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THE EFFECT OF DENTURE WEARING ON FACIAL MORPHOLOGY

A 7-YEAR LONGITUDINAL STUDY

by

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INTRODUCTION

The long-term wearing of complete dentures causes a marked reduction in morphologic face height due to resorptive changes in the alveolar processes, as was shown in a previous longitudinal investigation (*Tallgren,* 1966). Whether this process of reduction would cause morphological changes in basal parts of the jaws or affect other parts of the facial skeleton has not been elucidated on a longitudinal basis.

The opinions regarding such changes put forward in text-books and numerous articles have mainly concerned remodelling of the mandibular gonial region, the different views being based in part on findings from cranial material and in part on cross-sectional roentgenographic studies on living subjects.

According to these findings (*Kieffer,* 1908; *Hellman,* 1927; *Hrdlicka,* 1940; *Rogers & Applebaum,* 1941; *Keen,* 1945; *Kettunen,* 1965; *Dorier & Cimasoni,* 1965), the size and shape of the mandible is considered to remain fairly stable during adult age as long as the natural dentition is preserved, whereas the eden-

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lulous stage is held to bring out an increase in the gonial angle. *Lönberg* (1951), by comparing young and old individuals both with and without teeth, found an increase in the gonial angle in the young edentulous subjects only, most of whom were denture wearers, whereas such remodelling changes due to loss of teeth were not observed in the old age group.

Rogers & Applebaum (1941) in a study of skull material and *Keen* (1945) by comparing dentulous and edentulous individuals, came to the conclusion that the decrease in occlusal vertical dimension due to loss of teeth or wearing of dentures will cause a flattening of the gonial angle or even more severe remodelling of the mandible. The response of the masseter and the internal pterygoid muscles to the alteration in the intermaxillary relationship would account for such remodelling changes. However, cross-sectional data, especially from skull material, are difficult to evaluate owing to the wide range of variation within the test groups and lack of information on denture wearing.

While some follow-up studies have been reported on the response of the alveolar processes to different kinds of prosthetic treatment (*Lisowski,* 1944; *Atwood,* 1957; *Watt,* 1960; *Johnson,* 1963, 1964 a, b, c; *Wictorin,* 1964; *Carlsson & Persson,* 1965), there is little longitudinal information regarding the effect of protracted denture wear on the facial morphology. *Hedegård* (1962) in a 3-year roentgenographic check of individuals provided with immediate maxillary dentures reported a significant increase in the gonial angle and also in upper facial dimensions and anterior skull base. *Johnson* (1963, 1964 a, b, c) in a 1-year follow-up check of subjects treated with different types of maxillary dentures, found the relationship between the posterior part of the bony palate and the anterior skull base unchanged. Furthermore, *Heath* (1966) in a cross-sectional study of adults representing various dental conditions, found no relationship between upper facial dimensions and the number of years the subjects had been edentulous or had been wearing full upper dentures.

The present longitudinal study aims to ascertain whether resorptive changes in the alveolar processes and resultant alterations in jaw relationship following a 7-year period of denture wearing affect basal parts of the mandible and the upper facial skeleton or cause morphological changes in the cranial base.

Table I. *Distribution of the test subjects according to age, sex and method of treatment*

Age at the pre-extraction stage	Group A Complete denture wearers			Group B Partial denture wearers		
	Female	Male	Total	Female	Male	Total
20—29	1		1			
30—39	1		1	4		4
40—49	3	1	4	4		4
50—59	2	1	3	2	1	3
60—69	2		2			
Total	9	2	11	10	1	11
Mean age			47.6			41.9

MATERIAL AND METHODS

The present roentgenographic analysis was performed on cephalometric profile films from a series of 11 edentulous individuals provided with complete dentures and 11 partially edentulous subjects provided with a full upper and a partial lower denture. The reduction in face height of the test subjects had previously been examined during a 7-year period of denture wear (*Tallgren*, 1957, 1966).

The prosthetic treatment was performed at the Institute of Dentistry, University of Helsinki; the details are set forth in the above-mentioned publications. It should be noted that the treatment undertaken was of the conventional type, the dentures being constructed 2—3 months after completed extraction. All the dentures were fabricated using porcelain teeth.

The distribution of the test subjects according to age, sex and method of treatment is shown in Table I. The age distribution in the two groups is also illustrated graphically in Fig. 1. In accordance with previous definitions the two test groups were denoted Complete denture wearers (Group A) and Partial denture wearers (Group B). None of the test subjects had had their dentures relined or remade during the 7-year period of observation.

Roentgenographic procedure

The standardized lateral roentgenographic cephalometric recordings were obtained with the subjects positioned in a Björk's

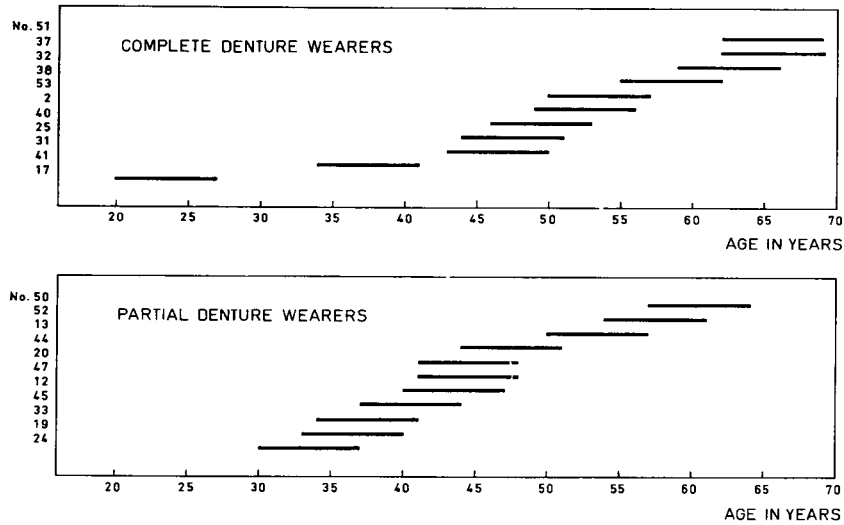

Fig. 1. Age distribution of the test subjects. Each line indicates the age of the subject at the initial stage of observation and after 7 years.

cephalostat; the details of which have been reported elsewhere (*Tallgren*, 1957, 1966). The enlargement of the structures in the median plane amounted to 6.6 %. No adjustments have been made for this enlargement.

The present study comprised the following stages of observation:

(a) Before extraction of the teeth
(b) After prosthetic treatment
(c) After 7 years of denture wear.

The films from the above-mentioned investigations consisted for each stage of one profile film taken in the occlusal position and 2—4 films taken in the rest position of the mandible. The rest position exposures at stages (b) and (c) were made with and without the dentures in the mouth. For each test subject the total number of films from the 3 stages of observation amounted to 12.

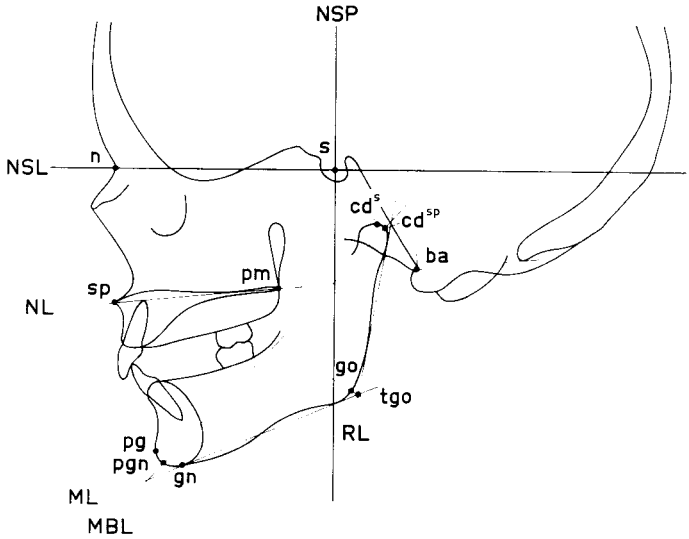

Fig. 2. Reference points and lines on the profile cephalometric films. Redrawn from *Björk* (1960).

Linear and angular measurements

DEFINITIONS OF MEASUREMENTS

The reference points and lines were defined according to *Björk* (1960) and *Solow* (1966) with minor modifications in some instances. The reference points and lines are listed in Table II and illustrated in Fig. 2.

The linear and angular variables are listed and interpreted in Table III. The shape of the mandibular base, expressed in terms of the angles β and RL-ML is illustrated in Fig. 3.

The variables 1—13 were studied in order to estimate changes in size, shape and position of craniofacial elements, which due to their relationship to the denture bearing structures might be affected. In addition these variables were studied in order to evaluate possible continued growth in the craniofacial structures concerned. The variables 14—18 were included for the assessment of changes in jaw relationship as a result of the prosthetic treatment and protracted denture wear. A special analysis, reviewed in the following section, was made of the height of the mandibular and maxillary alveolar processes (variables 19 and 20). In addi-

Table II. *Reference points and lines on the cephalometric films*

Reference points	
Basion (ba)	The normal projection of the anterior border of the occipital foramen (endobasion) on the occipital foramen line.
Condylion (cd^s)	The most superior point on the condylar head.
Condylion (cd^{sp})	The most superior and posterior point on the condylar head.
Gnathion (gn)	The lowest point on the mandibular symphysis.
Gonion (go)	The point on the bony contour of the gonial process determined by bisecting the angle RL-ML.
Gonion, tangent point (tgo)	The intersection between the ramus line (RL) and the mandibular line (ML).
Nasion (n)	The most anterior point on the fronto-nasal suture.
Pogonion (pg)	The most anterior point on the mandibular symphysis.
Prognathion (pgn)	The point on the mandibular symphysis farthest from cd^{sp}.
Pterygomaxillare (pm)	The point of intersection between the contour of the nasal floor and the posterior contour of the maxilla.
Sella (s)	The centre of the sella turcica. The upper limit of sella turcica is defined as the line joining tuberculum sellae and dorsum sellae.
Spinal point (sp)	The apex of the anterior nasal spine.
Reference lines	
Mandibular base line (MBL)	The line through cd^{sp} and *pgn*.
Mandibular line (ML)	The tangent to the lower border of the mandible through *gn*.
Nasion-sella line (NSL)	The line through *n* and *s*.
Nasal line (NL)	The line through *sp* and *pm*.
Nasion-sella perpendicular (NSP)	The line through *s* perpendicular to NSL.
Ramus line (RL)	The tangent to the posterior border of the mandibular ramus and the condylar head.

Table III. *Linear and angular variables*

No.	Variable	Interpretation
1	n-s	Anterior length of cranial base.
2	s-ba	Posterior length of cranial base.
3	n-s-ba	Flexion of cranial base.
4	n-sp	Anterior height of maxillary body.
5	s-pm	Posterior height of maxillary body.
6	sp-pm	Length of nasal floor (maxillary base).
7	NSL-NL	Inclination of nasal floor (maxillary base) to anterior cranial base.
8	s-n-sp	Position of nasal spine in relation to anterior cranial base. Sagittal relationship of maxillary body to anterior cranial base.
9	cd^{sp}-pgn	Length of mandibular base[r].
10	pg-go	Length of mandibular body[r].
11	cd^{s}-go	Ramal height[r].
12	RL-ML	Gonial angle[r].
13	β	Mandibular base angle[r].
14	NL-ML	Inclination of mandible to nasal floor.
15	n-gn	Total anterior face height.
16	NSL-ML	Inclination of mandible to anterior cranial base.
17	NSL-MBL	Inclination of mandible to anterior cranial base.
18	s-n-pg	Sagittal relationship of mandible to anterior cranial base (mandibular prognathism).
19	Anterior height of mandibular process[r].	
20	Anterior height of maxillary process[r].	

[r] *Measured on rest position films.*

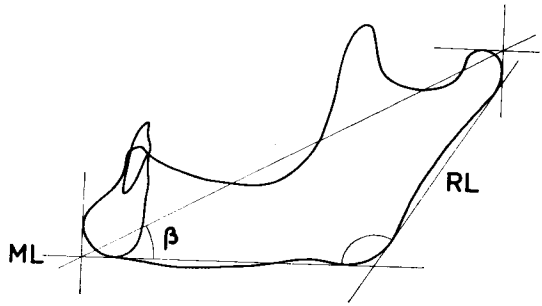

Fig. 3. The shape of the mandibular base in terms of the β-angle (*Lindegård*, 1953) and the gonial angle (RL-ML).

tion, a check of the bony contours, not included in the present measurements, was made by the aid of tracings and by superimposition of the films.

Regarding the variables 4—8, it should be noted that the upper face was defined as the area bounded cranially by n-s and caudally by sp-pm. The reference point *ss*, commonly employed in subjects with natural dentitions, was regarded less suitable owing to resorptive changes in the maxillary process (*Coccaro & Lloyd*, 1965; *Richardson*, 1965). The same applies to the reference point *sm* on the mandibular process.

METHOD OF MEASUREMENTS

All measurements with the exception of the mandibular base dimensions and the height of the alveolar processes were made on the occlusal films. The mandibular base dimensions (variables 9—13) were measured on the rest position films, since the contours of the condyles were often more distinct on those films. For stages (b) and (c) the rest position exposures without dentures were used. As an additional check of measuring points and of the bony contours, the rest position films with the dentures were used, and also duplicate films of the rest position without dentures.

All linear and angular measurements were made directly on the films with the aid of two transparent cellophane sheets: one printed with parallel lines one centimetre apart and the other

with two perpendicular mid-lines (*Björk & Solow*, 1962). With the exception of the reference points *n* and *gn*, previously marked on the films by puncturing (*Tallgren*, 1957), no additional markings were made on the films. In case of double projection the mid-points and mid-lines of the two images were used. The linear measurements were read to the nearest half millimetre by means of a ruler, the angular measurements to the nearest half degree by means of a protractor. Throughout the text the parameters of the linear variables are given in millimetres and those of the angular variables in degrees.

Measurements of resorption of the alveolar processes

Previous investigations (*Tallgren*, 1957, 1966) have shown that long-term wearing of dentures causes a marked reduction in morphologic face height. As this reduction is intimately related to resorption of the alveolar processes, a special analysis was performed in order to estimate the reduction of the maxillary and mandibular bony alveolar processes. This analysis was confined to the anterior region of the processes and comprised linear vertical as well as area measurements. The changes in the soft tissues were not examined.

LINEAR MEASUREMENTS

The anterior height of the maxillary process was defined as the perpendicular distance between the NL-line and the tangent through the lowest point on the top of the bony contour of the process, parallel to the NL-line (Fig. 4).

The anterior height of the mandibular process was defined as the perpendicular distance between the ML-line and the tangent through the uppermost point of the symphysis, parallel to the ML-line (Fig. 4).

The linear vertical resorption was determined as the difference in the height of the processes between the stages of observation.

The height of the maxillary and mandibular alveolar processes was measured on the rest position films, the exposures without dentures being used for stages (b) and (c).

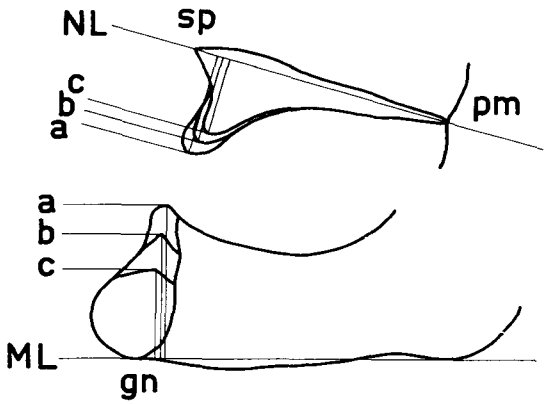

Fig. 4. Measurements of the anterior height of the maxillary and mandibular alveolar processes at the stages (a) before extraction, (b) after prosthetic treatment and (c) after 7 years of denture wear.

MEASUREMENTS OF AREAS OF RESORPTION

The measurements of the areas of resorption were performed to estimate the total amount of bone loss in the anterior segment of the processes during the 7-year period of denture wear. The recordings of the resorption areas were made by means of a rolling disc planimeter*). The method employed was based on preliminary experiments with various measuring methods and different types of planimeters. The method found to be preferable was a direct measurement of the size of the resorption areas according to the following procedure:

Contour tracings of the upper face and the mandible, respectively, were made from the rest position film without dentures (stage b) with special attention to the contours of the edentulous processes. By careful orientation the respective tracings were superimposed on the equivalent film from the later stage (c), so that all appropriate guiding structures coincided, whereafter the new contours of the processes were drawn in.

The area of resorption, determined as the area between the contours of the process at the two stages of observation could then be recorded directly by planimeter. The advantage of the tracing

*) OTT Scheiben—Rollplanimeter No. 131 L, A. Ott, Kempten, Bayern.

Table IV. *Statistical parameters*

	Parameter	Determination
$\bar{x}$	Arithmetical mean	$\frac{\Sigma x}{n}$
s^2	Variance	$\frac{\Sigma (x-\bar{x})^2}{n-1}$
s	Standard deviation	$\sqrt{s^2}$
$s(\bar{x})$	Standard error of the mean	$\sqrt{\frac{s^2}{n}}$
V	Variation coefficient	$\frac{100\ s}{\bar{x}}$
$\sqrt{b1}$	Skewness, based on the 3rd moment	$\sqrt{\frac{n\,[\Sigma(x-\bar{x})^3]^2}{[\Sigma(x-\bar{x})^2]^3}}$
b2	Kurtosis, based on the 4th moment	$\frac{n\Sigma(x-\bar{x})^4}{[\Sigma(x-\bar{x})^2]^2}$
a	— Geary's test	$\frac{\Sigma \lvert x-\bar{x} \rvert}{n\Sigma(x-\bar{x})^2}$
s(i)	Method error	$\sqrt{\frac{\Sigma(xb-xa)^2}{2\,n}}$

n is the sample size. $\sqrt{b1}$ is given the sign of the 3rd moment. xa and xb denote measurements on two films of the same individual. $\Sigma(x-\bar{x})$ represents the expression $\sum_{i=1}^{n} (x_i-\bar{x})$.

method for marking the measuring areas on the films is that it permits repeated checks on the bony contours.

The registration by planimeter was performed 5 times for each area concerned. The mean of the 5 registrations was used in the subsequent analysis. For determination of the method error, see p. 576.

Statistical analysis

The methods used in the statistical analysis of the data were mainly standard methods according to *Hald* (1952). The nu-

merical calculations were carried out with the aid of an electronic computer (GIER).

In the statistical analysis of the distributions the following parameters were employed: The mean $(\bar{x})$, the range (minimum and maximum), the standard deviation (s), the standard error of the mean $(s(\bar{x}))$, the variance (s^2), the coefficient of variation (V), the measure of skewness $\sqrt{b1}$, and the measures of kurtosis a, W and $b2$. The parameter W was determined as

$$\frac{\text{Max.—Min.}}{s}$$

(*Pearson & Hartley*, 1954). For the remaining parameters the definitions published by *Solow* (1966) were used (Table IV). The form of the distributions was also evaluated from probit diagrams plotted electronically.

The F-test *(Snedecor)* was used in comparison of variances and *Student's* t-test for the means. The 5, 1 and 0.1 per cent levels of significance were denoted *, ** and ***, respectively.

For a and for W the significance limits for sample sizes of 11 given by *Pearson & Hartley* (1954) were used. Significance limits for $\sqrt{b1}$ and $b2$ are not available for the present sample sizes. For $\sqrt{b1}$ the significance limits for $n=25$ (*Pearson & Hartley*, 1954) were used as a guide. The parameter $b2$ was studied for additional information of the distributions, although the significance limits were not available.

ERROR OF THE METHOD

The method errors of the special measuring procedure employed in the present study were recently evaluated by *Solow* (1966) and *Kisling* (1966). The method errors were found small in relation to the intersubject variation.

In the present study an estimate of the total method error related to the serial roentgenographic cephalometric recordings and the method of measurement was obtained from the two sets of films taken at stages (a) before extraction, and (b) after prosthetic treatment. The method error $s\,(i)$ (Table IV) was determined for variables 1—13. Changes in the craniofacial structures involved in these variables would hardly be expected during the short edentulous period between the two stages.

Table V. *Method errors, s(i), for linear and angular variables. $\bar{x}$ is the mean of the differences between measurements on two films of the same individual*

	Group A			Group B		
Variable	$\bar{x}$	$s(\bar{x})$	s(i)	$\bar{x}$	$s(\bar{x})$	s(i)
1 n-s	—0.09	0.09	0.213	—0.09	0.11	0.261
2 s-ba	—0.09	0.13	0.302	—0.05	0.14	0.320
3 n-s-ba	—0.14	0.12	0.282	—0.05	0.11	0.238
4 n-sp	0.14	0.10	0.238	—0.09	0.11	0.261
5 s-pm	—0.09	0.11	0.261	0.00	0.10	0.213
6 NSL-NL	—0.14	0.07	0.185	0.05	0.08	0.185
7 sp-pm	0.00	0.07	0.151	—0.18	0.10	0.261
8 s-n-sp	0.14	0.10	0.238	—0.05	0.13	0.282
9 cd^{sp}-pgn	—0.05	0.13	0.282	0.00	0.12	0.261
10 pg-go	—0.05	0.13	0.282	—0.05	0.13	0.282
11 cd^{s}-go	0.00	0.14	0.302	0.00	0.14	0.302
12 RL-ML	0.09	0.09	0.213	—0.14	0.12	0.282
13 β	—0.05	0.11	0.238	0.18	0.12	0.302

Sample sizes for all variables=11.

Table VI. *Distributions of the linear and angular variables at the pre-extraction stage (a)*

	Group A			Group B			
Variable	$\bar{x}$	$s(\bar{x})$	s	$\bar{x}$	$s(\bar{x})$	s	$\bar{x}A-\bar{x}B$
1 n-s	69.46	1.06	3.53	70.18	0.94	3.12	—0.73
2 s-ba	45.05	0.88	2.93	45.91	0.89	2.94	—0.86
3 n-s-ba	131.77	1.63	5.41	128.82	1.45	4.80	2.96
4 n-sp	54.18	0.93	3.08	51.73	0.90	2.98	2.46
5 s-pm	47.18	1.25	4.13	45.79	0.79	2.62	—0.41
6 NSL-NL	8.41	0.73	2.43	5.91	0.87	2.88	2.50*
7 sp-pm	55.46	0.77	2.56	56.46	0.64	2.13	—1.00
8 s-n-sp	86.77	0.86	2.84	89.68	1.02	3.38	—2.91*
9 cd^{sp}-pgn	118.91	1.99	6.59	121.68	2.37	7.86	—2.77
10 pg-go	76.32	1.19	3.94	75.86	1.05	3.49	0.46
11 cd^{s}-go	60.96	1.59	5.27	63.96	1.15	3.82	—3.00
12 RL-ML	126.00	1.98	6.56	126.14	2.25	7.46	—0.14
13 β	25.96	0.87	2.89	26.77	0.86	2.85	—0.82
14 NL-ML	24.32	2.28	7.56	23.55	2.43	8.05	0.77
15 n-gn	122.09	2.03	6.72	120.91	2.75	9.11	1.18
16 NSL-ML	32.73	2.47	8.20	29.36	2.17	7.19	3.36
17 NSL-MBL	56.91	1.65	5.47	54.32	1.54	5.12	2.59
18 s-n-pg	80.73	1.57	5.20	83.09	0.97	3.22	—2.36
19 Ant. height of mand. proc.	29.32	1.10	3.65	34.14	0.99	3.28	—4.82**
20 Ant. height of max. proc.	18.23	0.98	3.24	21.55	1.03	3.42	—3.32*

Sample sizes for all variables=11.

The distributions of the differences between the two sets of measurements are given in Table V. None of the mean differences displayed significant departures from zero. The method errors, *s(i)*, for the 26 variables ranged from 0.15 to 0.32 mm or degrees. These values may be considered small compared to those reported by *Solow* (1966) and *Kisling* (1966).

The method error for measurements performed by planimeter was studied by means of variance analysis, based on the 5 measurements available for each area. The homogenity of the variance within individuals was tested with *Bartlett's* test. No inhomogenity was found. The method error *(s2)* was determined as the square root of the variance within individuals. The method errors ranged from 0.41 to 0.46 mm^2 and were found to be extremely small in relation to the inter-subject variation (Table X).

FORM OF THE DISTRIBUTIONS

The distributions of the linear and angular variables and the differences in measurements between the stages of observation generally were approximately normally distributed. The few deviations noted were not so extreme as to invalidate the use of the testing methods employed. The measurements of the areas of resorption displayed no significant departures from normality.

FINDINGS

Morphological characteristics of the samples

The distributions of the linear and angular variables at the pre-extraction stage are shown in Table VI. A comparison of groups A and B showed that with the exception of the variables NSL-NL and s-n-sp, which displayed differences between the groups, significant at the 5 per cent level, the samples were fairly uniform in regard to craniofacial dimensions.

In regard to the initial height of the alveolar processes, on the other hand, the two groups displayed more marked differences. In the subjects requiring complete dentures, the height of the mandibular and the maxillary processes was found to be lower than in the partial denture group. The respective differences were significant at the 1 and 5 per cent levels.

Table VII. *Differences in craniofacial dimensions between the 7-year stage (c) and the pre-extraction stage (a)*

Variable	Group A $\bar{x}$	Group A $s(\bar{x})$	Group A s	Group B $\bar{x}$	Group B $s(\bar{x})$	Group B s	$\bar{x}A-\bar{x}B$
1 n-s	0.09	0.09	0.30	0.05	0.11	0.35	0.05
2 s-ba	0.05	0.13	0.42	—0.05	0.08	0.27	0.09
3 n-s-ba	—0.14	0.14	0.45	0.05	0.14	0.47	—0.18
4 n-sp	0.00	0.12	0.39	0.14	0.10	0.32	—0.14
5 s-pm	—0.09	0.09	0.30	0.09	0.13	0.44	—0.18
6 NSL-NL	—0.18	0.10	0.34	—0.09	0.11	0.38	—0.09
7 sp-pm	—0.05	0.13	0.42	—0.23*	0.08	0.26	0.18
8 s-n-sp	0.05	0.11	0.35	0.09	0.13	0.44	—0.05
9 cd^{sp}-pgn	0.05	0.11	0.35	—0.23*	0.08	0.26	0.27
10 pg-go	0.18	0.10	0.34	—0.14	0.10	0.32	0.32*
11 cd^{s}-go	—0.18	0.12	0.41	0.05	0.11	0.35	—0.23
12 RL-ML	—0.05	0.11	0.35	—0.05	0.05	0.15	0.00
13 β	—0.05	0.11	0.35	0.18*	0.08	0.25	—0.23

Sample sizes for all variables=11.

Table VIII. *Differences in jaw relationship between the stages of observation: (a) Before extraction, (b) after prosthetic treatment and (c) after 7 years of denture wear*

Stage	Variable	Group A $\bar{x}$	Group A $s(\bar{x})$	Group A s	Group B $\bar{x}$	Group B $s(\bar{x})$	Group B s	$\bar{x}A-\bar{x}B$
b—a	14 NL-ML	1.05	0.52	1.72	1.50*	0.60	2.00	—0.46
	15 n-gn	1.41	0.79	2.63	2.82*	0.99	3.28	—1.41
	16 NSL-ML	0.86	0.46	1.52	1.55*	0.60	1.99	—0.68
	17 NSL-MBL	0.96	0.44	1.46	1.78*	0.59	1.97	—0.82
	18 s-n-pg	—0.68	0.36	1.19	—0.96	0.45	1.49	0.27
c—b	14 NL-ML	—5.00***	0.51	1.67	—2.27**	0.62	2.05	—2.73**
	15 n-gn	—8.41***	0.70	2.32	—3.86**	0.93	3.08	—4.55***
	16 NSL-ML	—5.05***	0.46	1.52	—2.41**	0.60	1.99	—2.64**
	17 NSL-MBL	—5.14***	0.46	1.52	—2.59***	0.55	1.83	—2.55**
	18 s-n-pg	3.41***	0.39	1.28	1.68**	0.49	1.62	1.73*
c—a	14 NL-ML	—3.96***	0.64	2.12	—0.77	0.55	1.82	—3.18**
	15 n-gn	—7.00***	0.77	2.55	—1.05	0.73	2.43	—5.96***
	16 NSL-ML	—4.18***	0.57	1.87	—0.86	0.55	1.83	—3.32***
	17 NSL-MBL	—4.18***	0.55	1.82	—0.82	0.42	1.38	—3.36***
	18 s-n-pg	2.73***	0.44	1.47	0.73*	0.32	1.06	2.00**

Sample sizes for all variables=11.

Stability of craniofacial dimensions

The distributions of the differences in craniofacial dimensions between the 7-year examination and the pre-extraction stage are shown in Table VII.

With regard to the anterior and posterior length of the cranial base (n-s and s-ba) and its flexion (n-s-ba), no significant deviations were found in either group of study. Regarding the upper face, likewise, no appreciable changes were discernible. As estimated from n-sp, s-pm, NSL-NL and s-n-sp, a dimensional and positional stability of the maxillary body, the nasal floor and the nasal spine was found both in the vertical and sagittal directions. A slight decrease (mean 0.2 mm) in the sp-pm dimension was noted in the partial denture group. No changes in the contours of the posterior part of the bony palatal vault were observed in any of the individuals.

The dimensions of the basal parts of the mandible, likewise, exhibited a marked stability. In the complete denture wearers the length of the mandibular base (cd^{sp}-pgn), the ramal height (cd^{s}-go) and the length of the mandibular body (pg-go) exhibited no significant deviations after 7 years of denture wear. No significant changes in the gonial angle (RL-ML) or in the mandibular base angle (β) were found either. In the partial denture group slight decreases or increases (mean 0.2 mm) were noted in two dimensions (cd^{sp}-pgn and β-angle).

Superimposition of the films showed no deviations in the mandibular base curvature or the contours of the ramus in any of the test subjects. Furthermore, measurements and additional checks by tracings indicated that, regardless of a marked resorption of the edentulous mandibular process in the complete denture wearers, the basal part of the symphysis, including the reference points *gn, pgn* and *pg,* was not affected (Figs. 5 and 7 a, b). On the other hand, the region comprising *sm* was involved in the process of resorption in more than half the subjects (Fig. 5).

Changes in jaw relationship

The facial proportions exhibited marked changes. In both groups a general increase in the angles NL-ML, NSL-ML and NSL-MBL was found on completion of the prosthetic treatment (Table VIII). This increase in mandibular inclination, i. e.

a posterior rotation, was due to overestimation of the face height, the determination of the occlusal vertical dimension primarily being made according to aesthetic requirements (*Tallgren*, 1957).

After the 7-year period of denture wear a marked decrease in mandibular inclination, i. e. an anterior rotation, was found in both groups. In the complete denture wearers the decrease in relation to the cranial base (NSL-ML) amounted to 5°, on the average, the reduction in morphologic face height being 8.4 mm. In the partial denture wearers the mean reduction amounted to approximately half the above values. The respective differences between the groups were significant at the 1 and 0.1 per cent levels.

The prognathism of the mandible in relation to the cranial base, as determined from the s-n-pg angle, exhibited opposite changes. In both groups the posterior rotation of the mandible, noted upon completion of the prosthetic treatment, was accompanied by a decrease in mandibular prognathism. The anterior rotation of the mandible after 7 years of denture wear was associated with an increase in mandibular prognathism. In the complete denture wearers the mean increase over 7 years amounted to 3.4° and was approximately twice the value noted in the partial denture wearers. The difference between the groups was significant at the 5 per cent level. The changes in jaw relationship after 7 years, as compared with the pre-extraction stage, are shown in Table VIII.

Resorption of the alveolar processes

Linear vertical resorption

The reduction in anterior height of the alveolar processes during the period of observation is shown in Table IX and illustrated in Figs. 5 and 6.

In the complete denture wearers the total linear vertical resorption of the maxillary and mandibular processes during 7 years of denture wear amounted to 8.3 mm, on the average. This value corresponded closely to the reduction in morphologic face height during the same period (Table VIII). The vertical reduction of the mandibular process (mean 6.6 mm) was approximately 4 times greater than that of the upper, the difference between the jaws being significant at the 0.1 per cent level. During the initial

Table IX. *Differences in anterior height of the alveolar processes (linear vertical resorption) between the stages of observation: (a) Before extraction, (b) after prosthetic treatment and (c) after 7 years of denture wear.*
The resorption values are expressed in mm

		Group A			Group B			
Stage	Variable	$\bar{x}$	$s(\bar{x})$	s	$\bar{x}$	$s(\bar{x})$	s	$\bar{x}A-\bar{x}B$
b—a	19 Mand. res.	—1.41*	0.49	1.63	—0.18	0.14	0.46	—1.23*
	20 Max. res.	—1.27*	0.51	1.68	—2.36***	0.25	0.84	1.09
	Diff. 19—20	—0.14	0.48	1.58				
c—b	19 Mand. res.	—6.55***	0.76	2.52	—0.59*	0.22	0.74	—5.96***
	20 Max. res.	—1.73***	0.30	0.98	—2.96***	0.53	1.75	1.23
	Diff. 19—20	—4.82***	0.98	3.24				
c—a	19 Mand. res.	—7.96***	1.06	3.50	—0.77*	0.30	1.01	—7.18***
	20 Max. res.	—3.00***	0.59	1.96	—5.32***	0.65	2.16	2.32*
	Diff. 19—20	—4.96**	1.10	3.65				

Sample sizes for all variables = 11.
In Group B the variable 19 indicates resorption values for the mandibular process with natural teeth.

Table X. *Resorption areas of the alveolar processes during 7 years of denture wear (stage b—c). The resorption values are expressed in mm²*

Variable	Group	$\bar{x}$	$s(\bar{x})$	s	s_2	xA—xB
21 Mand. res.	A	49.80	8.91	29.54	0.42	
22 Max. res.	A	21.53	3.52	11.69	0.41	—11.28
22 Max. res.	B	32.80	5.74	19.02	0.46	
Diff. 21—22	A	28.27*	11.47	38.04		

Sample sizes for all variables = 11.

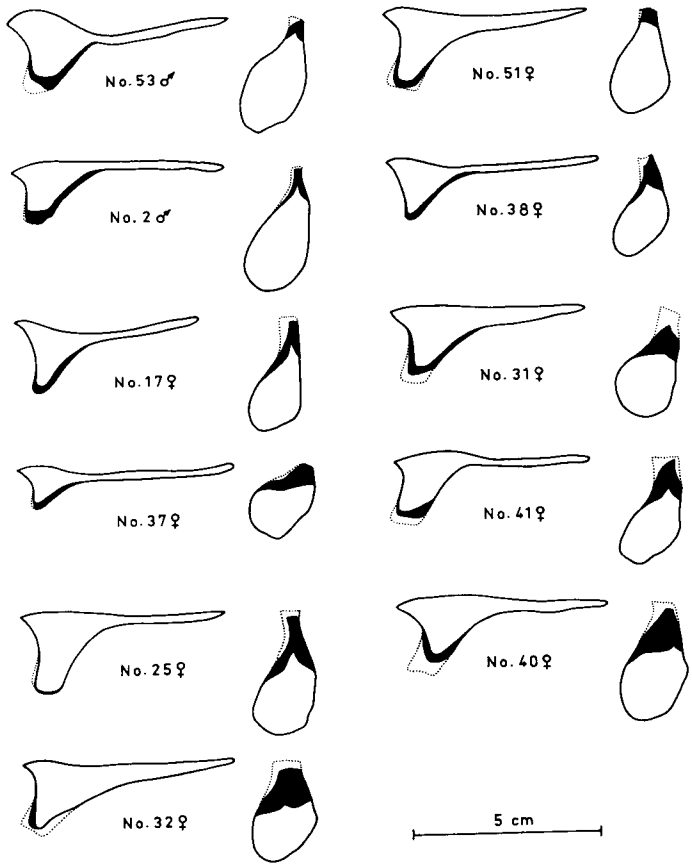

Fig. 5. Complete denture wearers. Individual tracings illustrating resorption of the anterior segments of the maxillary and mandibular alveolar processes during the initial period of healing (dotted) and during 7 years of denture wear (black). Sequence arranged according to magnitude of area resorption of symphysis during 7 years of denture wear. Both NL and ML are orientated to the horizontal plane.

period of healing, on the other hand, no significant difference in resorption values between the upper and lower jaw was found.

In the partial denture group the mean reduction of the maxillary process during 7 years was somewhat greater than in the complete denture group. However, the difference was not significant. On the other hand, the total reduction in pre-extraction maxillary height was markedly greater in the partial denture

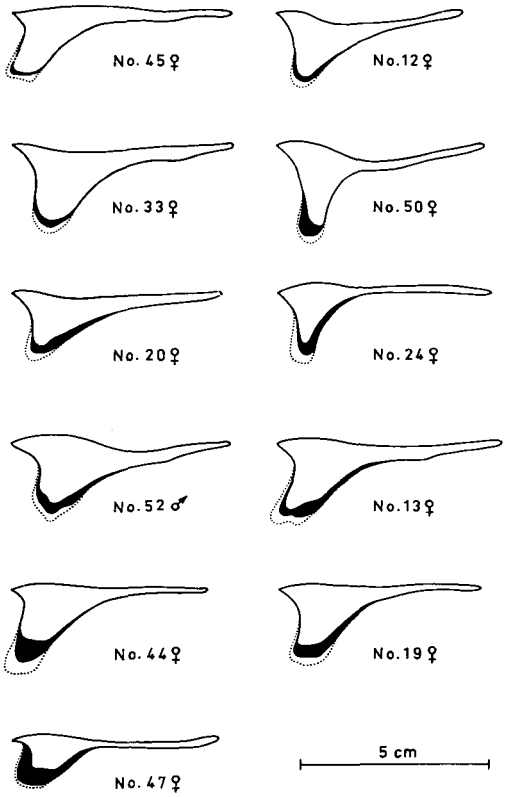

Fig. 6. Partial denture wearers. Individual tracings illustrating resorption of the anterior maxillary process during the initial period of healing (dotted) and during 7 years of denture wear (black). Sequence arranged according to magnitude of area resorption during 7 years of denture wear. NL orientated to the horizontal plane.

wearers, the difference between the groups being significant at the 5 per cent level. It should further be noted, that in the partial denture group, the total reduction in pre-extraction height of the dentulous mandibular process was only 0.8 mm, whereas in the complete denture group the reduction amounted to approximately 10 times that value.

Areas of resorption

The distributions of the areas of resorption during the 7-year period of denture wear are shown in Table X. In the complete

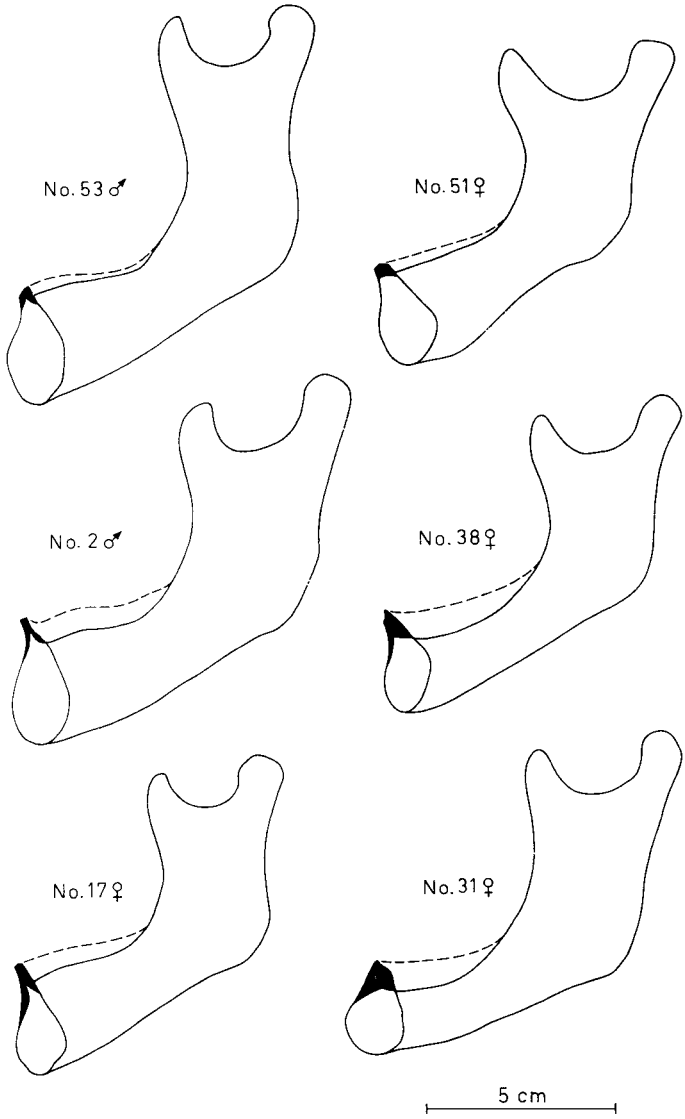

Fig. 7 a.

Figs. 7 a and b. Individual tracings illustrating stability of the basal parts of the mandible during 7 years of denture wear despite marked resorption of the symphysis and the posterior segments of the alveolar processes. Sequence arranged according to area resorption of symphysis. Mandibular position at stage (b), after prosthetic treatment, orientated to the NL-horizontal.

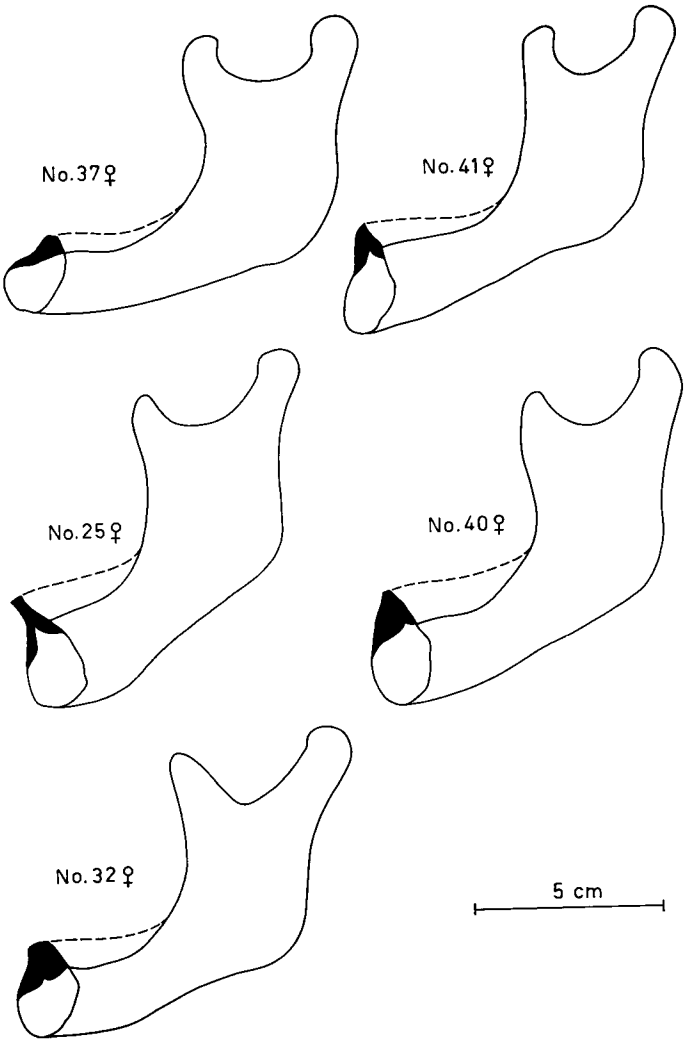

Fig. 7 b.

denture wearers the resorption of the edentulous mandibular symphysis was very marked, the average reduction amounting to 50 mm^2. The resorption patterns, illustrated in Figs. 5 and 7 a, b, exhibited great individual variations. The marked vertical reduction was accompanied by a horizontal resorption, which consisted of both labial and lingual bone loss.

The maxillary resorption areas in the complete denture wearers gave a mean of 21.5 mm^2, which was approximately half that of the mandibular. The difference between the jaws was significant at the 5 per cent level. As previously reported, the linear vertical reduction of the edentulous maxillary process was only 1/4 of the mandibular, on the average. These findings indicate, as is also illustrated by the individual tracings in Fig. 5 that the maxillary resorption in the complete denture wearers during the 7-year period was characterized by a prominent horizontal bone loss. The horizontal resorption often was found more marked on the palatal side.

In the partial denture group the resorption of the edentulous maxillary process was more marked than in the complete denture wearers. However, the difference between the groups was not significant. The resorption patterns, illustrated in Fig. 6, exhibited great individual variation both in shape and size. The marked vertical reduction was accompanied by a considerable horizontal bone loss, palatelly, labially or on both sides of the process.

DISCUSSION

The findings indicated that during the period of observation no growth in the cranial base or in the upper facial structures had occurred. Neither was there any evidence of condylar growth in the mandible. However, continued growth would hardly be expected, since the subjects with a few exceptions were middle aged and elderly individuals. On the other hand, as far as the outer structures were concerned, no senile atrophy in the craniofacial elements of the older individuals was indicated either.

The stability in size and shape of the cranial base further indicated that the wearing of complete or partial dentures over a period of 7 years had not affected the cranial base. The upper facial structures, likewise, exhibited a dimensional and positional stability, despite the marked resorptive changes in the closely

related maxillary alveolar process. No changes in the bony contour of the posterior palatal vault were indicated either. The unchanged relationship of the posterior part of the palate to the cranial base, reported by *Johnson* (1963, 1964 a, b, c), is in accordance with the present findings. Furthermore, *Heath* (1966), in a cross-sectional study of adults found that the dimensions of the middle third of the face were unaffected by age, loss of teeth and denture wear. Individual variations in position of the nasal spine in relation to the level of the hard palate, reported by *Heath*, were observed also in the present test subjects. However, such morphological variations would not seem to justify the use of the reference point *ss* in studies of edentulous subjects, as suggested by *Heath*. Previous studies by *Coccaro & Lloyd* (1965) and *Richardson* (1965) have indicated instability of the *ss* (A point) upon extraction of anterior teeth. In the present study, tracings and superimposition of the films showed that in some of the test subjects, the region including *ss* was involved in the process of resorption (Figs. 5 and 6). On the other hand, the stability of the nasal spine and the nasal floor, demonstrated in the present study, justified the employment of these structures as references.

With regard to the lower jaw it was found that the 7-year period of denture wear had not affected the basal parts of the mandible. Despite a drastic resorption of the mandibular process and marked alterations in the jaw relationship, the size and shape of the mandibular base was found to be unchanged. Neither was there any evidence of remodelling changes in the gonial process. The increase in the gonial angle in denture wearers and also in upper facial and cranial base dimensions, reported by *Hedegård* (1962) was in contrast to the present findings. Furthermore, the opinion based on previously reported cross-sectional findings, that resorption of the alveolar processes and a resulting reduction of the occlusal vertical dimension would cause not only flattening of the gonial angle but even more extensive remodelling changes of the mandible, was not corroborated by the findings from the present 7-year period of observation.

The alveolar processes, on the other hand, responded most markedly to the protracted wearing of dentures. The drastic reduction of the mandibular process in the complete denture wearers further implies that the lower ridge is more apt to

respond to the forces introduced by the wearing of dentures, than the upper. This may in part be due to the smaller denture bearing area and less favourable shape of the mandibular ridge. The direction of load, as determined by the occlusal plane and by the difference in behaviour of the upper and lower dentures in chewing and biting (*Smith* et al. 1963), may be contributory factors in regard to the difference in site and amount of resorption displayed by the maxillary and mandibular processes. A marked decrease in stability of the lower denture most likely will add to the destruction of the mandibular ridge. Regarding the upper jaw, the hard palate obviously offers considerable resistance to influence of the dentures on the edentulous alveolar process, at least in vertical direction.

In contrast to the marked resorption of the edentulous alveolar ridges, the mandibular process with natural teeth in the partial denture wearers exhibited no appreciable reduction. Partial denture treatment, therefore, should be considered and applied whenever possible, in order to avoid destruction of the alveolar processes and accompanying marked changes in position of the mandible, demonstrated in the present study and in previous investigations (*Tallgren*, 1957, 1966).

The present study was restricted to evaluating the magnitude of bone loss due to a 7-year period of denture wear. The difference in resorption noted between and within the groups and the resultant alterations in jaw relationship necessitate further analyses for evaluation of possible factors responsible for these changes.

SUMMARY

A longitudinal roentgenographic cephalometric study was performed in order to evaluate the effect of a 7-year period of denture wear on the skeletal morphology of the jaws and face. The test subjects comprised 11 individuals provided with complete dentures (mean age 47 years) and 11 individuals with a full upper and a partial lower denture (mean age 42 years). The cephalometric analysis comprised the following stages of observation: (a) before extraction, (b) after prosthetic treatment and (c) after 7 years of denture wear. The method errors were determined for

cephalometric linear and angular variables and for the measurements of the areas of resorption, performed by planimeter.

The edentulous alveolar processes responded most markedly to the 7-year period of denture wear. In the complete denture wearers the mean reduction in height of the mandibular process, as measured in the anterior region, was 6.6 mm and approximately 4 times greater than that of the maxillary process. The mean of the resorption areas of the mandibular symphysis was 50 mm^2. The partial denture wearers displayed a somewhat greater resorption of the edentulous maxillary process than the complete denture wearers, the difference between the groups not being significant, however. On the other hand, the dentulous mandibular process in the partial denture wearers exhibited no appreciable reduction.

The resorption of the alveolar processes caused a decrease in mandibular inclination (anterior rotation) with a resulting reduction in total face height and an increase in mandibular prognathism.

Despite the marked resorption of the alveolar processes and resultant changes in jaw relationship, especially marked in the complete denture wearers, the cranial base, the upper facial structures and the basal parts of the mandible, including the gonial angle, were found unaffected.

RÉSUMÉ

ACTION DU PORT DE PROTHÈSES SUR LA MORPHOLOGIE FACIALE

Une étude céphalométrique longitudinale par radiographies a été exécutée pour juger de la façon dont la morphologie du squelette de la face et des mâchoires réagit au port de prothèses pendant une période de sept ans. Cette étude a été faite sur 11 sujets porteurs de prothèses complètes (âge moyen 47 ans) et 11 sujets porteurs d'une prothèse supérieure complète et d'une prothèse inférieure partielle amovible (âge moyen 42 ans). L'analyse céphalométrique comprenait des observations faites aux stades suivants: (a) avant extractions, (b) après traitement prothétique et (c) au bout de 7 ans de porte des prothèses. Les erreurs liées à la méthode ont été déterminées pour des variables céphalométriques linéaires et angulaires et pour les mesures au planimètre des aires réduites par résorption.

Les procès alvéolaires édentés réagissaient d'une manière tres accusée au port de prothèses pendant 7 ans. Chez les porteurs de prothèses complètes, la moyenne de la diminution de hauteur du procès alvéolaire mandibulaire, mesurée dans la région antérieure, était de 6,6 mm et représentait environ quatre fois son équivalent au maxillaire supérieur. La symphyse mentonnière présentait une résorption réduisant en moyenne sa surface 50 mm^2. La résorption des procès alvéolaires édentés au maxillaire supérieur était légèrement plus grande chez les porteurs de prothèses partielles que chez les porteurs prothèses complètes, la différence entre ces deux groupes n'étant cependant pas significative. Par contre, chez les porteurs de prothèses partielles, le proces alvéolaire dentée de la mandibule ne présentait pas de résorption notable.

La résorption des proces alvéolaires déterminait une diminution de l'inclinaison de la mandibule (rotation antérieure), ce qui diminuait la hauteur totale de la face et augmentait le prognathisme mandibulaire.

Malgré la résorption marquée des procès alvéolaires et les altérations en résultant en ce qui concerne les rapports des maxillaires, altérations surtout marquées chez les porteurs de prothèses complètes, la base du crâne, la partie supérieure de la face et la base mandibulaire, y compris l'angle goniaque, ne présentaient pas de modifications.

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ZUSAMMENFASSUNG

DIE EINWIRKUNG VON PROTHESEN AUF DIE FAZIALE MORPHOLOGIE

Es wurde eine röntgencephalometrische Untersuchung über sieben Jahre hindurch vorgenommen, um das Einwirken totaler Prothesen, die in dieser Zeit getragen wurden, auf die skeletale Morphologie der Kiefer und des Gesichtes zu bewerten. Es wurden 11 Patienten mit totalen Prothesen (Durchschnittsalter der Patienten 47 Jahre) und 11 Patienten mit einer totalen Oberkieferprothese und einer partiellen Unterkieferprothese (Durchschnittsalter 42 Jahre) untersucht. Die cephalomethrische Analyse wurde

bei folgenden Observationsstadien vorgenommen: (a) vor der Extraktion, (b) nach der prothetischen Behandlung und (c) nach siebenjährigem Gebrauch der Prothesen. Die Fehler dieser Methode wurden bestimmt für die cephalometrischen linearen und angulären Varianten ebenso wie für die Arealmessungen der Resorption, die mit dem Planimeter durchgeführt wurden.

Die zahnlosen Processus alveolares zeigten sehr grosse Veränderungen nach dem siebenjährigen Prothesengebrauch. Bei den Vollprotheseträgern war die Reduktion der Höhe des Processus mandibularis durchschnittlich 6.6 mm gemessen in der anterioren Region und damit ungefähr 4 mal so gross wie im Oberkiefer. Das Resorptionsareal der Symphysis mandibularis war durchschnittlich 50 mm^2. Bei den Trägern von partiellen Prothesen schien die Resorption des zahnlosen Processus maxillaris etwas grösser zu sein als bei den Totalprotheseträgern, jedoch war der Unterschied zwischen beiden Gruppen nicht significant. Andererseits war eine Reduktion des bezahnten Processus mandibularis bei den Trägern der partiellen Prothesen unbedeutend.

Die Resorption der Processus alveolares begründet eine Abnahme der mandibulären Inklination (eine kranielle Rotation der Mandibel) und dadurch eine Reduktion der totalen Gesichtshöhe und eine Zunahme der mandibulären Prognathie.

Trotz der grossen Resorption der Processus alveolares und der damit verbundenen Veränderung der Kieferverhältnisse, welches besonders merkbar bei den Trägern von totalen Prothesen war, erschienen basis cranii, die oberen fazialen Strukturen und die basalen Strukturen des Unterkiefers einschliesslich des Kieferwinkels unverändert.

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