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DETERMINATION OF THE MOVEMENTS OF IMPACTED UPPER CANINES BY X-RAY PHOTOGRAMMETRIC METHODS

by

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INTRODUCTION

Berghagen & Hjelmström (1951, 1954, 1956) have described an X-ray method for non-subjective evaluation of intra-oral X-ray stereopairs. During 1955—1959 Berghagen and Rönnerman have used this method for studies of the movements of impacted upper canines when spring forces are applied in order to perform an active correction (Figs. 1, 2). The difficulty in this measurement was to find fixed points in the stereomodel to which the movements can be referred.

MATERIAL

The group of patients, used in these investigations, was composed of about 30 youths with impacted upper canines. There were indications for active correction with spring forces. The orthodontic treatment was performed by Rönnerman. Some of the patients were checked during two years at intervals of 3—6 months. About 10 complete check series, suitable for evaluation, were selected. The result of the evaluation of one of these cases,

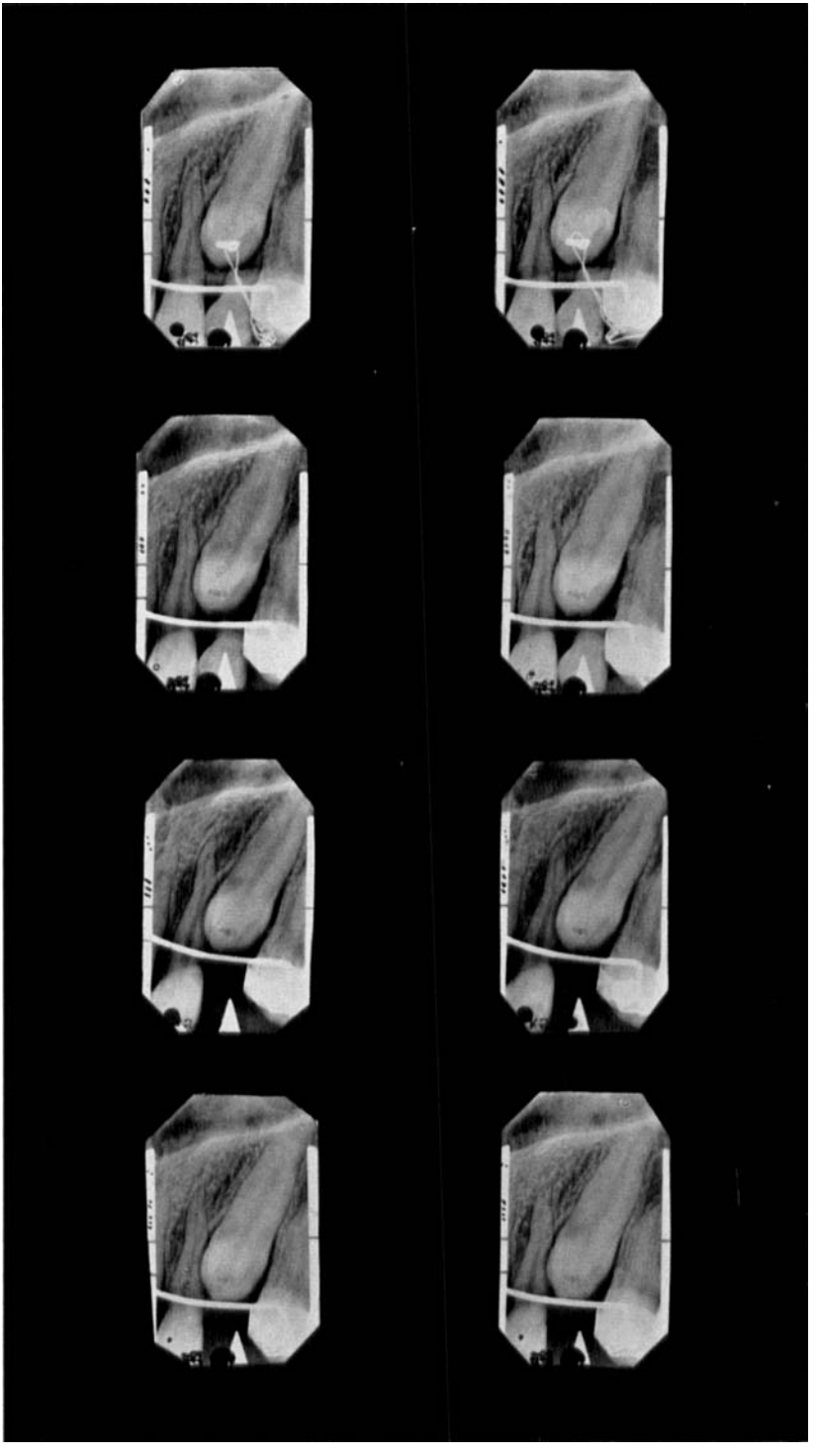


Fig. 1.

carried through in order to test the method and demonstrate it, will be given below.

METHOD

For the X-ray photography the Berghagen apparatus for intraoral X-ray photography was used. For further details regarding apparatus and photography technique see the abovementioned publications.

In broad lines the investigation was carried out as follows:

The first time a patient was to be photographed, one of us (Berghagen) placed the filmholder with impression compound so that the impacted tooth had a central position in the picture. The transversal axis of the filmholder was placed as perpendicularly as possible to the long axes of the adjacent teeth. The stereopictures were taken with such a variation of the outer orientation that focus was moved altogether 10 mm parallel to the plane of the film. The relationship between filmholder and the arm was unchanged (0-position). The impression was then destroyed and the other investigator (Rönnerman) repeated the photographic procedures following the same rules. Next time the patient was to be photographed, the same double procedure was followed though the first photographs were studied beforehand in order to guide the positioning of the filmholder. The same procedure was followed all through the checking series.

THE STEREOPHOTOGRAMMETRIC PROBLEM

Through its restitution a photogrammetric stereopair gives the relative position of a number of points in the bone structure of the jaw as well as in the tooth. These same points must be identifiable all through the series of stereopairs. We assume that the points in the jaw are stable and use them as reference points to which we refer the movements of the tooth points.

First we leave out of consideration the tooth points. Each stereopair gives the jaw points' position in an arbitrary three-dimensional coordinate system. The variations in the orientation of the axes of those systems — one for each stereopair — depends upon the difference in the setting of the X-ray apparatus. Ac-

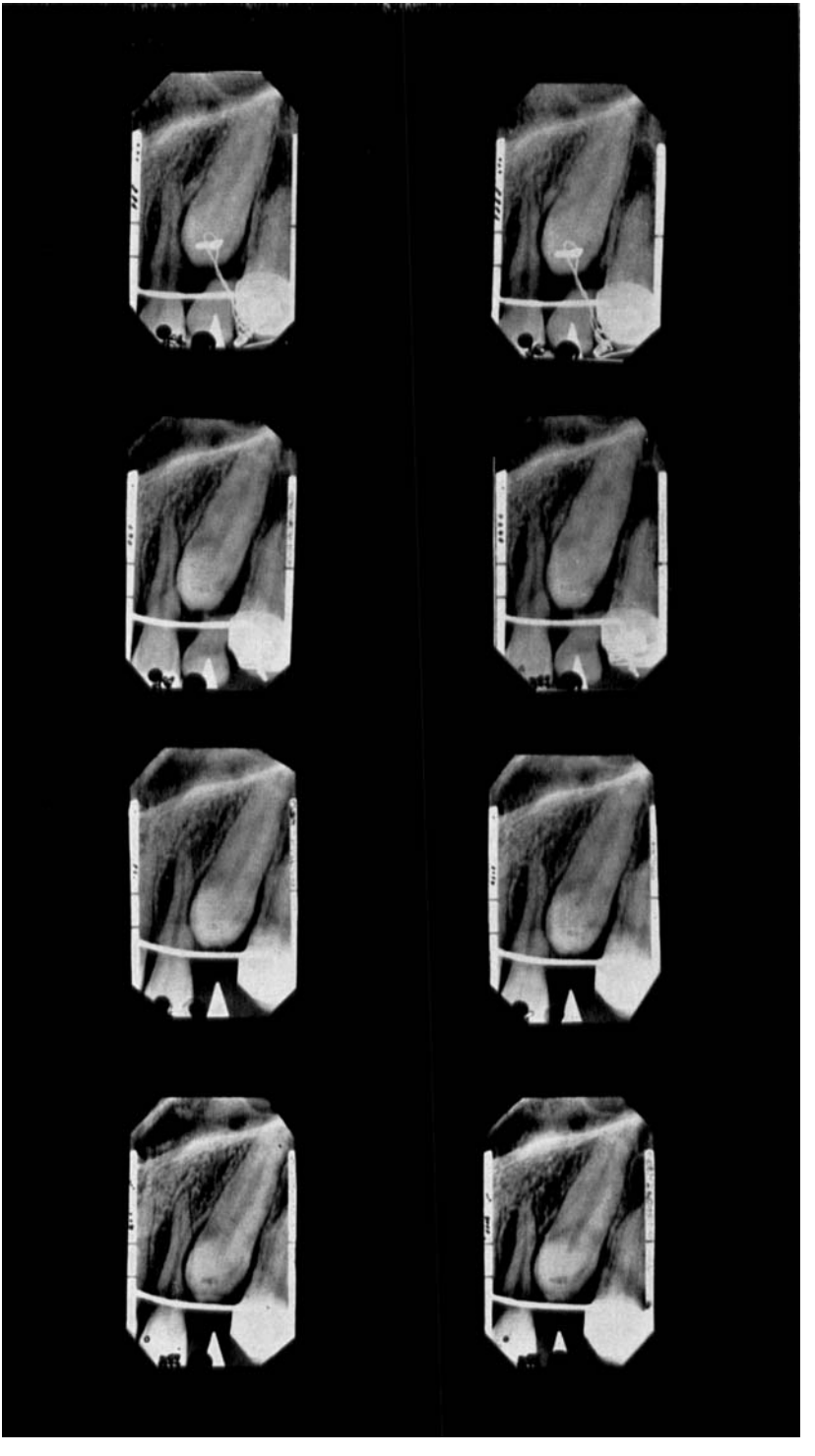


Fig. 2.

cepting the coordinate system of the first stereopair as reference system we accomplish a three-dimensional coordinate transformation of the coordinates obtained through the restitution of the other stereopairs. That means that we transform the point group so that it coincides as closely as possible with the corresponding point group of the first stereopair. For the calculation of the affine transformation coefficients four points are needed. Every additional point gives redundant observations which are used in an adjustment procedure. If the identifications and the measurements of the points were absolutely free from errors, there should be no discrepancies between the transformed coordinates of stereopair No. 2 and the reference coordinates of stereopair No. 1, which means that the two point groups should coincide. However, this is not the case due to among other things minor errors of identifications and measurements. The differences between the jaw point coordinates indicate the accuracy of the method, expressed as a root mean square value.*) For the jaw points the magnitude of this value is found to be ± 0.2 to ± 0.3 mm (± 1/100 inch).

Proceeding to the tooth points we assume first that the tooth has not grown and consequently that the tooth points group in itself is unchanged during the investigation period. The group has, however, been moved and rotated after the first stereopair was taken. To obtain a fixed reference coordinate system we take that of the first stereopair. Using the same transformation coefficients as for the jaw points of the second stereopair we transform the tooth points of the second pair to the reference system. The same is done with stereopair No. 3 etc.

The differences in the x-, y- and z-coordinates for the tooth points — all transformed to the reference system — represent the movement of the tooth which is mainly composed of three translations and three rotations.

*) The term accuracy means that one set of coordinates is regarded as given and fixed. Because both sets of coordinates can be regarded as affected with errors of the same order of magnitude, the geometrical quality of each of the sets can be found from the root mean square valued in dividing by square root of 2 or approximately by 1.4. A certain correlation between the two sets of coordinates may be possible, however, and should always be noted. In case of a strong correlation the term precision might be better than accuracy as expression for the geometrical quality.

The geometrical quality of the result is influenced by several factors. The precision of the three-dimensional identification of the tooth point, especially of the enamel points which are very hard shadowed, is less than for the jaw points. Some of the tooth points are also outside the space enclosed by the jaw points, for which the transformation coefficients are calculated. This means that minor errors in the coefficients have a greater influence on some of the points.

A comparison of the results of the restitutions of the Berghagen and the Rönnerman stereopairs taken independently on the same day and transformed to the reference system give an indication of the geometrical quality of the method. The differences, calculated as three-dimensional distances, between the tooth point positions according to Berghagen and according to Rönnerman, range from 0.25 mm to 0.82 mm (1/100 inch—3/100 inch) with a root mean square value of ± 0.57 mm (2/100 inch). If better identification were achieved through sharper details in the tooth, the root mean square value could probably decrease to ± 0.3—± 0.4 mm (1/100 inch—3/200 inch).

An attempt was made to determine the growth of the tooth through calculation of the distances between the tooth points. The result is, however, not significant due to the fact that the possible growth is of the same magnitude as the above-mentioned quality of the entire procedure.

Generally speaking, the dominating source of error is the indistinctness of the identification in the X-ray stereomodels. The photogrammetric part of the procedure is more reliable. In any case, the geometrical quality obtained is encouraging and if better points could be secured in the jaw and in the tooth, the quality would be much higher and the measuring work less time-consuming.

The apparatus and the method were described earlier by *Berghagen & Hjelmström* (1951, 1956).

DESCRIPTION OF THE PHOTOGRAMMETRIC WORK

Berghagen and Rönnerman took stereopairs independently on 19th March 1958. The stereobase was 10 mm.

The stereopairs were studied under a stereoscope in order to select jaw and tooth points well identifiable all through the series. The tooth points were numbered 1—5, the jaw points 6—12.

The points were measured in a Zeiss stereocomparator (1939, 18×18 cm). An example of the record is given in Table 1; Lm is a fiducial mark. x and z are the coordinates of the points in the left picture and p_x the horizontal parallax (*Hallert*, 1956).

The coordinates (x, y, z) of each point were first calculated in a separate coordinate system for each stereopair (see *Berghagen & Hjelmström*, 1951, appendix).

Table 1

Image pair no. 6836—6837 Berghagen 31 VIII —57

$y_s = 252.83$ mm
$b = 10$ mm

Point	Comparator readings			Reduction					Calculated results		
	x	z	P_x	P_x	x_s	z_s	b+ px	μ	x_M	z_M	y_M
Lm.	98.00	401.68	17.30	0.00	—4.80	+50.20	10.00	1	—4.80	50.20	252.83
1	107.01	406.23	18.32	1.02	+4.21	54.75	11.02	0.9074	+3.82	+49.68	229.42
2	113.64	404.26	18.15	0.85	10.84	52.78	10.85	9217	9.99	48.65	233.03
3	105.98	398.56	18.02	0.72	3.18	47.08	10.72	9328	2.97	43.92	235.84
4	106.02	395.20	17.99	0.69	3.22	43.72	10.69	9355	3.01	40.90	236.52
5	114.24	413.54	18.28	0.98	11.44	62.06	10.98	9107	10.42	56.52	230.25
6	100.51	416.64	18.06	0.76	—2.29	+65.16	10.76	9294	—2.13	+60.56	234.98
7	103.13	417.20	18.01	0.71	+0.33	65.72	10.71	9337	+0.31	61,36	236.07
9	99.16	413.85	18.08	0.78	—3.64	62.37	10.78	9276	—3.38	57.85	234.53
10	104.15	411.47	18.46	1.16	+1.35	59.99	11.16	8961	+1.21	53.76	226.56
11	100.74	405.02	18.12	0.82	—2.06	53.54	10.82	9242	—1.90	49.48	233.67
12	100.41	402.41	18.10	0.80	—2.39	50.93	10.80	9259	—2.21	47.16	234.10

The coordinate transformation to a common reference system — that of the first Berghagen stereopair — was accomplished as an affine transformation, Table 2, according to the following formulae:

$$\begin{aligned} X &= ax + by + cz + C_x \\ Y &= dx + ey + fz + C_y \\ Z &= gx + hy + jz + C_z. \end{aligned} \qquad (1)$$

By choosing the gravity centre of the transformation point group (the jaw points) as origin we get $C_x = C_y = C_z = 0$. In-

Table 2

Affine coordinate-transformation in space

Reference system (X Y Z): Exp. 19 VI -57 Berghagen No. 6780—6781

System to be transformed (x y z): Exp. 31 VIII -57 Berghagen No. 6836—6837

Transformation formulae:

$X = +1.19222\,x + 0.06127\,y - 0.04722\,z - 11.947$

$Y = -0.22426\,x + 0.20249\,y + 0.04392\,z + 191.681$

$Z = -0.18400\,x - 0.22164\,y + 1.08183\,z + 48.530$

Jaw points	Coordinates 31. VIII 1957 mm			Coordinates 19. VI 1957 Given mm			Calculated			Difference		
	x	y	z	X_G	Y_G	Z_G	X_B	Y_B	Z_B	X	Y	Z
6	—2.13	234.98	60.56	—2.65	242.19	61.97	—2.95	242.40	62.36	—0.30	+0.21	+0.39
7	+0.31	236.07	61.36	—0.12	242.19	62.67	—0.01	242.11	62.53	+0.11	—0.08	—0.14
9	—3.38	234.53	57.85	—4.57	242.64	60.05	—4.34	242.47	59.75	+0.23	—0.17	—0.30
10	+1.21	226.56	53.76	+0.83	239.66	56.26	+0.84	239.65	56,25	+0.01	—0.01	—0.01
11	—1.90	233.67	49.48	—2.21	241.48	50.61	—2.23	241.60	50,62	—0.02	+0.12	+0.01
12	—2.21	234.10	47.16	—2.44	241.71	48.02	—2.47	241.65	48,07	—0.03	—0.06	+0.05
							Root mean square value			0.16	0.13	0.21
Tooth points												
1	3.82	229.42	49.68	+4.20	239.43	52.25	+4.32	239.46	50.72	+0.12	+0.03	—1.53
2	9.99	233.03	48.65	10.22	240.11	50.90	11.94	238.76	47,67	+1.72	—1.35	—3.23
3	2.97	235.84	43.92	3.30	241.71	45.30	3.97	240.70	43,23	+0.67	—1.01	—2.07
4	3.01	236.52	40.90	3.42	242.19	42.26	4.20	240.70	39,80	+0.78	—1.49	—2.46
5	10.42	230.25	56.52	10.49	238.75	58.19	11.91	238.45	56,73	+1.42	—0.30	—1.45

stead of using the minimum 4 points for the calculation of the transformation coefficients a—j, 6 points were used. The adjustment operation, based on the presence of redundant observations and the method of the least squares,*) increased the accuracy and also gave the root mean square value (in millimeters) of the discrepancies in the transformation points as found overleaf.

*) An adjustment operation according to the method of the least squares means that such values of the coefficients of (1) shall be determined that make the sum of the squares of the residual coordinate differences a minimum.

Date	Berghagen x mm	Berghagen y mm	Berghagen z mm	Rönnerman x mm	Rönnerman y mm	Rönnerman z mm
31st Aug. 1957	0.16	0.13	0.21	0.06	0.19	0.18
18th Dec. 1957	0.18	0.10	0.13	0.09	0.26	0.17
19th March 1958	0.14	0.05	0.13	0.11	0.44	0.18
Root mean square value B + R	0.13	0.23	0.17			

Table 3

Coordinates in the reference system and the differences in relation to 19. VI. 1957. Berghagen.

	Point no.	x mm	y mm	z mm	Dx mm	Dy mm	Dz mm	DS mm
19. VI. 1957	1	4.20	239.43	52.25				
	2	10.22	240.11	50.90				
	3	3.30	241.71	45.30				
	4	3.42	242.19	42.26				
	5	10.49	238.75	58.19				
31. VIII. 1957	1	4.32	239.46	50.72	+0.12	+0.03	—1.53	1.54
	2	11.94	238.76	47.67	+1.72	—1.35	—3.23	3.90
	3	3.97	240.70	43.23	+0.67	—1.01	—2.07	2.40
	4	4.20	240.70	39.80	+0.78	—1.49	—2.46	2.98
	5	11.91	238.45	56.73	+1.42	—0.30	—1.46	2.06
18. XII. 1957	1	4.57	239.66	50.12	+0.37	+0.23	—2.13	2.17
	2	11.77	238.67	47.56	+1.55	—1.44	—3.34	3.95
	3	3.79	240.76	43.24	+0.49	—0.95	—2.06	2.32
	4	3.84	240.94	40.07	+0.42	—1.25	—2.19	2.56
	5	—	—	—	—	—	—	—
19. III. 1958	1	3.89	239.19	49.59	—0.31	—0.24	—2.66	2.69
	2	11.22	238.13	47.21	+1.00	—1.98	—3.69	4.31
	3	3.98	240.58	42.29	+0.68	—1.13	—3.01	3.29
	4	4.35	240.45	38.99	+0.93	—1.74	—3.27	3.82
	5	—	—	—	—	—	—	—

The system of "Rönnerman" transformed to the reference system gives the following values: 0.14, 0.08, 0.25.

The value of the coefficients a—j for each transformation were inserted in the formulae (1) and three transformations of the tooth points were accomplished with the results shown in Table 3 for Berghagen and in Table 4 for Rönnerman. The movements were also calculated as coordinate differences (Dx, Dy, Dz) as well as three-dimensional (DS) and are shown in the same tables.

Table 4

Coordinates in the reference system and the differences in relation to 19. VI. 1957. Rönnerman.

	Point no.	x mm	y mm	z mm	Dx mm	Dy mm	Dz mm	DS mm
31. VIII. 1957	1	4.18	239.32	50.55	—0.02	—0.11	—1.70	1.70
	2	11.56	238.46	47.40	+1.34	—1.65	—3.50	4.09
	3	3.55	240.46	43.07	+0.25	—1.25	—2.23	2.57
	4	3.87	240.73	39.67	+0.45	—1.46	—2.59	3.01
	5	11.63	237.79	56.66	+1.14	—0.96	—1.53	2.14
18. XII. 1957	1	4.03	239.30	49.93	—0.17	—0.13	—2.32	2.33
	2	11.33	238.12	47.30	+1.11	—1.99	—3.60	4.26
	3	3.86	240.55	42.65	+0.56	—1.16	—2.65	2.95
	4	4.12	240.94	39.30	+0.70	—1.25	—2.96	3.29
	5	11.75	237.33	56.87	+1.26	—1.42	—1.32	2.31
19. III. 1958	1	4.19	239.69	49.71	—0.01	+0.26	—2.54	2.55
	2	11.49	238.46	46.92	+1.27	—1.65	—3.98	4.49
	3	3.87	240.37	42.22	+0.57	—1.34	—3.08	3.41
	4	4.33	240.57	38.69	+0.91	—1.62	—3.57	4.02
	5	—	—	—	—	—	—	

A comparison of the movements according to Berghagen and Rönnerman gives the differences in Table 5. These values are an indication of the geometrical quality of the method.

The results of a calculation of the possible growth of the tooth is shown in Table 6. No significant tendency can be traced.

Table 5

The differences between the coordinates of Berghagen and Rönnerman

	Point no.	Dx mm	Dy mm	Dz mm	DS mm
31. VIII. 1957	1	+0.14	+0.14	+0.17	0.26
	2	+0.38	+0.30	+0.27	0.55
	3	+0.42	+0.24	+0.16	0.51
	4	+0.33	—0.03	+0.13	0.36
	5	+0.28	+0.66	+0.07	0.72
18. XII. 1957	1	+0.54	+0.36	+0.19	0.68
	2	+0.44	+0.55	+0.26	0.75
	3	—0.07	+0.21	+0.59	0.63
	4	—0.28	0.00	+0.77	0.82
	5	—	—	—	—
19. III. 1958	1	—0.30	—0.50	—0.12	0.60
	2	—0.27	—0.33	+0.29	0.52
	3	+0.11	+0.21	+0.07	0.25
	4	+0.02	—0.12	+0.30	0.32
	5	—	—	—	—

Table 6

Calculation of the possible growth of the tooth in mm

Berghagen Distance	19. VI. 1957	31. VIII. 1957	18. XII. 1957	19. III. 1958
1—2	6.21	7.22	6.43	6.77
1—4	10.39	11.32	10.20	10.00
2—4	11.19	11.00	11.17	10.89
3—4	3.08	3.10	3.19	3.23
5—4	17.76	18.39	—	—
Rönnerman				
1—2	6.67	7.22	6.68	7.36
1—4	9.96	10.23	10.18	11.07
2—4	10.95	11.13	10.94	10.62
3—4	2.91	3.10	3.13	3.58
5—4	19.09	18.73	—	—

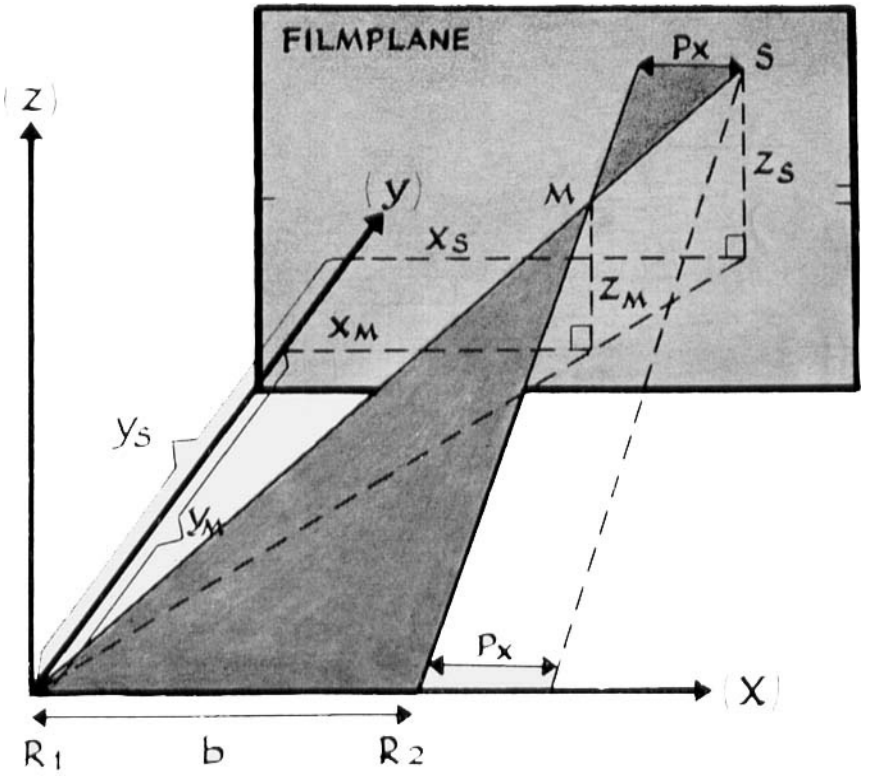


Fig. 3

The coordinate system consists of three mutually perpendicular axes (x), (y), and (z) with the origin at the focus R_1 and so placed that the axis (y) is perpendicular to the image plane, and the axis (x) passes through the focus R_2. The ray from R_1 that reproduces a certain object point is represented by the two vectors M and S, which begin in R_1 and end in the object and image points, respectively. (The letters M and S are placed in the figure at the end of the respective vectors). This is expressed vectorially by the formula $M = \mu S$, where μ is a number indicating the ratio of the magnitudes of M and S.

This vector expression corresponds to three coordinate expressions

$x_M = \mu x_s$
$y_M = \mu y_s$
$z_M = \mu z_s$

The value of the ratio (μ) is obtained from the figure when a construction line is drawn from the point S parallel to the ray from R_2 that reproduces the object point M in the image plane at a distance p_x from S. We then have

$$\mu = \frac{b}{b + p_x}.$$

To determine M it is necessary to know b, p_x, x_s, y_s and z_s. b and y_s are constants of the apparatus. p_x, x_s and z_s are measured on the radiograph for a particular object point; for this measurement the inner orientation must be known, so that the coordinate system can be placed as indicated.

RESULTS

The positions of the measured points and the movements of the tooth points (according to Berghagen) are shown in Fig. 4. The x-components of the movements are in the mesio-distal direction, the y-components in the palato-labial direction, and the z-components mean a movement towards the occlusal plane.

In order to improve the clarity of the presentation of the three-dimensional movements of the tooth points, stereoscopic sketches were drawn. The paper surface is to be regarded as parallel with the xz-plane which is parallel with the film plane of the first stereomodel (see Fig. 3). From the coordinates, Tables 3—4, Diagrams 1—5, as well as from the stereosketches, Figs. 5—8, it is

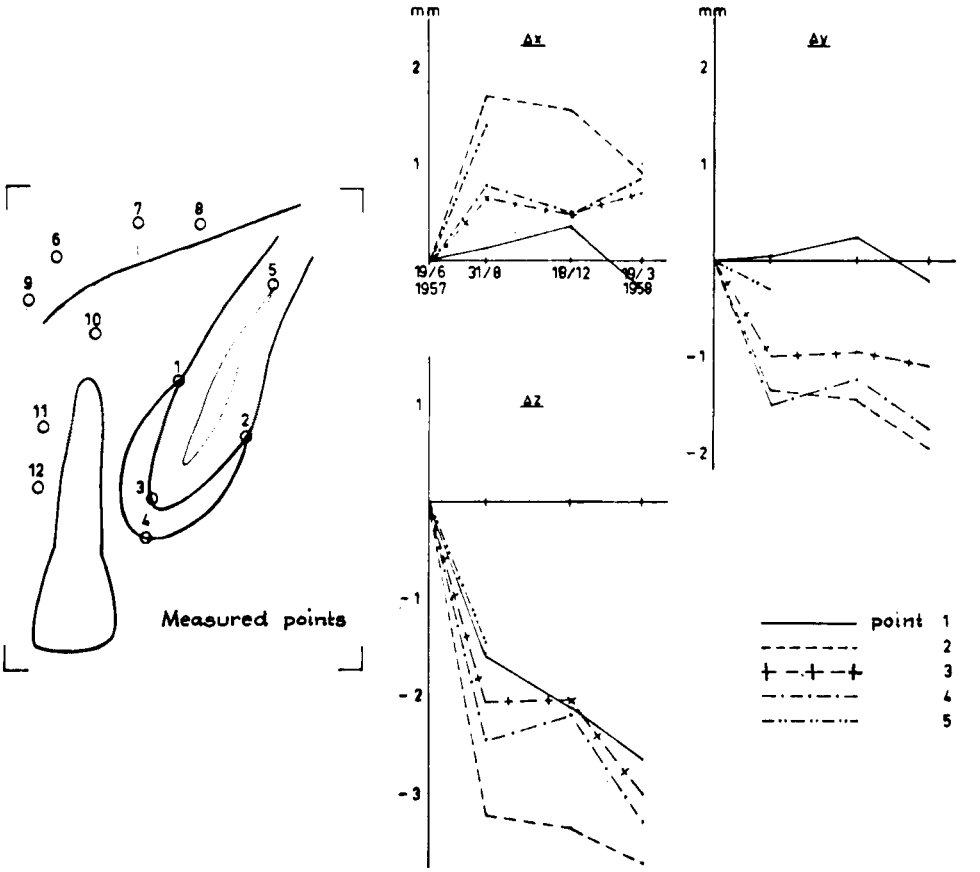


Fig. 4.

obvious that the tooth moved a longer distance between the first and the second examination than during the later intervals. This was due to the application to the tooth of a spring force during the former period. During the first period the tooth moved to-

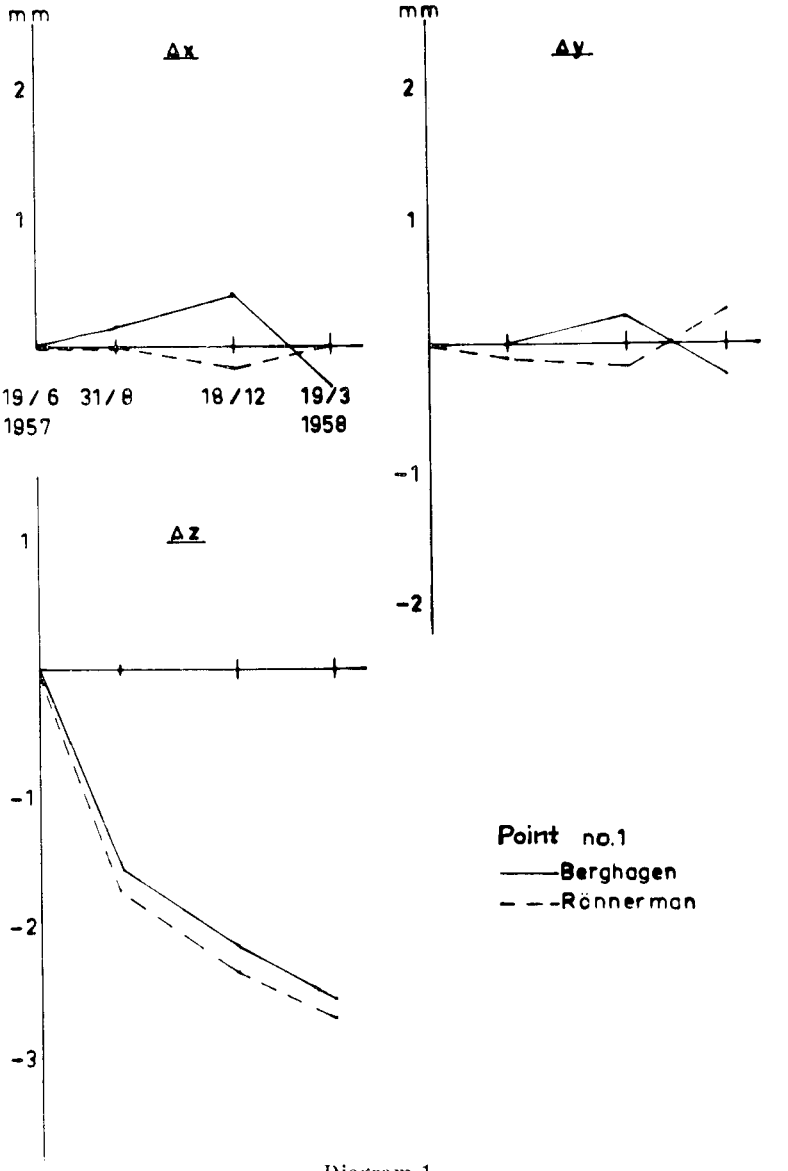


Diagram 1.

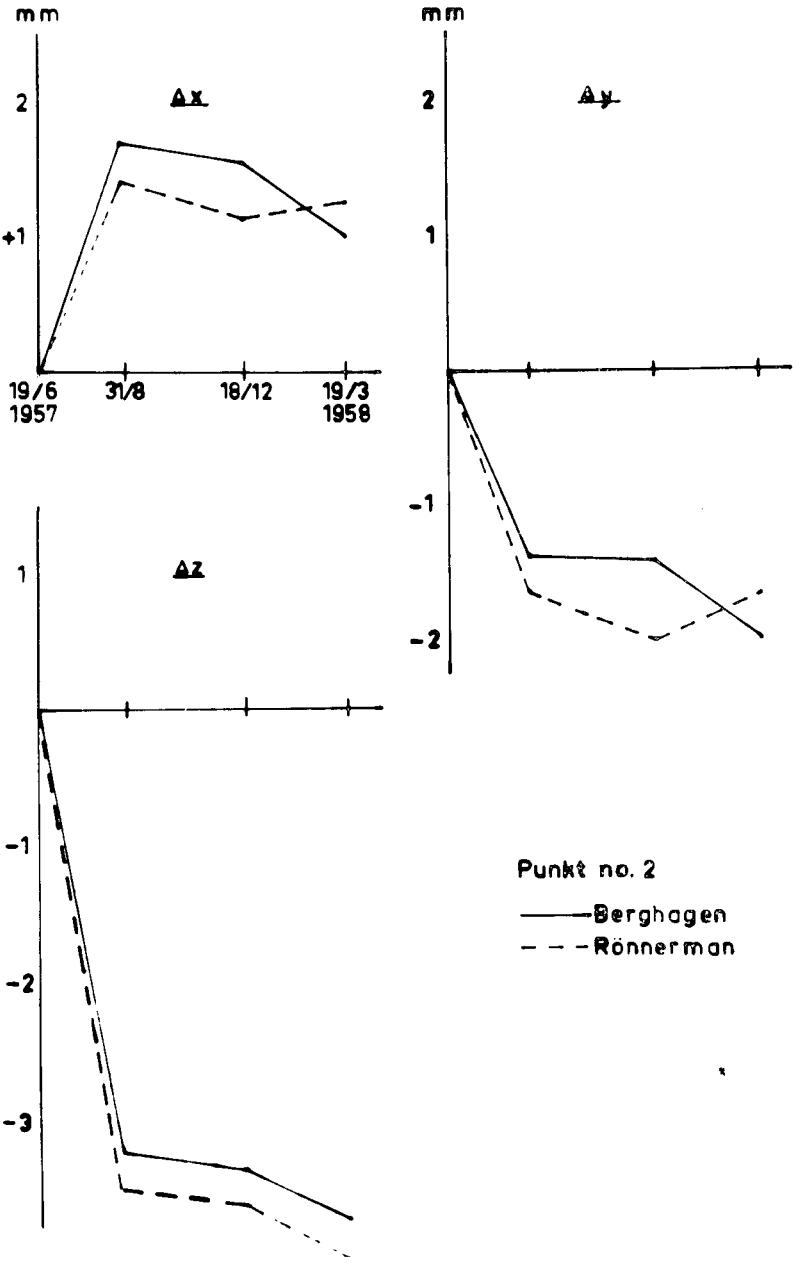
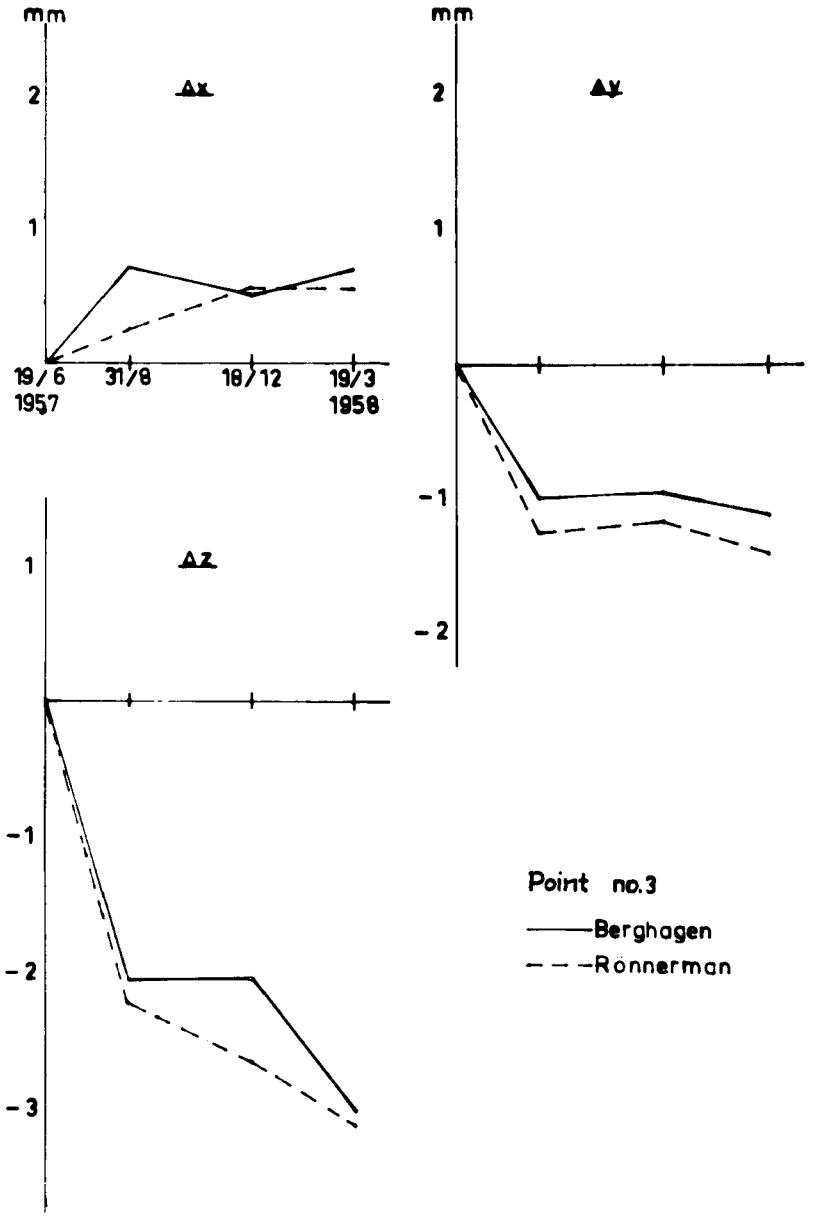

mm
Δx
2
+1
19/6
1957
31/8
18/12
19/3
1958
mm
Δy
2
1
-1
-2
Δz
1
-1
-2
-3
Punkt no. 2
Berghagen
Rönnerman

Diagram 2.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Δx
19/6
1957
31/8
18/12
19/3
1958
mm
2
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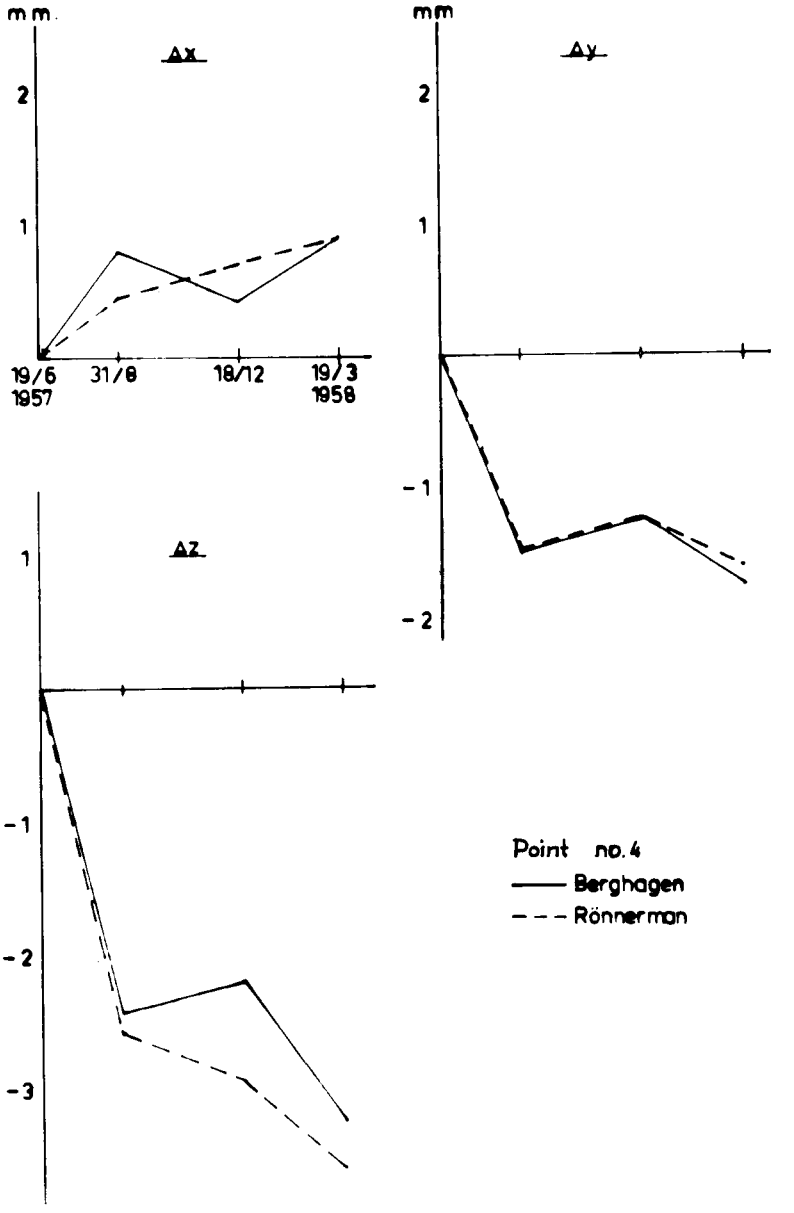
Δy
-1
-2
1
Δz
-1
-2
-3
Point no.3
Berghagen
Rönnerman

Diagram 3.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1958
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Δz
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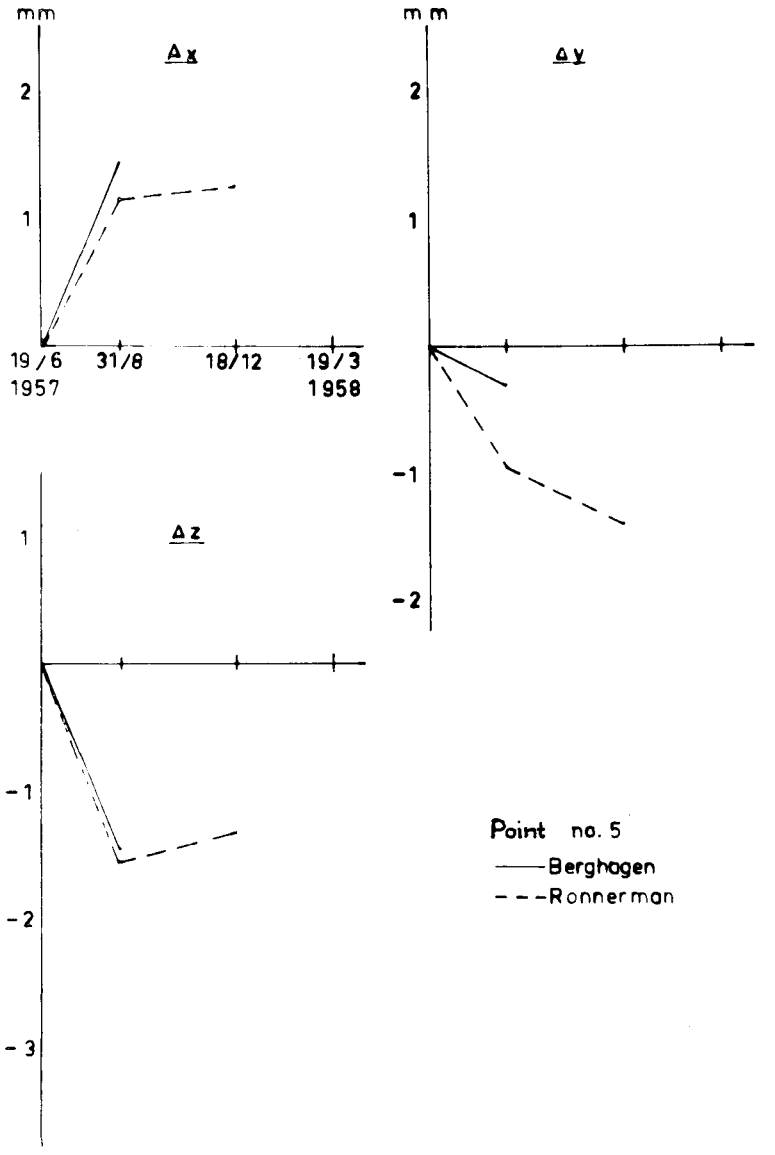
-2
-3
Point no. 4
Berghagen
Rönnerman

Diagram 4.


mm
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1958
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Δz
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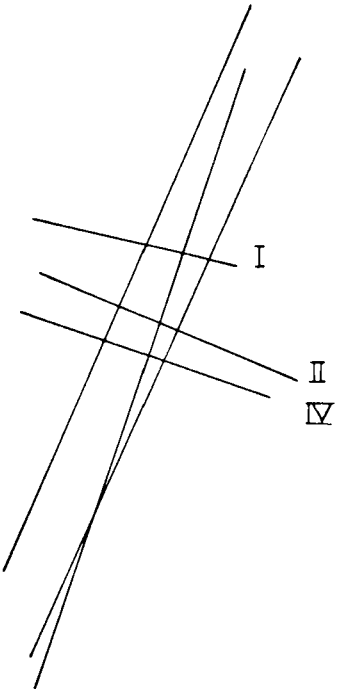
-2
-3
Point no. 5
Berghagen
Ronnerman

Diagram 5.



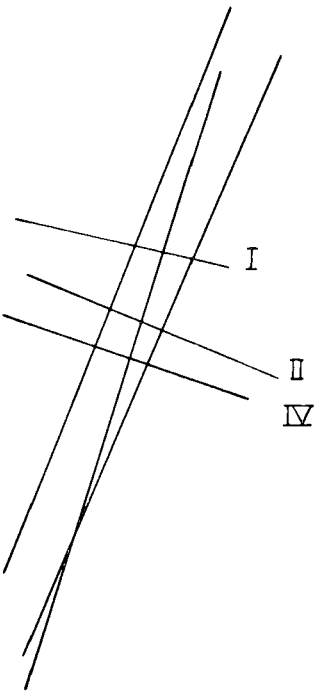
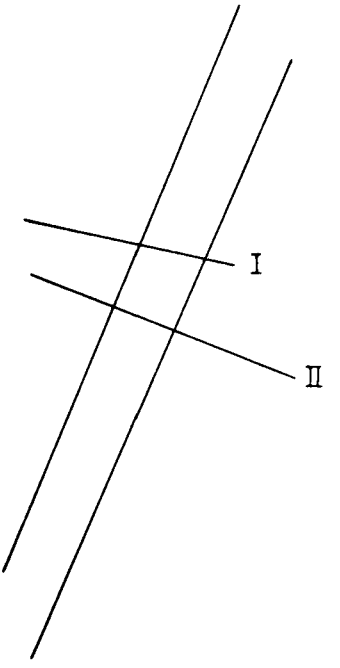


Fig. 5.



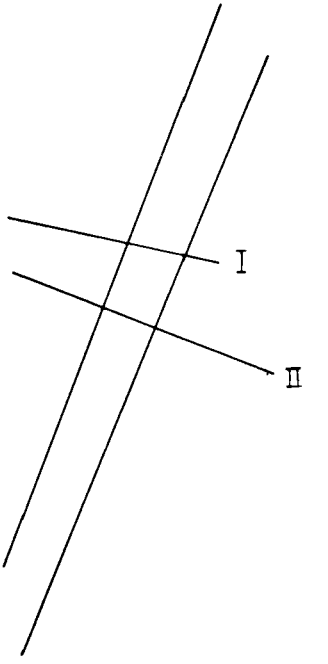


Fig. 6.

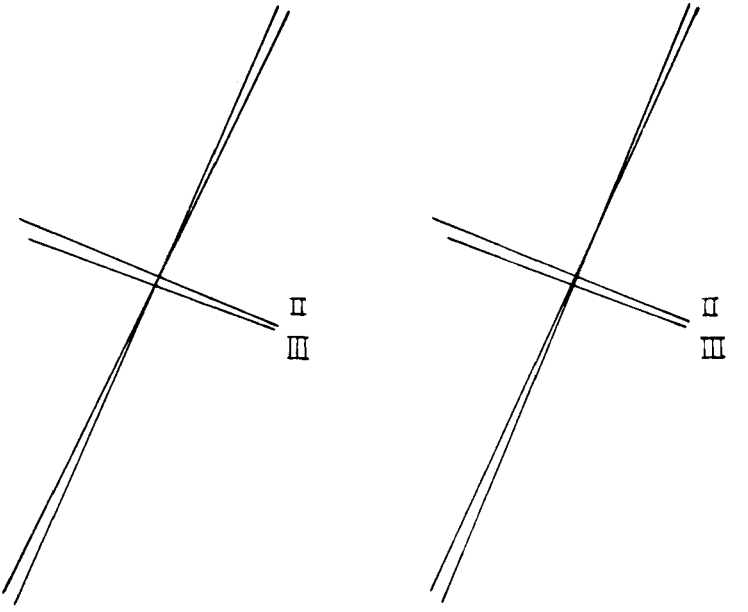


Fig. 7.

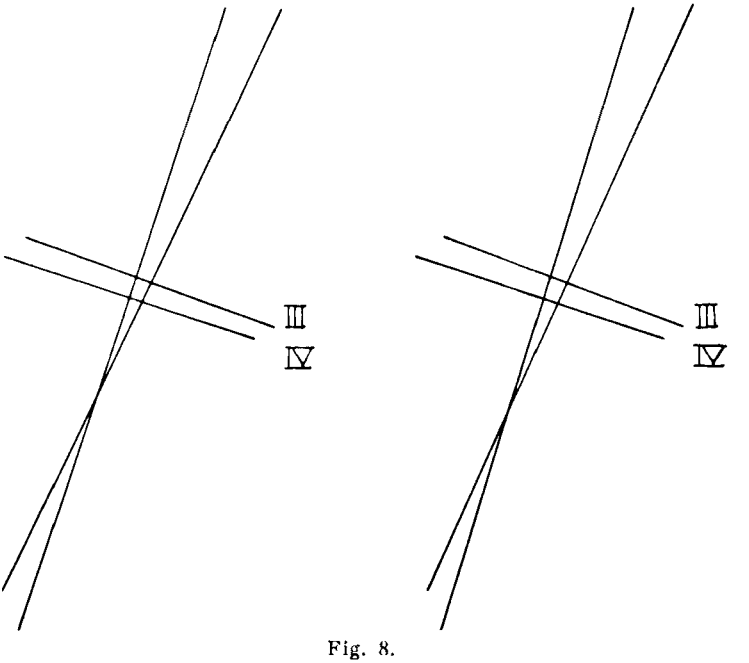


Fig. 8.

wards the occlusal plane, but also rotated a little so that the mesial enamel-cement-point moved in a palatal direction simultaneously with a general movement of the tooth in a labial direction. The crown had approached the labial side more than had the root. The tooth, as a whole, had also moved in a distal direction. As already mentioned, the movement between the second and the third examination was much smaller than during the first period, but it should be observed that the crown returned a little towards the palatal side and also showed a small movement in the mesial direction. Further on, a rotation was observed causing the mesial enamel-cement-point to move more in a palatal direction than the distal point in a labial direction. During the third period the movement towards the occlusal plane continued. The crown moved in a distal direction, simultaneously with a labially directed movement of the tooth in general.

Figs. 1—2 show that systematically performed X-ray photography resulted in a good conformity as to the perspective between two full series of investigations, in spite of the fact that the two investigators on each occasion used different impressions for the fixation of the film-holder to the jaw.

The diagrams show the movements of each point as determined by Berghagen and Rönnerman. The conformity is good.

CONCLUSIONS

1. It is quite possible to determine by means of X-ray photogrammetry in a non-subjective way, position variations for an object in the jaw area.

2. Even small variations in the translational and rotational movements can be detected.

3. A determination of small changes of dimensions, as for instance growth of a tooth, calls for a still greater accuracy, but may be possible after a further refinement of the entire procedure.

4. The fixed points should surround the moving object as much as possible.

5. It is of the greatest importance that the points to be measured are well defined.

6. As the points are "shadows" in X-ray photographs, it is important that the perspective is as nearly the same as possible all through a series, in order to fulfill the requirement in point 5.

7. Good perspective conformity can be obtained even when investigators differ in a series provided an apparatus-fixed system is used and the working procedure standardized.

SUMMARY

This work is an X-ray photogrammetric investigation of the movements of impacted upper canines in the jaws when an orthodontic procedure is applied for correction of their positions.

Completely independently but with the same apparatus and working procedure, two investigators took stereoscopic X-ray photographs with a base of 10 mm. In broad lines the research work was carried out as follows:

The first time a patient was to be photographed, one of the authors (Berghagen) placed the filmholder with impression compound so that the impacted tooth had a central position in the picture. The transversal axis of the film-holder was placed as perpendicularly as possible to the long axes of the adjacent teeth. The stereopictures were taken with such a variation of the outer orientation that focus moved altogether 10 mm parallel with the plane of the film. The relationship between film-holder and arm was unchanged (0-position). The impression was then destroyed and one of the authors (Rönnerman) repeated the photographic procedures following the same rules. Next time the patient was to be photographed, the same double procedure was followed. The first photographs were studied beforehand in order to guide the positioning of the film-holder. The same procedure was followed all through the checking series.

The stereophotogrammetric study, illustrated by diagrams, sketches and tables, shows that it is quite possible to follow the position variations through translational and rotational movements. Good conformity was achieved between the results of the two investigators.

Acknowledgement

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RÉSUMÉ

DÉTERMINATION DES MOUVEMENTS DES CANINES SUPÉRIEURES INCLUSES PAR RADIO-MENSURATIONS

Le présent travail rend compte d'une étude par radio-mensuration des mouvements dans les maxillaires des canines supérieures incluses lorsqu'un appareillage orthodontique est appliqué pour leur correction.

Entièrement idépendamment l'un de l'autre, mais avec le même appareil et suivant le même procédé, les deux examinateurs ont pris les radiographies stéréoscopiques avec une base de 10 mm. Dans leurs grandes lignes, les travaux ont été menés de la manière suivante.

La première fois qu'un patient devait être radiographié, l'un de nous (Berghagen) plaçait le porte-film avec le stents de manière à ce que la dent incluse occupe une position centrale sur l'image. L'axe transversal du porte-film était placé aussi perpendiculairement que possible par rapport aux axes longitudinaux des dents voisines. Les clichés stéréoscopiques étaient pris en variant l'orientation externe de telle manière que le foyer ait subi un déplacement total de 10 mm parallèlement au plan du film. Le rapport entre le porte-film et le bras restait inchangé (position 0). L'empreinte de stents était ensuite détruite et l'un de nous (Rönnerman) reprenait les radiographies en suivant les mêmes règles. La fois suivante où le patient devait être radiographié, le même double procédé était employé. Les premières radiographies avaient été étudiées auparavant pour guider la mise en place du porte-film. Le même procédé a été employé dans toutes les séries de contrôles.

L'ensemble des radio-mensurations stéréoscopiques, illustré par des diagrammes, des croquis et des tableaux, montre qu'il est

parfaitement possible de suive les variations de position pendant les mouvements de translation et de rotation. Une conformité satisfaisante a été obtenue entre les résultats des deux examinateurs.

ZUSAMMENFASSUNG

BESTIMMUNG DER BEWEGUNGEN RETINIERTER OBERER ECKZÄHNE MITTELS RÖNTGENPHOTOGRAMMETRISCHEN METHODEN

Die Arbeit berichtet über eine Untersuchung der Bewegungen von retinierten oberen Eckzähnen nach Einsetzen einer orthodontischen Behandlung. Die Messungen sind mit Hilfe von Röntgenphotogrammetrie durchgeführt worden.

Zwei Forscher haben vollständig unabhängig von einander aber mit demselben Apparat und nach demselben Verfahren stereoskopische Röntgenbilder mit einer Basis von 10 mm aufgenommen. Die Untersuchungen sind wie folgt durchgeführt worden.

Bei der ersten Röntgenaufnahme hat einer von den Verfassern (Berghagen) den mit Abdruckmasse beschickten Filmhalter so eingestellt, dass der Zahn eine zentrale Lage im Bild erhielt. Die Kreutzachse des Filmhalters wurde möglichst gut orthogonal zur Längsachse der angrenzenden Zähne eingestellt. Die Stereobilder wurden mit so einer Variation der äusseren Orientierung aufgenommen, dass das Projektionszentrum (Focus) 10 mm parallel mit der Filmebene bewegt wurde. Die Relation zwischen Filmhalter und Halterschaft war unverändert (0-Lage). Nach der Zerstörung des Abdruckes hat der andere Verfasser dieses Aufnahmeverfahren nach gleichen Prinzipien wiederholt. Bei der darauf folgenden Untersuchung wurde dieses "Doppelverfahren" wiederholt. Um die Einstellung des Filmhalters zu erleichtern wurden die ersten Aufnahmen studiert. Dasselbe Verfahren ist dann für die ganze Untersuchung benutzt worden.

Das stereophotogrammetrische Verfahren, mit Diagrammen, Skizzen und Tafeln erläutert, zeigt, dass es möglich ist die Lagevariationen zu bestimmen. Gute Übereinstimmung ist hinsichtlich der Ergebnissen der beiden Verfassern gefunden worden.

REFERENCES

Berghagen, N., 1951: *Photogrammetric principles applied to intra — oral radiodontia.* Thesis. Stockholm.

Berghagen, N. & P. Hjelmström, 1954: Intra-oral röntgenfotografering i belysning av tredimensionell geometrisk beskrivning. Svensk tandläk.-T. *47:* 135.

—»— 1956: Three-dimensional intra-oral radiography. Acta odont. scand. *14:* 189.

—»— 1956: Radiographic measurements of bone changes in the alveolar limbus in a case of marginal periodontal disease. Acta odont. scand. *14:* 221.

Berghagen, N., 1956: Metodik för lägesbestämning och behandling av retinerade överkäkshörntänder. Sverig. Tandläk.-Förb. Tidn. *17:* 448.

Hallert, B., 1964: *Fotogrammetri.* Kungl. Boktr. P. A. Norstedt & Söner, Stockholm.

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