metry is at present subject to a limitation: the minimum range of the usual cameras is about 1 m., which is insufficient for the purpose in hand. Due to lack of a photogrammetric camera, a good amateur camera was taken into use. It was first necessary, however, to study the inner orientation and the lens distortion of this instrument.

In order to connect the results of measurements in height, arrangements were made as shown in Figures 1 and 2. With reference to a plane *R*, passing through the highest points of the "ones" and the "sevens" of the lower jaw, the two surfaces were prepared in such a manner that they represented two planes *A* and *B*, both parallel to *R* and separated by a distance of "*a*" mm.

For the connection in plane the casts were provided with vertical holes, bored through the two halves, which were laid together in a precision "Sip" boring machine. See Figure 3.

The stereo-measurement was executed in the "Autograph A 5." A computation of the principal distance for the reconstruction of the inner orientation gave 179.0 mm. A check on the stereo-measurement, however, gave 173.5 mm. as the correct value. The stereo-measurement was made with an equidistance of 1 mm. The characteristic high-points were determined to the tenth part of a millimeter. In order to connect the contour lines of the two jaws, the altitude values of the contours were determined. The results of the measurement are shown in Figure 4. To obtain a direct connection of the contour lines of the two jaws, which implied that one of them had to be represented as a "reflected image," the drawings were made on a transparent material. By laying the drawings together, it is possible immediately to detect the contact points between corresponding teeth, which are situated where contour lines of the same value intersect or touch one another.

This application of "close-up" photogrammetry to odontology has given rise to other questions which, however, belong to the sphere of micro-photogrammetry. As examples may be mentioned the morphology of a single tooth and the structure of the fillings.

METHOD OF MEASURING VOLUME MOVEMENTS OF IMPRESSION, MODEL AND PROSTHETIC BASE MATERIALS IN A PHOTOGRAMMETRIC WAY*

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Introduction

OUR task has been to work out a method to measure the complicated volume movements, which impression, model and prosthetic base materials undergo during their setting or curing. If possible the volume movements of the prosthesis should be examined even after having been worn by the patient for some time. The discussion about this subject for the last years makes a method eminently real, which is suitable as well by laboratory as by clinical researches.

Testing Arrangements

A. Odontological Arrangements

To make clear the application of the photogrammetric method we have chosen an upper jaw model without teeth, with ridges in good condition without undercuts and with the palate evenly arched. In order to get rid of the volume movements influencing the measurements, the master-model was made of metal. Control points, which are necessary for the photogrammetric measuring were stamped into the vestibulum of the model. The mouldings, however, were beset with difficulties, mainly due to the stamped marks, which stood out like elevations of the negatives of acrylics or vulcanite. It means that in one case the adjustment of the measuring mark of the stereoinstrument on a control point must be done to the lower surface of the stamped marks; in the other case to the upper one, which appeared like an elevation, as mentioned above. In principle it does not mean anything, but in practice systematic errors can arise. After repeated

* Abstract from "Method of Measuring Volume Movements of Impression, Model and Prosthetic Base Materials in a Photogrammetric Way," *Acta Odontologica Scandinavica* 1951. Vol. 9. Fasc. 2. Stockholm.

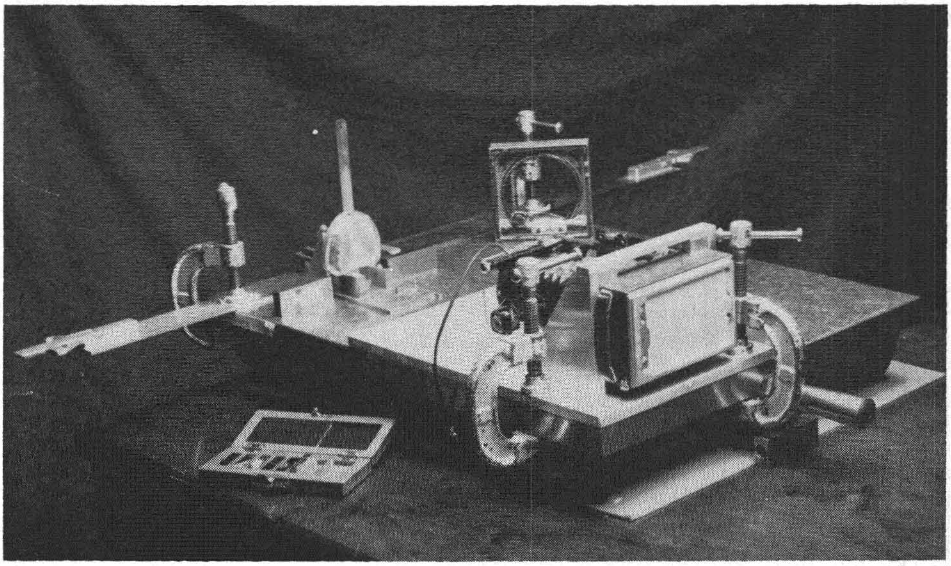

Fig. 1. Photographic arrangements.

tests triangular-formed marks were chosen, which were stamped into the master-model. The side of the triangle was 1 mm. and the depths of the stampmark 0.5 mm.

As a further applicable object test specimens were then chosen of vulcanite and acrylic. At first plaster models were made by duplicating with alginate on standard stipulations and the same kind of stone. Over the whole duplicated model was placed a layer of wax of one sheet's thickness and over the alveolar ridges three more layers of the same thickness and about 10 mm. broad. By fissures in the vestibular part of the model we made sure that the test specimens got the same base surface. Their rims were made parallel with the basic plan of the plaster model. In this way we got specimens, for which as a matter of fact all had about the same volume. On producing the test specimens of acrylics the mucous surface was tin-foiled and the tongue surface glazed. No isolation was used for vulcanite. All specimens were cured in identical conditions. They were not polished.

B. PHOTOGRAMMETRIC ARRANGEMENTS

From the photogrammetric point of

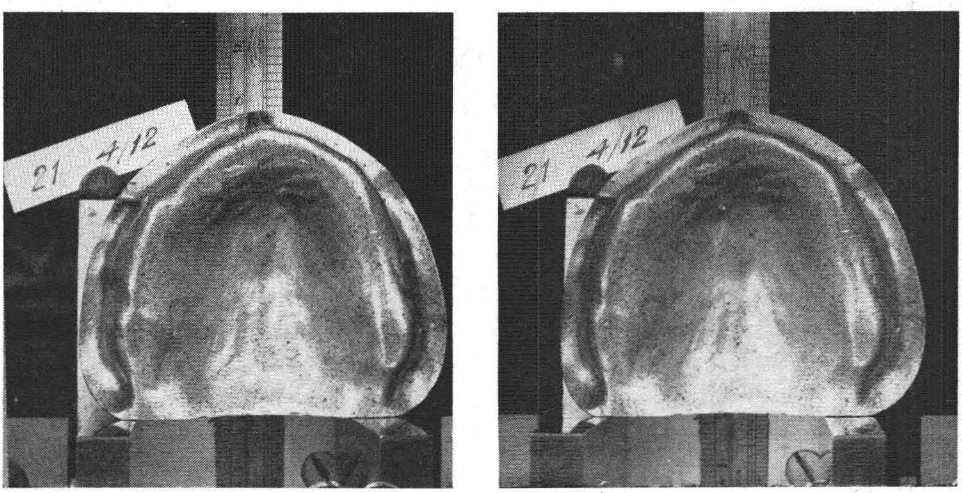

Fig. 2. The pair of pictures of the master model.

view the photographing itself was the greatest problem, because there are no cameras for photogrammetric purposes which are suitable for close-up photographing. The stereocameras, which are introduced on the market, do not admit larger scales than about 1:10 between an object and its picture. A suitable camera must be procured in our case. As the application of the method just intended a comparison between the master-model and the test specimen, the problem was limited to the *relative* changes between them. That is the reason why it is not necessary making the same requirements for the camera, which normally must be made in photogrammetry. A good fitting amateur camera could be used in this case. From the photogrammetric point of view such a camera differs from a measuring camera because its inner orientation is not known.

Instead of moving the camera itself in front of the object we have for practical reasons arranged it so that the object is moved. In both cases the geometric conditions will be the same.

In accordance with this principle the photographing is executed as per Figure 1. For that purpose a camera was chosen of the type of Zeiss-Ikon, 1:3.5 and a focal distance of 10.5 cm. With a basis of 4 cm., through which the whole breadth of the photo plate of the pictures, 6.5×9 cm., could be used, we got a total distance of about 450 mm. between the object and the negative plane, corresponding to a scale of 1:1.4. The whole testing arrangement could by this be placed on a "flat plate" so called, by which a high precision could be guaranteed for the moving of the object parallel to itself. As seen the camera is clasped in a metal frame. The object was placed at a nonius arrangement, belonging to the ruler of a coordinatograph. The length of the basis could by this be decided with an exactness of the adjustment of 0.1 mm. By the perpendicular adjustment of the ruler to the optical axis of the camera the photogrammetric "normal case" was received.

The loss of collimating marks on the camera was a problem. The problem was solved by help of "fitting pieces" of C. E. Johansson-type (Fig. 1), which were placed on, and on both sides of the object in order to be visible on the picture. As the support was a flat-plate and the camera was clasped in its position, the photographed horizontal upper edges of the "fitting pieces" could serve as collimating marks at the reciprocal orientation of the pictures at the stereomeasuring.

In order to get the photogrammetric normal case, the ruler must be adjusted perpendicularly to the optical axis of the camera.

A pair of stereoscopic pictures of a master-model is shown in Figure 2.

The Performance of the Measuring

For measuring a coordinate system (xy) was chosen in such a way that the origo of the system was placed at the lower control point in the left vestibulum of the model and with the positive direction of the x-axis to the right (Fig. 3). Perpendicularly

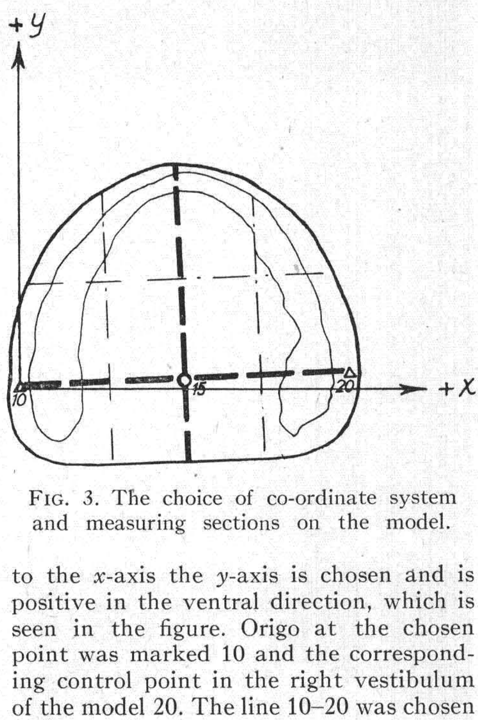

FIG. 3. The choice of co-ordinate system and measuring sections on the model.

to the x-axis the y-axis is chosen and is positive in the ventral direction, which is seen in the figure. Origo at the chosen point was marked 10 and the corresponding control point in the right vestibulum of the model 20. The line 10–20 was chosen as a reference line at a division of the model in profiles, partly parallel, partly perpendicular to it. For that purpose the distance 10–20 was divided in 10 parts, 10, 11, 12, . . . , 20, which were not marked off on the specimen but were directly reckoned from the measuring values of the terminal points 10 and 20. Through the medium point 15 a profile was further chosen perpendicularly to the line 10–20, which in an identical way was divided in parts of the same size. To avoid double-marking the points along this line were called 138, 149, 150 . . . . As only a determination of the method was in principle intended, the measuring was limited to a profile along the line 10–20 and another profile perpendicularly to the former through its medium point 15 (150). If the measurings should be increased to several profiles through the mentioned points, the model should be overdrawn by a square system.

The stereomeasuring was executed in a stereocomparator at the Division of Photogrammetry at the R. Institute of Technology, Stockholm.

Measuring Results

A. METHOD

The performance of the method in detail was executed by the help of the mastermodel. By deciding in the stereo-compara-

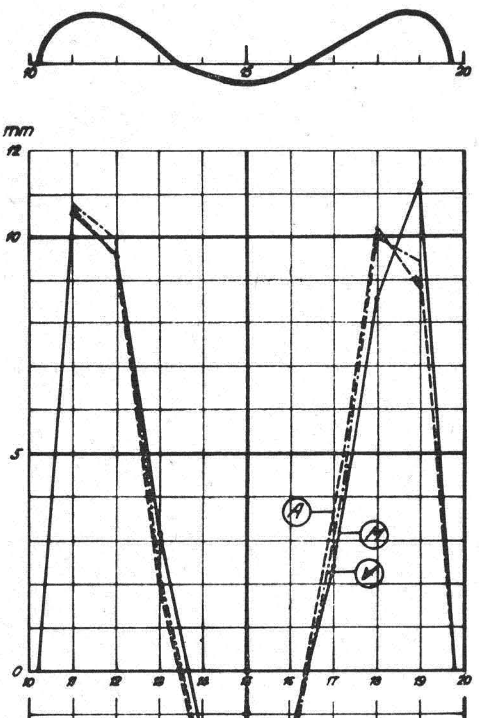

FIG. 4. Result of the measurement of the frontal section. The figure above shows the section in normal proportions. The diagram below is drawn with a height scale×10. M = metal master model, A = acrylic and V = vulcanite specimen.

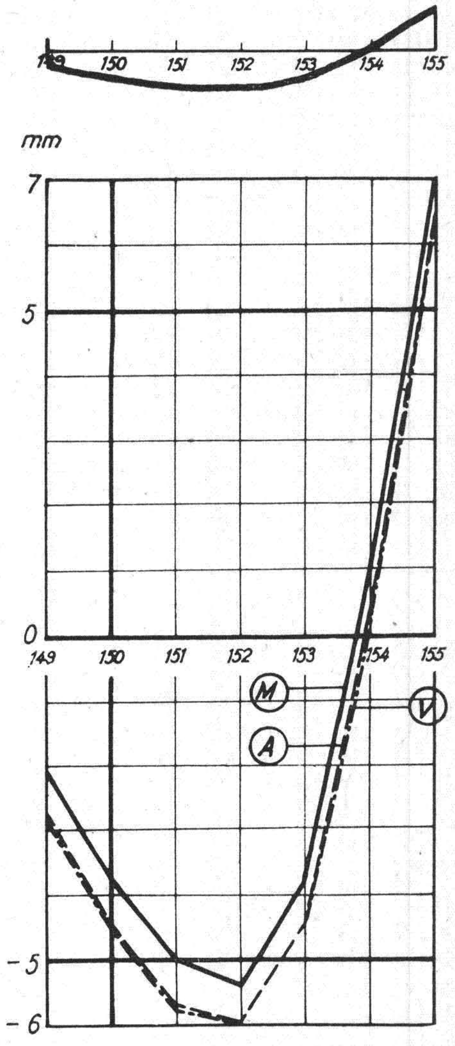

FIG. 5. See Figure 4. Corresponding result in the sagittal section.

tor at first the components of x and y of the line 10–20 in the coordinate system, the adjustment values of all the partial points could be reckoned. The camera constant c was empirically determined by the help of the graduated scale, which was placed on the holder of the test specimen immediately behind the latter (Fig. 1). The distance a from the negative plane to the scale was measured. By transformation of the formula of the normal case for x and y we arrive at

$$c = a \cdot \frac{x^1}{x + x^1}$$

and by this the product $b \cdot c$ is known. By the latter then the three space coordinates can be reckoned from the measuring values of the parallaxis of the different partial points. The received z-values have further been transformed in such a way that they state the depths of the different partial points in relation to the line 10–20 as a zero line. The same thing was done in a corresponding way along the profile through the point 150.

B. APPLICATIONS

The employment of the method for practical use was examined twice on two test specimens of acrylic and vulcanite. The measurements were made by the same method as for the master-model. In a similar way the profile 10–20 was compared to the other profile perpendicularly cut through the point 150 of the master-model and the test specimen.

The values of the table are graphically given an account of in Figures 4–5. The diagrams show that the maximum of the deviations is about 2 mm. The deviations are especially visible in the frontal section 10–20, while those of the sagittal section through point 150 are insignificant.

Finally we must emphasize that the aim has just been to state a method, which measuring technically is more reliable than those, which were hitherto used. For scientific purpose the testing arrangements must and should be improved in detail. As a result of this fact, the measuring values of the examined prosthetic base materials, of course, can not be considered as typical for the quality of these materials.

CONCLUSIONS

1. The photogrammetric testing arrangement has principally functioned satisfactorily.

2. The results of the technical measurements are acceptable with an error of about 0.1 mm.

3. The method is suitable among other things for examination of the exactness of impression materials, volume movements of model materials and the ability of prosthetic base materials for surface adaption.

4. The greatest value of the method is, however, that eventual changes of forms of different prostheses or just one prosthesis can be followed during an arbitrary time.

NEWS NOTES

PHOTOGRAPHY OF LARGE ALBERTA AREA

Extending its forest inventory program, the Alberta Department of Lands and Forests has awarded The Photographic Survey Corporation a contract to procure aerial photography covering some 28,000 square miles, north of latitude 57.

All photography will be at a scale of 1320′ to 1″, as in the previous 100,000 square miles of the Alberta Forest Inventory program recently completed by PSC.

The largest block in the new flying operation is concentrated in the North Peach River area, with an additional block north of Fort McMurray.

As differentiation between coniferous and hardwood trees is an important requisite of the operation, modified infra-red photography will be used during the summer season when hardwoods are in full leaf. The modified infra-red program will entail use of infra-red film with a minus-blue filter.

After defoliation and before snowfall, photography will be procured using standard panchromatic film.

ONTARIO FORESTERS GET MORE MAPS

Photographic Survey Corporation's first client, the Ontario Department of Lands and Forests, has awarded the Company a contract to produce air photography and planimetric mapping at a scale of 1320′ to 1″, covering 16,500 square miles in Northern Ontario. This program will be carried out as part of the national forest inventory provided for in the Canada Forestry Act, with foresters of the Department's Forest Resources Inventory Section compiling the inventory.

The new inventory area lies north of Latitude 51 between Lake Nipigon and the Manitoba boundary, and is immediately north of the western section of "Job 1," the 127,472-square-mile area photographed and mapped by PSC for the Ontario Government between May, 1946 and April, 1951.