3 to 4 repetitions of a working course, and with the light signs altered for every new working course by automatic connections. This method permits a reliable identification of the various working movements which is quite impossible with the usual light point's process. The stereoscopic observation offers, furthermore, some very considerable advantages as against monocular observation, since only in the former may the differences of depth also be observed.

The plotting was executed with the "Wild"—Autograph A 5 with the scale of 1:2. The plotting permits also determining the way passed over in units of time. These experiments led for instance to the following statements.

1. The greater the distance run, the greater the velocity and the straighter the course of the movement.
2. The shorter the distance run, the smaller the velocity and the vaster the course of the movement.
3. The plotting of the courses of the movements further shows, that the right hand sometimes has to wait for the left, and that there occur shiftings of time between the two hands which are caught up at the fix points of movement.
4. The experiments confirm the fundamental rule, that human work has the tendency to rhythmical movement.

There should be no doubt that the stereoscopic plotting of movements opens up quite new perspectives for the scientific study of working processes and for the determination of working depositions giving maximum results.

A NEW METHOD FOR INTRA-ORAL RADIOGRAPHY[1]

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THERE exists in the science of odontology a real need of an accurate method for following physiological and pathological processes in the jaws with the aid of radiography.

The radiographic material at the disposal of the practicing odontologist does not, unfortunately, always possess the most desirable properties, so that the opportunities of performing good diagnoses in odontology, and particularly in oral surgery, are much restricted. In most cases the diagnosis is made and the therapy decided from clinical examinations and from the study of single radiographs. These single pictures can, however, be of great value when the object is to estimate changes in a particular region of the jaw, provided that one works on the principle of serial identical radiography. The term "serial identical radiography" should not mislead one into thinking that it is a question of identity in the mathematical sense. It is in fact a question of a greater or lesser degree of geometrical similarity in orientation.

Rather than to study single pictures, however, we have found it preferable to exploit the advantages of stereo-radiography. After interpretation of 3,000 radiographs taken by our method we have found that a comparison between a single picture and a stereo-pair taken in the correct manner has proved that the latter is superior. The information yielded by the stereo-picture, despite shortcomings inherent in the character of the radiograph, is always more detailed than that given by the single picture. Even if, on account of the distribution of contrasting points in the object, a correct space conception of all such points cannot be obtained, the stereo-picture can be said to reproduce, in some degree, the three-dimensional effect.

So long as stereo-radiography is performed in accordance with the theoreti-

[1] The contents of this paper are based on experiments treated in the thesis "Photogrammetric Principles Applied to Intra-oral Radiodontia," by Nils Berghagen, Stockholm 1951, and on later developments. A more complete account will appear in *Acta Odontologica Scandinavica*, Volume 11, 1953.

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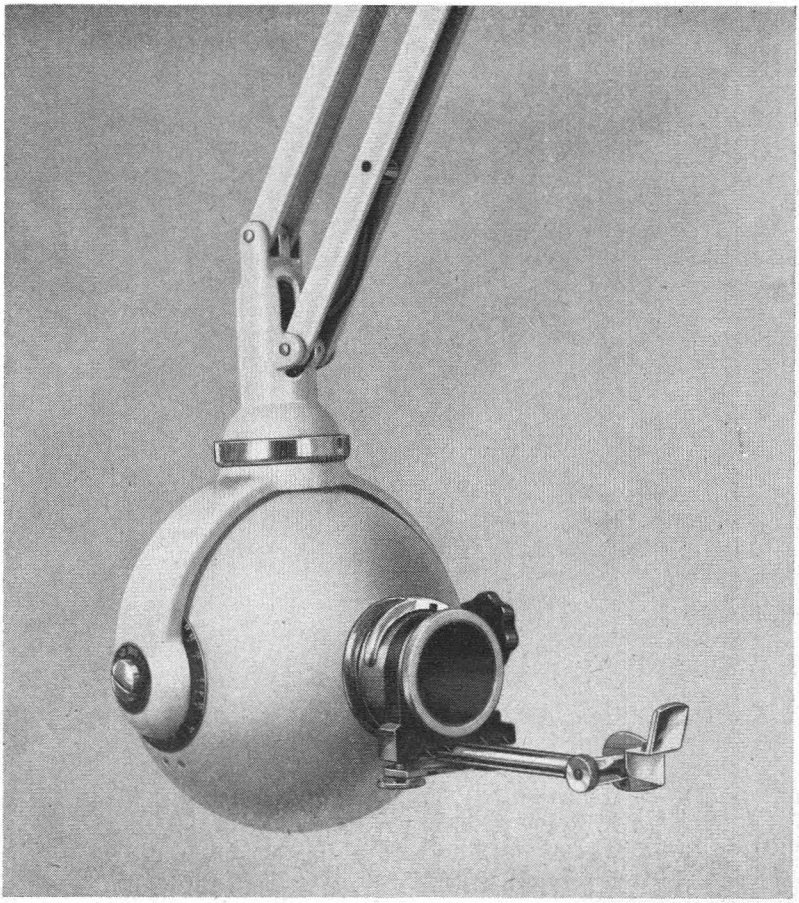


FIG. 1. The apparatus for intra-oral radiography.

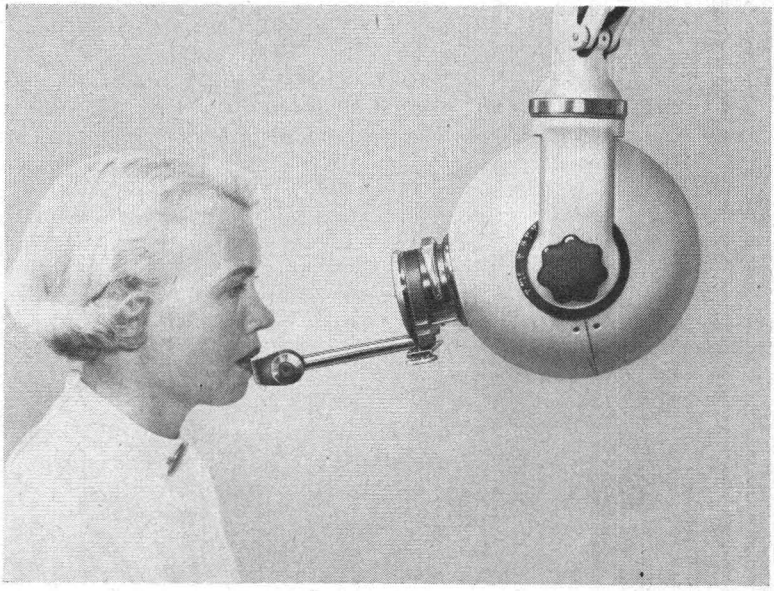


FIG. 2. Relation between the positions of patient and apparatus when radiographing lower incisal region.

cally correct method, it is of secondary importance whether the orientation for the separate pictures is reconstructed in the same way for successive pictures in serial investigations. It is not the absolute position of the points in the picture which is the crucial factor, but rather the position of the points in relation to the corresponding points in the second picture. This becomes clear if one compares the two stereoscopic pictures with one another. The bases used in our work are such that the two component pictures are so nearly similar that no striking difference can be observed. Differences (horizontal parallaxes) nevertheless exist and on viewing are converted in depth and on measuring can be determined directly. They are sufficiently large to make it impossible for the pictures to be interchanged in a serial identical investigation. It may be concluded from this that a change of orientation through displacement of focus with the base used in our work cannot prejudice the conception of the object according to the stereo-model. So great a displacement of focus should not occur in serial identical single picture radiography, since the resulting pictures will have completely different geometric properties. If single pictures are to be used for measurements, the similarity in orientation must be carried further than being contented with pictures which on first inspection are similar in appearance.

To summarize, it can be established that the stereotechnique is very useful for intra-oral radiography and has the additional advantage that the principle of serial identical radiography can be abandoned. The exposures need not be serial identical other than in respect of the stereography's mutual orientation. In order to facilitate the understanding of our method for intra-oral radiography, it may be helpful to give a short account of some photogrammetric ideas that have been utilized.

Radiography can be considered as a central projection, i.e. it is characterized by the fact that straight lines which join the points of the object with their image points all pass through one and the same point, the center of projection. In radiography the focus is the center of projection. The term inner orientation denotes those elements which define the shape of the central projection. The shape of the central projection is determined by the position of the center of projection in relation to the image. As inner orientation data, elements are used which define this position. It is convenient to state the distance between the center of projection and the plane of the image, called by us the *principal distance*, and the position in the plane of the image of the base of the perpendicular through the center of projection on to the plane of the image (the principal point of the image). It is, of course, not necessary to choose these as orientation data, since any data may serve so long as they define the relative position between the image plane and the center of projection. The outer orientation gives the position of the image and the center of projection in relation to the object and is given by outer orientation data. By means of these, the positions of the center of projection and the image are fixed in relation to the object at the moment of exposure in terms of the known points and directions.

Base, relative orientation and absolute orientation are terms which have application in stereo-photography. The base is the distance between two positions of the center of projection. Relative orientation is determined by the directions of the base and the one central projection in relation to the other central projection. Absolute orientation signifies that the model

1. has the correct scale
2. fits, in plane and height, into a coordinate system which may be applied to the object.

For the treatment of all intra-oral picture material it is required that:

1. The image should be plane
2. The inner orientation should be known.

In addition it is required that:

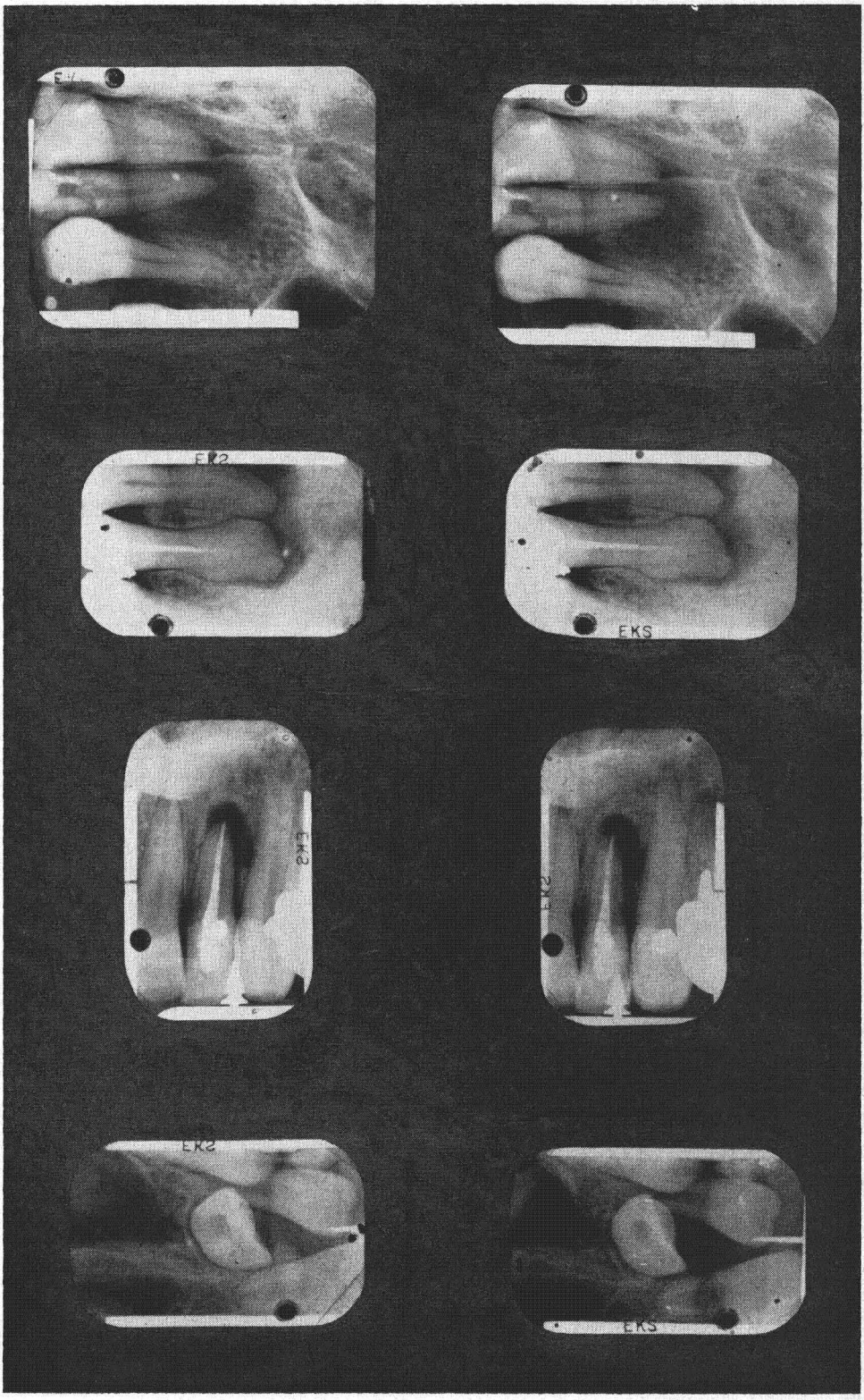
for treatment of single pictures, the outer orientation should be reconstructable, and

for working up of stereo-pairs

1) the relative orientation should be known beforehand and

2) the length of the base should be known.

On the basis of the described principles we have constructed an apparatus for intra-oral radiography (Figures 1 and 2): In order that the image shall be plane and that the condition of inner orientation shall be satisfied, the film is placed in a plane holder whose edges (frame) are provided with at least two marks, the images of which serve as reference points of measurement on the film. The film-holder


EK2
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EK2
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must also be attached to the x-ray tube so that the inner orientation may be fixed. This attachment should be made adjustable in such a way that the inner orientation may be determined for each position of the film-holder.

The outer orientation requires connection between the object and the system comprising the film-holder and the ray source. If the connection is made adjustable the outer orientation should be determinable for each position. This connection can be made by means of a matrix of the jaw in suitable impression compound which sets to the required hardness: this matrix is immovably or adjustably attached to the film-holder. This device will permit the film-holder to be reset in the same position relative to the object (the teeth) after changing the film. If the film-holder is fixed to the object the stereo-radiography must be performed by changing the inner orientation in some way. This may be effected by moving the center of projection, i.e. the focus, in such a way that the intended base is obtained. For effective working it is therefore expedient to place the base parallel to the plane of the film. With this arrangement the same principal distance will serve for both components of the stereo-pair with consequent simplification of the measurement of the co-ordinates of the image system.

For practical reasons the connection between the film-holder and the ray source might be made adjustable in two places. The following arrangement makes this possible. At one of the places, a movement of the ray source can be effected by known steps, corresponding to a number of known bases parallel to the plane of the image. At the second place, the ray source can be rotated about an axis situated between the film plane and the focus, and parallel to the line joining the reference marks. The rotation can be read off on a scale which is calibrated so that it gives a direct reading for each base. The scale has its zero at that adjustment which corresponds to the maximum principal distance, and the stereo-photographing with relative similar principal distance is performed through symmetrical rotations about the zero point.

A survey of the properties of the apparatus with regard to the demands in question may be of value here.

1. The picture should be plane: film-holder is used.
2. The inner orientation should be known: mechanical connection between film-holder and focus. Orientation can be determined by separate measurement performed once and serving for repeated use.
3. The outer orientation should be reconstructable: impression compound is used.
4. The base distance should be known: the base is adjustable by known steps and by rotation indicated on a scale.
5. Relative orientation should be known: this follows from 1–4.

The chief advantages of our method for intra-oral radiography are the following:

1. The photographic procedure is simple;
2. it is advantageous to view three dimensions instead of two;
3. the quality of the pictures will always be superior to those taken with "free technique" (as an example, no movement during exposure); and
4. it is possible to make accurate measurements by means of the pictures (contrary to what is the case if the principles are not followed).

The photogrammetric investigations were mainly performed at the Division of Photogrammetry at the Royal Institute of Technology, Stockholm.

FIG. 3. Illustrations of stereo-radiographs.

No. 1. Region: the upper incisors. Adjustments: base 40 mm. (−2, +2), basehole IV. Viewed in the direction of projection.

No. 2. Region: the lower bicuspids. Adjustments: base 40 mm. (−2, +2), basehold IV. Viewed in the direction of projection.

No. 3. Region: the upper incisors. Adjustments: base 40 mm. (II-VI) cylinger 0. Viewed in the direction of projection.

No. 4. Region: the upper incisors. Adjustments: base 40 mm. (−2, +2), basehold IV. Viewed in the direction of projection.