing, which may be technically difficult to control in terms of achieving an even, disturbance-free progress of the movement involved in the radiographing. Another problem consists of the fact that the acceleration of the linear component of the movement is at its greatest at the beginning and at the end of the movement. This is also difficult to control so as to eliminate undesirble jerks at the beginning of the movement.

However, if the linear movement of the source of radiation takes place perpendicular to the axis of symmetry of the dental arch according to the second alternative, the above drawbacks do not exist, the direction of the linear movement remains unchanged throughout the procedure; in addition, the velocity of the movement, the procedure; in addition, the velocity of the movement, at its middle the velocity of the linear movement is at its maximum, whereafter the velocity again decreases evenly until it reaches zero. Such an evenly increasing and decreasing movement is straightforward to control; Evenness of movement and the lack of vibration is of primary importance in terms of successful panoramic radiography.

Acocrding to one feature of the present invention, there is provided a mechanism for moving an X-ray source and an X-ray sensitive film holder around a patient's head so that the image of an object, having at least partly the shape of a dental arch, can be obtained on a film, the mechanism comprising: a stationary frame, a rotatable support arm supported by the frame, attached to one end of the support arm a film holder attached to the opposite end of the support arm, means for positioning the patient's head between the X-ray source and the film holder, and means for moving the center of rotation of the support arm throughout the radiographic procedure along a rectilinear path perpendicular to the axis of symmetry of the dental arch, in such manner that the position of the center of rotation along the rectilinear path is dependent at any given movement on the angular position of the support arm so that X-ray beam from the X-ray source at any given moment during the radiographic procedure substantially perpendicular to that part of the object which has the shape of the dental arch.

It may be desired to investigate curved bodies other than but similar in part to the shape of the dental arch, using techniques other than sensitised film X-ray radiography. For example, techniques such as ultra-sound might be employed for a variety of testing or examining routines performed on animate or inanimate bodies.

According to a further feature of the invention there is provided apparatus for

deriving a panoramic image of a curved body having at least in part the shape of a dental arch and having an axis of symmetry, comprising a support, a carriage moveable linearly with respect to the support and an arm rotatably mounted to the carriage, the arm having attached thereto, so as to straddle the body, a source of imaging radiation and a receptor for radiation which has interacted with the body, there being camming means responsive to the rotation of the arm for shifting the carriage and the arm rectilinearly and unidirectionally perpendicular to the said axis of symmetry, the arrangement being such that the incident radiation on the body is generally perpendicular to that part of the body which has the shape of the dental arch.

The invention is described below in more detail in the form of examples and with reference to the accompanying drawings, in which

Figure 1 depicts schematically a side view of one embodiment of the moving mechanism according to the invention,

Figure 2 depicts a plan view of the mechanism according to Fig. 1,

Figure 3 depicts the principle of operation of the mechanism moving the X-ray source in relation to the dental arch. The X-ray source 12 is on the right at the beginning of the radiographing, from where it moves, as shown in the figure, to the middle, at which time the procedure is halfway completed. At the middle, the X-ray source 12 continues in the same direction to the left so that the radiographing movement is a continuous, even movement, symmetric in relation to the axis of symmetry of the dental arch.

In the moving mechanism depicted in the figures, some parts, especially those which belong to the frame, have been left undepicted for the sake of clarity.

The plate 1 (Figs. 1 and 2) has been attached to the frame of the apparatus through frame members not depicted. On both sides of the plate 1 there are members 2 which have running grooves for bearings 5. The plate 1 and the members 2 constitute the stationary frame of the moving mechanism. Also attached to the frame is a guide pin 3 which moves in the groove 16 in the grooved plate 7.

Moving rectilinearly in relation to the frame, there is a plate 4; the bearings 5 moving in the running grooves in the members 2 have been attached to the plate 4. Attached to the plate 4, there is a member 6 to which a support arm 15 has been pivoted. The center point of the bearing of the member 6 is the rotation center of the pivoting movement of the support arm 15. In the member 6 there is an opening 17 through which an attachment member 13 has been attached to the plate 1. Head positioners 14 have been suspended from the attachment member 13. The plate 4, the bearings 5, and the member 6 constitute the rectilinearly moving member of the movement mechanism, i.e. the linear section.

The X-ray source 12 and the film holder 11 have been suspended from the support arm 15, and a rotatable axle 9 attached to a drive wheel 8. The axle 9 is rotated by an electric motor 10. The drive wheel 8 moves, rotated by the electric motor 10, along the surface of the member 6, owing to friction between the drive wheel 8 and the member 6, whereby the support arm 15 pivots relative to the member 6, supported by the bearings between the member 6 and the support arm 15 .The grooved plate 7 with a groove 16 has been attached to the support arm 15. When the support arm 15 pivots, the guide pin 3 moves along the groove 16. Since the distance of the groove 16 from the member 6, i.e. from the center of rotation of the support arm 15, is variable and the guide pin 3 has been attached to the plate 1 of the frame, the plate 4 and the member 6 attached to it move rectilinearly relative to the frame while the support arm 15 pivots relative to the member 6.

The patient's head (not shown) is situated between the X-ray source 12 and the film holder 11, supported by the head positioner 14 shown in Figure 1. The dental arch 18 in the patient's head is situated in the manner shown in Figure 3 relative to the moving mechanism. Figure 3 also shows the movement of the X-ray beam 19 relative to the dental arch.

The operation of the mechanism described above is as follows. It was required of the mechanism to be implemented that the X-ray source 12 should move, relative to the dental arm 18, in the optimal manner in terms of the projection of the teeth. It was also required that the mechanism could be implemented in such a manner that mechanical movements during the radiographing should be as continuous and vibration-free as possible so as to eliminate defects due to vibration in the radiograph. The bearings of the mechanism were to be simple in order to achieve the necessary steadiness. The simplicity of the mechanism makes low-cost production possible, which also makes the invention commercially significant.

The invention is characterised by the fundamental observation that the movement of the center of rotation of the X-ray source 12 can be effected using a unidirectional movement. In such a case the movement of the X-ray source 12 is a combination of a continuous rotational

movement and a unidirectional rectilinear movement. The unidirectinal movement has been implemented according to the principle of a cam, by means of a guide pin 3 and a grooved plate 7; the distance of the groove 16 in the grooved plate 7 from the center of rotation, i.e. the member 6, has been chosen so as to ensure that the X-ray source 12 radiographs a layer 18 of the correct anatomical shape and thickness in such a manner that the X-ray beam 19 is as perpendicular as possible to the layer 18 being radiographed. Such a perpendicular projection, in which the dimensions of the image are correct, is dignostically much more informative and easier to read.

It is evident that the moving mechanism of the described type is easy to implement in practice since in it the moving mass has been attached simply by using one rotational and one linear bearing. A model of the moving mechanism was made, and using this model it was observed that the mechanism fulfilled the requirements set on it.

In the moving mechanism according to the invention, the movement of the support arm 15 can be effected by means of transmission provided between the member 6 and the support arm 15; in practice, the friction drive illustrated in Figure 1 seems to be an alternative which is superior to, for example, belt, chain or gear transmission, which may cause vibration in the movement of the support arm 15.

The moving mechanism according to the invention can also be used with a patient in a lying position, in which case the linear section moves advantageously in a horizontal plane and the electric motor 10 driving the X-ray source 12 need not be very powerful.

It is evident that the embodiments described can be varied without deviating from the idea of the invention. However, an inexpensive, very sturdy but still precise moving mechanism can be implemented in the manner described above.

WHAT WE CLAIM IS:—

1. A mechanism for moving an X-ray source and an X-ray sensitive film holder around a patient's head so that the image of an object, having at least partly the shape of a dental arch, can be obtained on a film, the mechanism comprising: a stationary frame, a rotatable support arm supported by the frame, an X-ray source attached to one end of the support arm, a film holder attached to the opposite end of the support arm, means for positioning the patient's head between the X-ray source and the film holder, and means for moving the center of rotation of the support arm throughout the radiographic procedure along a rectilinear path perpendicular to the axis of symmetry of the dental arch, in such manner that the position of the center of rotation along the rectilinear path is dependent at any given moment on the angular position of the support arm so that the X-ray beam from the X-ray source at any given moment during the radiographic procedure is directed substantially perpendicular to that part of the object which has the shape of the dental arch.

2. A mechanism according to claim 1, wherein the stationary frame is provided with a rectilinearly movable member, the support arm being pivoted to the rectilinearly movable member and moving the rectilinearly moveable member relative to the stationary frame during rotation thereof.

3. A mechanism according to claim 2, wherein a rotatable axle is attached to the support arm and a drive transmission is provided between the axle and the rectilinearly movable member so as to effect rotational movement of the support arm relative to the said member.

4. A mechanism according to claim 2 or 3, wherein the support arm has associated therewith a plate having a groove therein, the frame has a guide pin which follows, when the support arm rotates, the groove in the plate, whereby the centre of rotation of the support arm moves relative to the frame in a manner determined by the shape of the groove.

5. A mechanism according to claim 2, 3 or 4, wherein the support arm is operatively connected to the rectilinearly movable member by a bearing, said mechanism further including an attachment member connected to the frame and head positioning means suspended from the atachment member, the attachment member extending from the stationary frame through the middle of the bearing and through an opening in the rectilinearly movable member.

6. A mechanism according to claim 3, or either of claims 4 and 5 when dependent on claim 3, wherein the movement of the rotatable axle is effected by an electric motor connected to the axle and being supported by the support arm.

7. A moving mechanism according to claim 3, or any of claims 4 to 6 when dependent on claim 3, wherein movement of the rotatable axle is transmitted to the rectilinearly movable member by means of a friction drive between a drive wheel on the axle member operatively connected to the rectilinearly movable member.

8. Apparatus for deriving a panoramic image of a curved body having at least in part the shape of a dental arch and having an axis of symmetry, comprising a support,

a carriage movable linearly with respect to the support and an arm rotatably mounted on the carriage, the arm having attached thereto, so as to straddle the body, a source of imaging radiation and a receptor for radiation which has interacted with the body, there being camming means responsive to the rotation of the arm for shifting the carriage and the arm rectilinearly and unidirectionally perpendicular to the said axis of symmetry, the arrangement being such that the incident radiation on the body is generally perpendicular to that part of the body which has the shape of the dental arch.

9. A mechanism for moving an X-ray source and an X-ray sensitive film holder around a patient's head, substantially as herein described with reference to and as shown in the accompanying drawings.

10. Apparatus for deriving a panoramic image substantially as herein described with reference to and as shown in the accompanying drawings and as claimed in claim 8.

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Sheet 1

Fig. 1

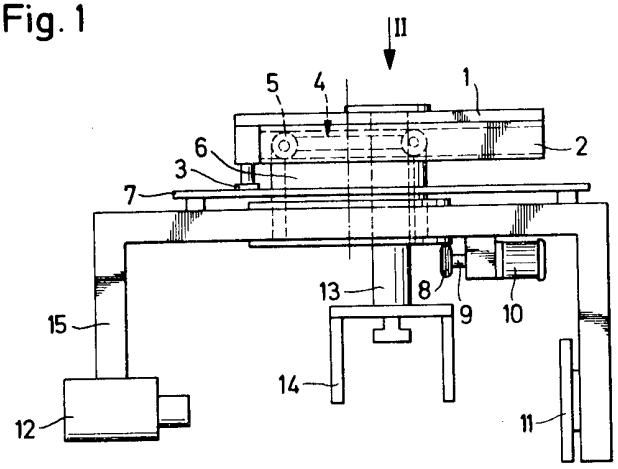
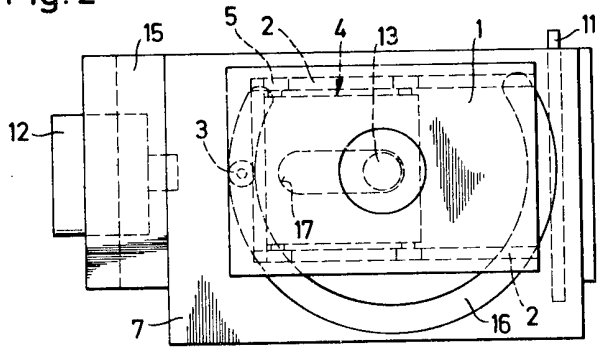


Fig. 2



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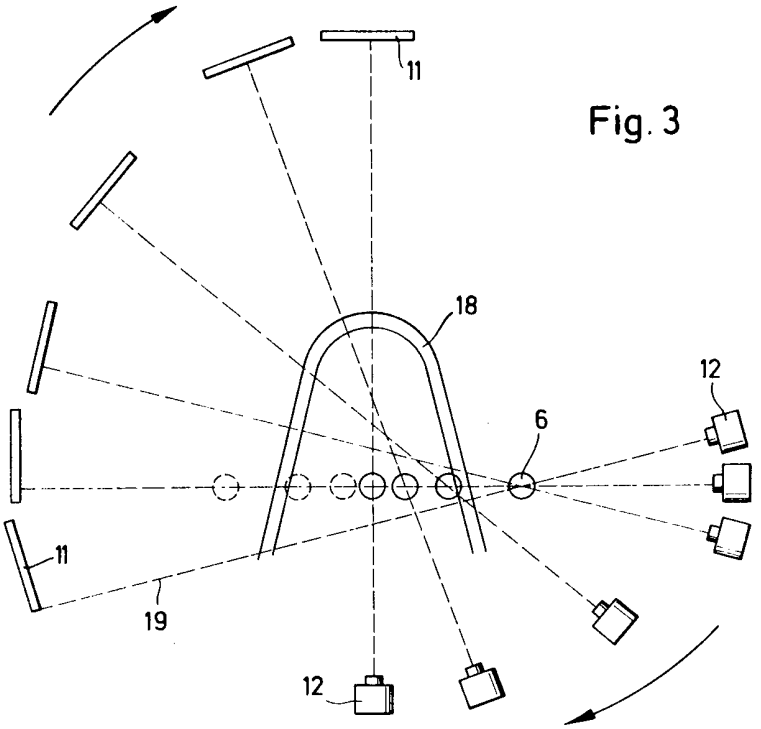

Fig. 3