

From: The Departments of Stomatognathic Physiology and Prosthetics, School of Dentistry, University of Umeå, and the Department of Prosthetics, School of Dentistry, Karolinska Institutet, Stockholm, Sweden.

CHANGES IN CONTOUR OF THE MAXILLARY ALVEOLAR PROCESS UNDER IMMEDIATE DENTURES

A LONGITUDINAL CLINICAL AND X-RAY CEPHALOMETRIC STUDY COVERING 5 YEARS

by

G. E. CARLSSON

B. BERGMAN

B. HEDEGÅRD

INTRODUCTION

The possibility of influencing the changes in the contour of the alveolar process after extractions has received much attention in the literature. Interest has centred on various surgical methods associated with extraction, especially the question of whether or not bone resection is advisable, the time at which the denture should be inserted, and variants of prosthetic technique. In recent years the possible association between the resorption of the alveolar process and functional, anatomic, metabolic and other biologic factors has also been discussed (*Atwood, 1962; Ortman, 1962*).

The numerous papers on resorption of the alveolar process include but few longitudinal investigations of bone resorption after full extraction.

Using X-ray cephalometry, *Atwood (1957, 1962)* and *Hedegård (1962)* have examined the changes in contour of the upper alveolar process after extraction and insertion of immediate full dentures; they have represented the changes with tracings. With a radiographic and photogrammetric method *Victorin (1964)*

followed 70 patients for one year after extraction of all the maxillary teeth. The patients were assigned to two groups, one receiving their dentures immediately after the extractions and the others after 3 months. The former group displayed on average less resorption than the latter. By measurements on casts prepared at different intervals after extraction of the maxillary teeth *Watt* (1960) and *Johnson* (1963, 1964 *a, b, c*) calculated the changes in shape of the alveolar process. *Johnson* found larger changes in patients without dentures during the first 10—20 weeks of extraction than in those receiving immediate dentures.

In connection with longitudinal studies of the changes in the face height, resorption in the denture-supporting tissues has been demonstrated indirectly by *Thompson* (1946), *Atwood* (1956, 1957, 1958), *Tallgren* (1957, 1966), *Swerdlow* (1964) and *Carlsson & Ericson* (1965).

As regards the surgical methods for extraction there is a group of authors that recommend removal of parts of the buccal alveolar wall (alveolectomy) so as to reduce the resorption and the need for rebasing, and to promote aesthetic adaptation of the denture (*Snoddy & Sherman*, 1937; *Schuchardt*, 1951; *Östlund*, 1961). The view that the resorption would be less marked after alveolectomy has been refuted by the results obtained by, among others, *Lisowski* (1945) and *Koivumaa* (1954), where the opposite tendency was observed. In the most recent papers on immediate dentures the risk of increased resorption after labial alveolectomy has been pointed out (*Heartwell & Salisbury*, 1965; *Anderson & Storer*, 1966).

Dean (1953) performed intra-septal alveolotomy, in which the buccal bone plate was bent inwards after resection of the intra-alveolar septa. The subsequent changes in contour of the alveolar process were examined in two small series by means of measurements on casts. *Johnson* (1964 *c*) found the resorption after this operation to be about the same as after extraction alone. *Gazabatt, Parra & Meissner* (1965) concluded that intra-septal alveolectomy is followed by less resorption than is labial alveolectomy.

Another group of authors consider that extraction alone or extraction and a minimum resection of bone should be performed to preserve as much of the alveolar process as possible (*De*

Van, 1930; Smedley, 1941; Hildebrand, 1946; van der Ven, 1954; Rheinwald, 1957; Schüle, 1957). This view would seem to be the one most widely accepted at present (Sharry, 1962; Heartwell & Salisbury, 1965).

The present study was undertaken to examine the changes in the maxilla that occur after extraction of all the upper teeth and insertion of an immediate denture. It was performed by X-ray cephalometry, supplemented with clinical observations, during a period of 5 years. The patients were divided into two groups for comparison of two methods of surgical treatment namely, extraction alone and extraction and modified "intra-septal alveolotomy".

MATERIAL AND METHODS

Case series. The patients were selected from those registered during the Autumn Term of 1959 and the Spring Term of 1960 for immediate full upper denture treatment at the Department of Prosthetics, The Royal School of Dentistry, Umeå. The patients were selected on the following basis:

1. All 6 upper anterior teeth (3+ . . . +3) should be present.
2. There should be no serious periapical or periodontal alterations in the upper anterior segment.

Patients with periapical changes calling for surgical measures apart from an extraction were not accepted, nor were those with periodontal changes that had resulted in an increase in mobility of the teeth or loss of marginal bone for more than one quarter of the length of the root, as judged on intra-oral radiographs by the conventional bisector setting.

3. The patients should be in good health. No medical examination was performed, reliance being placed on the clinical odontological examination and general medical history.

During the time the material was collected (the 1959—60 session) 38 patients satisfied these requirements. During the Autumn Term extraction alone was performed on 18 patients (group E) and during the Spring Term extraction and intra-septal alveolotomy was performed on 20 patients (group A) (Table I). Apart from the surgical measures the treatment was the same for the two groups.

Clinical treatment. The treatment was given by two of the authors and by students under supervision of the authors in accord-

Table I
Age and sex distributions at the beginning of the treatment

		Number of patients aged					Total	Mean age
		≤ 29	30—39	40—49	50—59	60—65		
<i>Group E</i>	Women	3	3	6	1	—	13	39.2
	Men	1	1	1	1	1	5	43.4
<i>Group A</i>	Women	2	6	5	1	—	14	36.6
	Men	2	1	2	1	—	6	38.2
Total		8	11	14	4	1	38	38.9

ance with the following programme.

1. Radiographic examination of the alveolar processes and remaining teeth; recording the patient's history; impression for study casts.

2. Extraction of molars and premolars — with the exception, where relevant, of the upper and lower first premolars on one side, which were left so as to maintain the vertical dimension. Healing period of 2—3 months.

3. Any indicated treatment in the mandible. Preliminary impressions.

4. Definitive impressions; combined impression with zinc oxide paste in individual trays over the edentulous parts of the denture-bearing area; alginate in standard trays for over-all impression.

5. Recording of jaw relations by means of record blocks with occlusal rims.

6. Removal of the cast teeth: for group E to the level of the gingival border; for group A also phasing off of the labial part of the alveolar process corresponding to the thickness of the denture flange about 1 mm nearest the teeth and diminishing upwards to about 2 mm from the vestibular limit of the denture.

7. Testing of the trial denture for the edentulous areas, as a check of the jaw recordings.

8. Extraction of the remaining upper teeth and, in group A, intra-septal alveolotomy. Insertion of the upper immediate dentures and any lower denture. The patient was asked not to remove the immediate denture before the first check.

9. Within 48 hours the first check and any requisite corrections.

10. Checks of healing, correction of occlusion, articulation, retention and fit. Rebasings when necessary, using cold-polymerizing acrylic; for the first few months the direct technique was used, and subsequently the indirect technique from impressions with zinc oxide paste in the wax-trimmed denture.

Surgical treatment. For the extractions, forceps and elevator were used, care being taken to avoid fracturing the alveolar margins. In neither group were sutures inserted.

The intra-septal alveolotomy in group A was performed by a modification of Dean's method (1953). After the extractions the marginal parts of the

interdental septa were removed to a depth of about 7—10 mm with narrow resection forceps. The labial bone plate from 3+ . . . +3 could then be pressed inwards towards the palatal part of the alveoli without raising a flap. By means of a transparent base plate fitted to the trimmed cast it was checked that the alveolar process had been pressed in sufficiently. Transection of the labial bone plate opposite the alveoli of the canines, as recommended by *Dean*, was seldom done.

Method of examination

To follow the alterations after full extraction and denture treatment the patients were examined before extraction and at the following times after extraction and insertion of the denture: 2 and 14 days, 2, 4 and 6 months, 1, 2 and 5 years (62 months). The attendance to the various checks is shown in table II. For the 5-year follow-up a range of ± 2 months was accepted; at the earlier checks comparatively narrower limits were required.

At the follow-ups clinical observations of the healing, mucosal changes, state of the denture, and the patient's own remarks were recorded. Profile radiographs were taken before the extractions and at the 6-month, 1-, 2- and 5-year follow-ups.

Table II

Loss to the various follow-ups. R indicates that profile radiographs were taken

	No. of subjects	Before extr. R	Follow-up examination							
			2 d	14 d	2 mo	4 mo	6 mo	1 y	2 y	5 y
<i>Group E</i>	18	0	0	0	0	0	1	2	0	2
<i>A</i>	20	0	0	1	0	5	2	2	0	0
Total		0	0	1	0	5	3	4	0	2

For the X-ray cephalometric examination the head was placed in a cephalostat. It was positioned by means of ear-rods and neck and forehead rests, and the central bundle of rays was directed so as to pass through the external auditory meatus, and perpendicular to the sagittal and film planes. The exposure data were: 0.4 s, 80—82 kV, about 300 mA; focus — film

distance 300 cm, distance from the median plane of the head to the film 18.0 cm; enlargement 6.4 per cent*.

For the exposure all dentures were removed. A line of contrast medium 2—3 mm wide was applied along the midline of the maxilla, from the vestibulum to the soft palate, but to the right of the incisive papilla as to reproduce the actual alveolar process in this region. The patient was requested to relax the face during the exposure so that the mandible would assume the postural position. Before extraction, radiographs were taken after gentle closure into habitual occlusion; at the final follow-up an extra radiograph was taken with the dentures in the mouth and gentle closure into habitual occlusion.

The reference points and lines used in the X-ray cephalometric analysis are shown in Fig. 1. The definitions have been given elsewhere (*Carlsson, 1967*). The points *ab* and *as* in figure 1 and the tables correspond to the points *abu* and *asu* used in the text

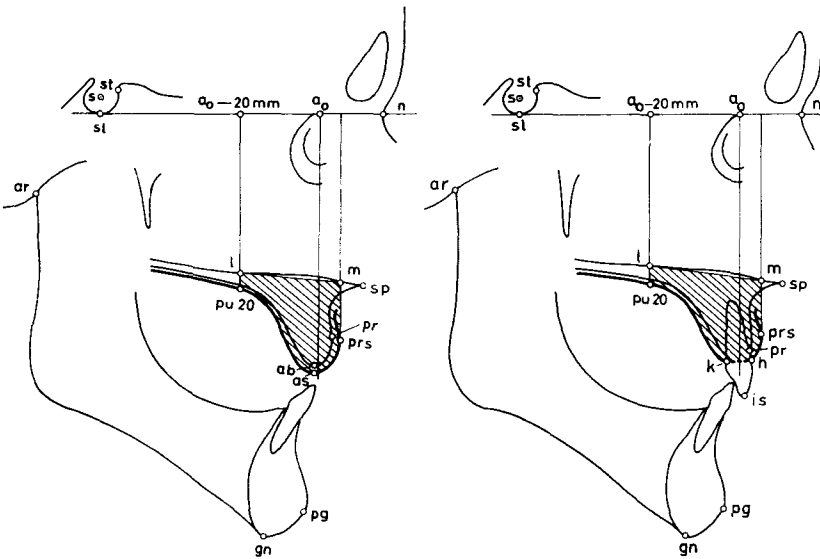


Fig. 1. The cephalometric reference points and areas.

* Because of reconstruction of the Department the focus—film distance at the 5-year follow-up was 282 cm. The apparatus was otherwise the same as before. To obtain the same enlargement the distance from the median plane to the film was changed to 17.0 cm. The changes in scale for details not in the median plane are negligible compared with the total error of the method (see *Carlsson, 1967*).

and in the method study (*Carlsson, 1967*). *u* denotes upper and has been added to differentiate *abu* and *asu* from the corresponding points in the lower jaw, *abl* and *asl*.

The measurements were performed directly on the radiographs. For the measurements of distance calipers graduated in tenths of a millimetre was used; angles were measured with a protractor graduated in halves of a degree but the readings were made by estimate to one-tenth of a degree; coordinates were measured with a millimetre grid made of transparent acrylic and the readings were estimated to a tenth of a millimetre. Coordinate measurements were used for measuring the mucosal and skeletal contours in the maxilla. The coordinate system was constructed with the nasion as the origin and $n - sl$ as the base line, *NSL* (axis of abscissa). Horizontal (*x*) and vertical (*y*) coordinates for the various points in the maxilla were read off by means of the grid. The vertical (*y*) coordinates of the contour of the palatal mucosa were read off at intervals of 5 mm posterior to an ordinate (the zero line) through the mid-point of the alveolar process (a_0) on the first radiograph (points *pu* 5, 10, 15 . . .).

The area of the alveolar process was measured directly on the films with a planimeter by the following construction (Fig. 1). On the first radiograph the mid-point of the alveolar process, a_0 , was marked on *NSL* and its *x* coordinate in relation to the nasion (the origin) was noted so that it could be transferred to other films of the same patient. From a point 20.0 mm posterior to a_0 the perpendicular to *NSL* was drawn to the mucosal contour of the palate. From the intersection of this line with the nasal floor (*l*) a line was drawn to the anterior nasal spine. The perpendicular from *prs* to *NSL* intersects *l-sp* in *m*. The area delimited by the mucosal contour between *prs* and *pu* 20 and the lines *pu* 20-*l-m-prs* was measured with a polar planimeter (Aristo 1130 L). On the first radiographs with the upper incisors present a straight line was drawn between *h* and *k*, that is the points of contact between the contrast medium on the mucosa and the labial and palatal surfaces of the teeth.

Study of the method error; statistical methods

A more detailed account of the X-ray cephalometric method, an analysis of its sources of errors and the statistical analysis of the data has been given elsewhere (*Carlsson, 1967*).

The significance of the difference of the means from zero and the means of the groups were calculated by the *t* test. The levels of significance observed were: $P \leq 0.001$ highly significant***; $0.001 < P \leq 0.01$ significant**; $0.01 < P \leq 0.05$ almost significant*.

RESULTS

X-ray cephalometric measurements

Alveolar process. — The changes in contour of the anterior segment of the maxillary alveolar process during the various follow-up periods were expressed in terms of the differences between the coordinates for the most anterior (*prs*, *pr*) and inferior (*asu*, *abu*) reference points on the mucosal and skeletal contours, measured on profile radiographs from the various follow-ups (Table III).

The mucosal and skeletal contours changed at largely the same mean rate and to about the same extent. The change in the horizontal coordinates (0—6 months) for *prs* and *pr* was greater for group A than group E (Fig. 2) but the differences were less than might be expected, having regard to the different surgical measures at extraction and were not statistically significant. The vertical resorption between 6 months and 5 years was greater in group E than group A (Fig. 3). The difference was almost significant for the skeletal contour (*abu*).

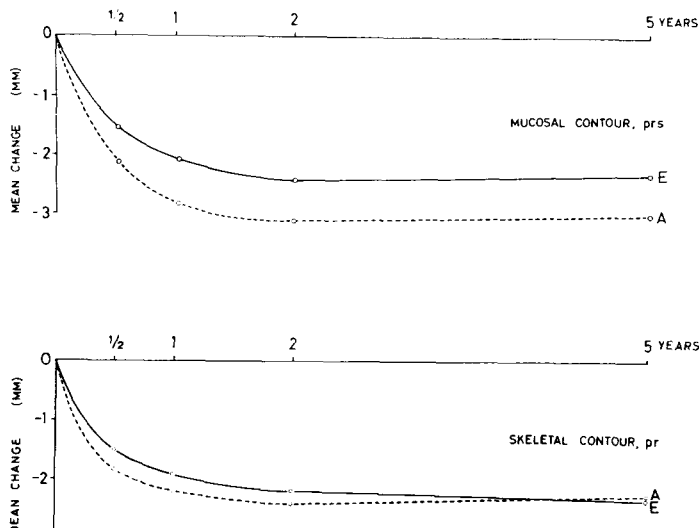


Fig. 2. Horizontal displacement of the most prominent points of the alveolar process over the 5-year period after extraction. *Upper*, mucosal contour: the *x* coordinate of *prs*; *lower*, the skeletal contour: *x* coordinate of *pr*. E and A denote the two treatment groups: E = extraction only, A = extraction and intraseptal alveotomy.

Table III

Means, \bar{d} , and standard deviations, s , of differences between coordinate measurements of points on anterior segment of alveolar process on profile radiographs taken at different examinations; millimetres. Values of t for differences between the means of the groups

Group	0— $\frac{1}{2}$				$\frac{1}{2}$ —1				1—2				
	$prs(x)$	$pr(x)$	h/as	k/as	$pr(y)/ab$	$prs(x)$	$pr(x)$	$as(y)$	$ab(y)$	$prs(x)$	$pr(x)$	$as(y)$	$ab(y)$
$E \bar{d}$	1.6***	1.5***	1.6***	2.0***	0.6	0.4**	0.4*	0.7***	0.4*	0.6*	0.4	0.7**	0.6
s	0.9	0.8	1.6	1.7	1.5	0.3	0.6	0.5	0.6	0.7	0.8	0.6	1.4
$A \bar{d}$	2.1***	1.8***	2.7***	1.7**	1.0*	0.9**	0.4*	0.4*	0.2	0.2	0.2	0.4*	0.4*
s	1.5	1.0	1.5	2.1	1.4	0.9	0.5	0.7	0.6	1.0	0.5	0.7	0.5
$E-A$	-0.9	-1.0	-2.2†	0.5	-0.9	-2.2†	0.0	1.5	1.0	1.4	0.9	1.4	0.6

Group	2—5				0—5				$\frac{1}{2}$ —5				
	$prs(x)$	$pr(x)$	$as(y)$	$ab(y)$	$prs(x)$	$pr(x)$	h/as	$pr(y)/ab$	$as(y)$	$ab(y)$	$prs(x)$	$pr(x)$	$as(y)$
$E \bar{d}$	-0.1	0.2	1.0*	1.0**	2.3***	2.4***	4.0***	2.5***	2.2*	2.2**	2.2**	2.2**	2.2**
s	0.7	0.5	1.4	1.1	1.2	1.2	2.6	2.4	3.1	2.2	2.2	2.2	2.2
$A \bar{d}$	0.1	-0.1	0.3	0.4**	3.0***	2.3***	3.8***	2.0***	1.0***	1.0***	1.0***	1.0***	1.0***
s	0.8	0.6	0.6	0.5	1.5	1.3	1.6	1.2	0.9	0.8	0.8	0.8	0.8
$E-A$	-0.8	1.6	2.2*	2.2*	1.5	0.2	0.3	0.8	1.7	2.2†	2.2†	2.2†	2.2†

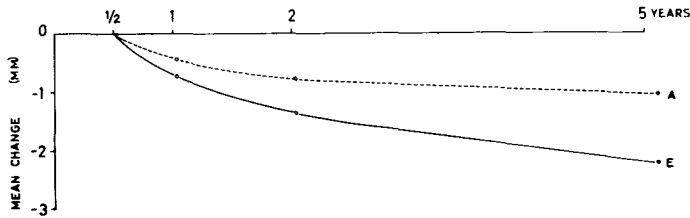


Fig. 3. Reduction in the height of the alveolar process between 6 months and 5 years after extraction. (The y coordinate of asu). E and A denote the two treatment groups.

Since asu and abu were not entered on the first radiograph of the series it was difficult to obtain a numerical measure of the vertical reduction of the alveolar process occurring during the first six months. An attempt was made by comparing the y coordinates of h , k and pr on the first film with those of asu and abu on the later films (Table III), but the points are not fully comparable and the comparisons probably give too small values for the changes during this period.

Another measure of the vertical reduction of the alveolar process was provided by the y coordinates of the anterior points on the palatal part of the alveolar process. During the first 6 months the y coordinate for pu 5 (that is, a point on the medial mucosal contour of the maxilla situated 5 mm posterior to a line through the mid-point of the alveolar process, a_0) diminished by a mean for the whole material of 3.0 mm and by 5.3 mm for the whole 5-year period. In the posterior segments the changes were less marked (Table IV; Fig. 4).

After the first 6 months the reduction in the palatal part of the alveolar process took place on average more rapidly in group E than group A.

The area of the anterior part of the alveolar process decreased greatly during the first 6 months after extraction, but thereafter to a much smaller extent (Table V; Fig. 5). The ranges for the material were large, however; for the whole material the mean reduction over the 5-year period was 119 mm², with extremes of 37 and 288 mm². Between the 6-month and 5-year checks the reduction was greater in group E than group A (almost significant).

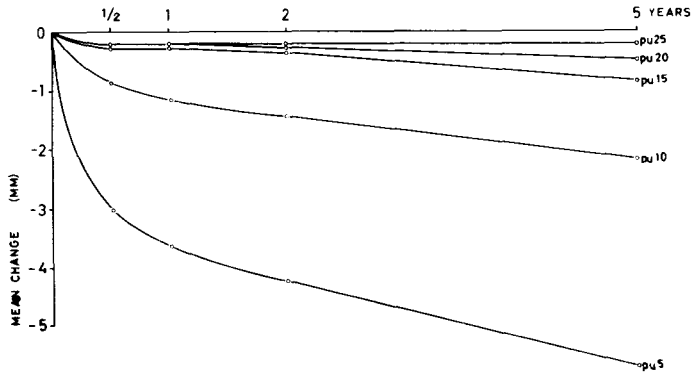


Fig. 4. Reduction in the vertical direction of the palatal part of the alveolar process over the 5-year period after extraction. (The *y* coordinates of the points *pu* 5, 10 15 . . ., situated on the median line 5, 10, 15 . . . mm posterior to the middle of the alveolar process). Means for the two groups combined.

Table IV

Means, \bar{d} , for differences between vertical coordinates of points on the mucosal contour of the palate on profile radiographs taken at different examinations millimetres

	Follow-up periods (years)										
	0—1/2		1/2—1		1—2		2—5		0—5		
	E ¹	A	E	A	E	A	E	A	E	A	
y-coordi- nates ²											
<i>pu</i> 5	2.8***	3.2***	0.9**	0.4	0.6	0.7*	1.4*	0.7*	5.9***	4.8***	
10	1.1*	0.7*	0.5*	0.0	0.3	0.3	1.0*	0.4	3.4**	1.3***	
15	0.4*	0.2	0.3	-0.2	0.0	0.2	0.7*	0.2	1.5**	0.4	
20	0.3*	0.2	0.1	0.1	0.1	0.1	0.3*	0.0	0.8**	0.2	
25	0.1	0.3*	0.0	-0.2	-0.1	0.0	0.3*	0.1	0.2	0.2	
30	-0.1	0.1	0.3	-0.1	0.0	0.1	0.1	0.1	0.1	0.1	
35	0.1	0.2*	0.1	-0.1	0.0	-0.1	0.1	-0.1	0.1	-0.1	
40	0.2	-0.1	-0.1	-0.1	0.0	0.1	0.1	-0.1	-0.2*	-0.2	

¹ E and A denote treatment groups E and A.

² The numbers (*pu* 5, 10, 15 . . .) denote the horizontal distance (mm) of the reference points (*x* coordinate) posterior to the axis of *y* through the midpoint of the alveolar process (*a*).

At the outset the mean area was 365.4 mm² for group E and 381.6 for group A. The respective mean reductions over 5 years were 34.6 and 29.5 per cent of the original areas — that is, 31.7

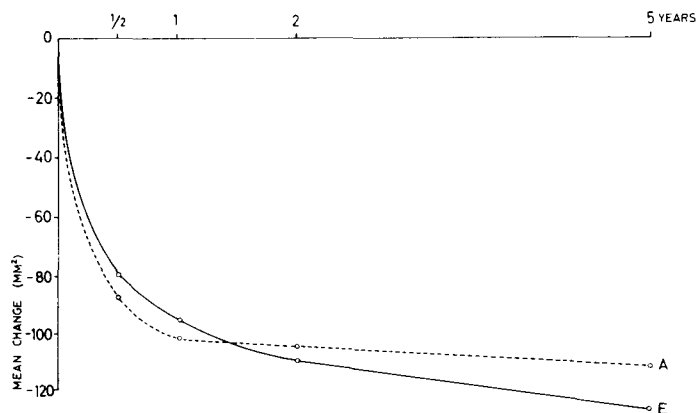


Fig. 5. Reduction in the area of the anterior segment of the alveolar process over the 5-year period after extraction. E and A denote the two treatment groups.

per cent for the whole series. The individual extreme values were 11.0 and 65.2 per cent.

Hard palate. — The mucosal contour of the palate is extremely stable in the posterior part (25—40 mm posterior of the mid-point of the alveolar process, a_0) and over the 5-year follow-up period only small changes were recorded (Table IV).

Anterior cranial base and anterior height of the maxilla. — As there were no significant changes in the distances $n-st$ and $n-sp$ during the follow-up period, only the values for the full 5-year period are presented (Table VI).

Table V

Means, \bar{d} , and standard deviations, s , of differences between measurements of areas of the anterior segment of the alveolar process on profile radiographs taken at different examinations; square millimetres. Values of t for differences between the means of the groups

		Observation period (years)					
		0— $\frac{1}{2}$	$\frac{1}{2}$ —1	1—2	2—5	0—5	$\frac{1}{2}$ —5
Group E	\bar{d}	80.5***	12.5*	16.1*	16.5*	127.6***	45.3**
	s	28.4	15.8	21.0	28.2	61.3	46.0
A	\bar{d}	88.7***	14.7**	0.7	8.1*	112.5***	20.1**
	s	35.2	15.6	11.2	16.4	46.8	23.8
E—A	t	—0.8	—0.4	2.9*	1.1	0.8	2.1*

Table VI

Means, \bar{d} , and standard deviations, s , of differences in $n-st$, $n-sp$ and $n-gn$ measured on profile radiographs taken before and 5 years after full extraction of the upper teeth (for postural height $\frac{1}{2}$ —5 years after extraction); millimetres. Values of t for differences between the means of the groups.

Group		$n-st$	$n-sp$	$n-gn$	
				Occlusion	Postural position
E	\bar{d}	0.1	0.1	0.6	2.6**
	s	0.5	0.7	2.3	3.5
A	\bar{d}	0.1	0.3	3.6***	1.5**
	s	0.4	1.6	3.7	2.1
E—A	t	0.0	—0.5	—2.5*	1.2

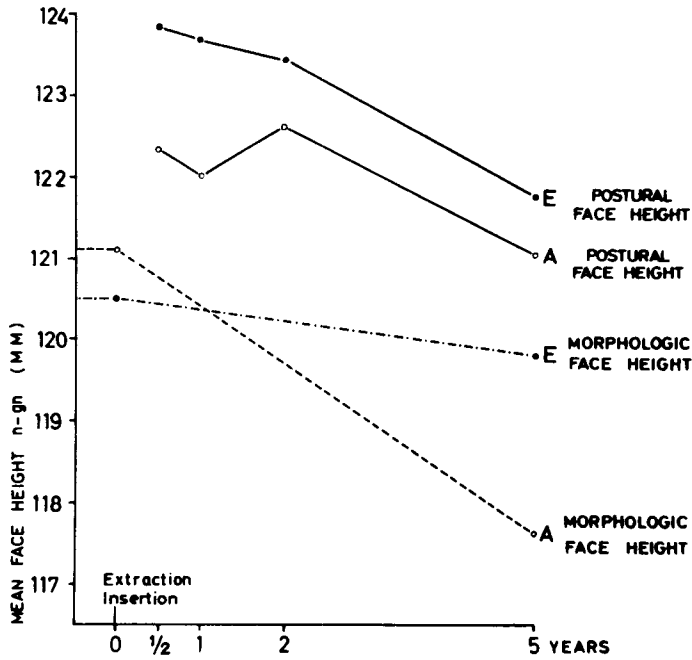


Fig. 6. Change in face height during the 5-year follow-up period. E and A denote the two treatment groups.

Face height. — The morphologic face height, expressed as the distance $n-gn$, and measured before extraction with residual teeth in habitual occlusion, and 5 years later with the dentures in occlusion, diminished during this period by a mean of 2.3 mm for the whole series (significant). The reduction was almost significantly greater for group A than group E (Table VI; Fig. 6).

In 12 patients where the premolars and molars were removed about 2 months before the extraction of the anterior teeth there was no significant change in the morphologic face height ($d = 0.07$ mm; $t = 0.26$) during the period up to full extraction.

Between the 6-month and 5-year follow-ups the postural height of the face, measured as the distance $n-gn$ with no dentures in the mouth, diminished by a significant mean of 2.0 mm for the whole series (Table VI; Fig. 6).

Position of the upper incisors. — The horizontal and vertical coordinates of is were measured for the natural teeth before extraction and for the denture teeth at the 5-year follow-up, when a radiograph was taken with the dentures inserted. A comparison between the two occasions showed that after the dentures had been worn 5 years the incisal edges of the upper incisors were situated 1.8 mm higher and 2.3 mm further forward than the corresponding points on the natural teeth (means for the whole series).

Analysis of factors possibly governing the changes in the alveolar process

There were great variations of the resorption values within the material, as seen in the standard deviations of various measurements (Tables III and V). The wide range in resorption pattern is visualized in the superimposed tracings of the mucosal contour in the median plane of the maxilla for all patients (Fig. 7).

To examine the effect of some factors that might have a bearing on the extent of the bone resorption the whole series was divided according to various criteria.

Sex. — The mean changes were closely similar for the two sexes, the differences in no case being statistically significant (Table VII).

Table VII

Means, d, of changes in upper alveolar process; division according to sex (groups A and E combined); millimetres and square millimetres

	No. of subject	$pu\ 5(y)$ 0—5	$as(y)$ $\frac{1}{2}$ —5	$ab(y)$ $\frac{1}{2}$ —5	$prs(x)$ 0—5	$pr(x)$ 0—5	Area 0—5
Men	11	5.5	1.4	1.6	2.6	2.5	122
Women	25	5.2	1.5	1.5	2.8	2.3	118

Table VIII

Means, d, of changes in upper alveolar process; division according to age; limit at 50 years at final follow-up; millimetres and square millimetres

	No. of subjects	$pu\ 5(y)$ 0—5	$as(y)$ $\frac{1}{2}$ —5	$ab(y)$ $\frac{1}{2}$ —5	$prs(x)$ 0—5	$pr(x)$ 0—5	Area 0—5
≥ 50 years	15	5.7	2.1	1.8	2.4	2.0	128
< 50 years	21	5.0	1.1	1.3	3.0	2.6	113

Age. — To test the possible influence of age the series was divided into two groups according to whether the patient had or had not reached 50 years at the time of the final follow-up. No significant differences were found (Table VIII).

Full or partial denture, or natural dentition in the mandible. — It might be reasonable to assume that the resorption of the maxillary alveolar process would be dependent on the mechanical forces to which the upper denture is subjected. The load on the upper denture-bearing area might be considered to vary with, for instance, the intermaxillary relations, the muscular force, and the number, position and status of the residual lower teeth. To examine whether the contour changes in the alveolar process are dependent on the dentitional status of the mandible the series was divided as follows:

- (1) Full dentures; 10 patients
- (2) Natural teeth + partial denture; 10 patients
- (3) Natural teeth with no denture; 16 patients (including 4 who had stopped using their partial dentures in the first 6 months).

The mean changes were smallest for the group with full lower dentures (1) as compared to the other groups (2 and 3) (Table

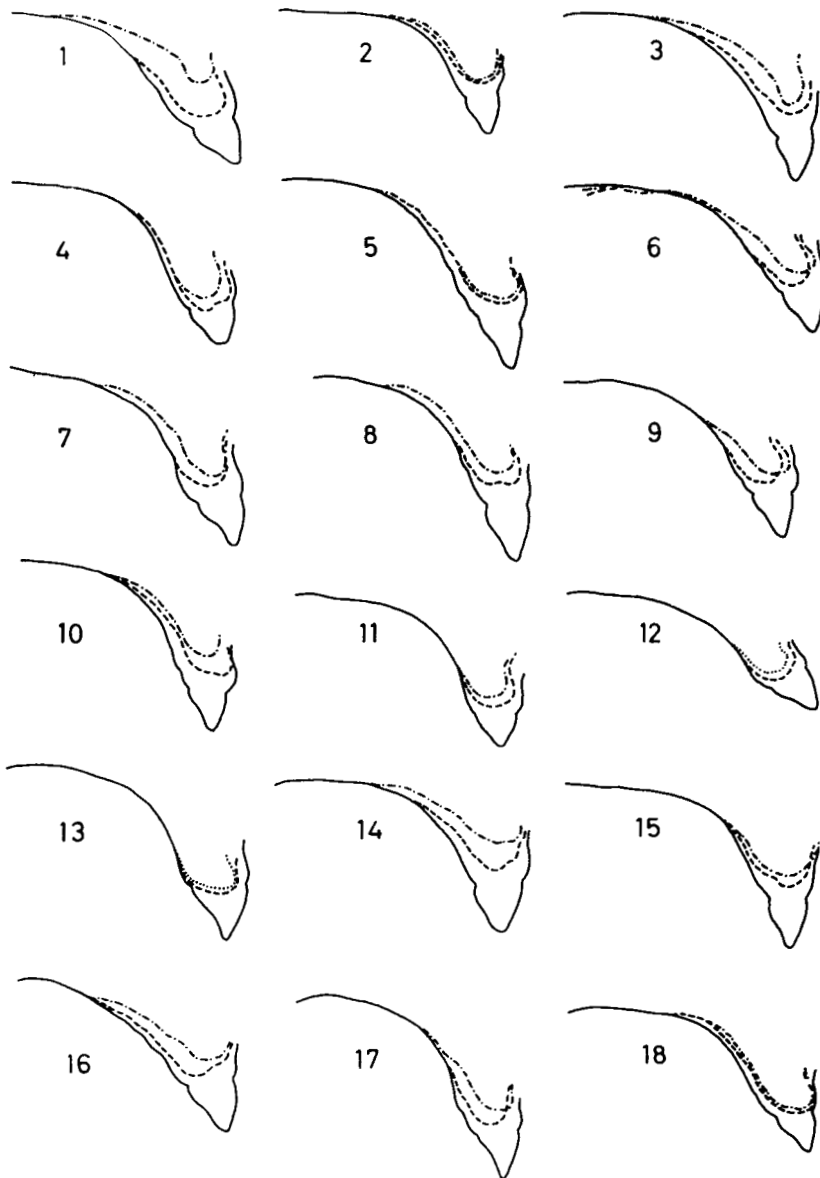
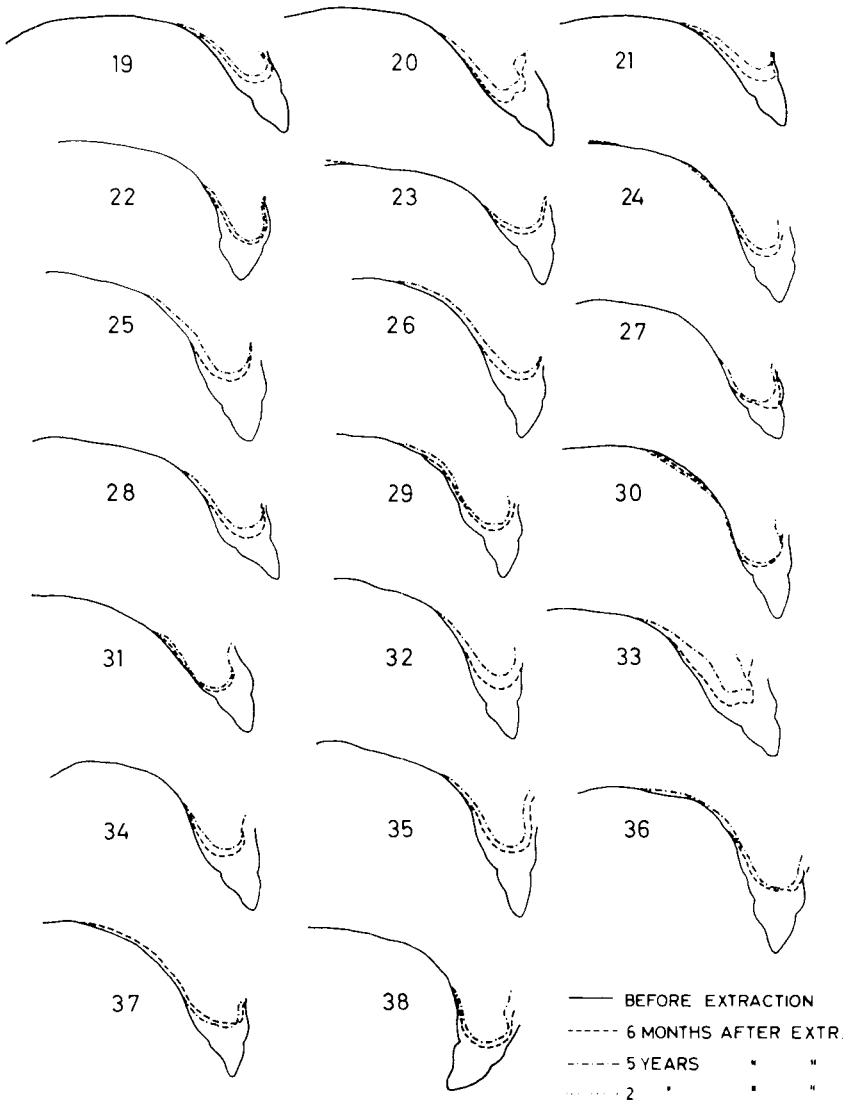


Fig. 7. Superimposed tracings of the mucosal contour in the median plane of the maxilla for all patients at various examinations. Nos. 1—18 relate to group E (extraction only); 1—13 women, 14—18 men; nos. 12 and 13 are the 2 that could be followed only 2 years; nos. 19—38 relate to group A (extraction and intraseptal alveotomy); 19—32 women, 33—38 men. The tracings were mutually oriented with respect to the structures in the anterior cranial base, and in particular the nasion and sella regions. ($\times 0.6$)



IX). The differences between the groups did not reach the level of significance, however.

To further analyse the effect of the dentitional status of the mandible and thereby probably the distribution of the masticatory force on the upper denture the material was divided as follows.

Group I. — Full dentures or natural teeth including lower molars (19 patients).

Group II. — Lower anteriors present, with or without dentures in the lateral segments (17 patients).

The percentage reduction in area of the alveolar process over the 5-year period was greater for group II than group I: 36.8 and 27.2 per cent, respectively (almost significant). The same applies to the comparison of the absolute changes in area during this period (means 148 and 98 mm², respectively; the inter-group difference is almost significant). Further to this division according to dentitional status of the lower jaw, grouping of the series in according to treatment, age and sex disclosed the same tendency in the sub-groups as in the whole material (Table X). A comparison in respect of the absolute change in area for the period between the 6-month and 5-year follow-ups also disclosed a greater reduction for group II (48 and 20 mm², respectively; almost significant).

Size of alveolar process. — The dependence of the extent of the resorption on the size of the alveolar process was examined by dividing the material into two groups according to whether the

Table IX

Means, d, of changes in upper alveolar process; division according to presence of lower denture or natural teeth; millimetres and square millimetres

	No. of subjects	<i>pu</i> 5(<i>y</i>)		<i>as</i> (<i>y</i>)		<i>ab</i> (<i>y</i>)		<i>prs</i> (<i>x</i>)		<i>pr</i> (<i>x</i>)		Area
		0—5	½—5	½—5	½—5	0—5	0—5	0—5	½—5			
1 Full denture	10	4.5	1.0	0.9	2.1	1.8	101	27				
2 Partial denture	10	6.4	2.6	2.6	2.9	3.0	137	49				
3 Natural teeth	16	5.0	1.1	1.3	3.0	2.3	119	23				

Table X

Mean reduction in area of upper alveolar process over the observation period (\bar{d}); division according to dentitional status of the lower jaw, sub-grouping according to treatment, age and sex. Group I, patients with full denture or residual teeth, including molars; group II, residual anterior teeth with or without partial dentures

		Whole													
		series		group E		group A		> 50 years		< 50 years		Women		Men	
		n	\bar{d}	n	\bar{d}	n	\bar{d}	n	\bar{d}	n	\bar{d}	n	\bar{d}	n	\bar{d}
Group	I	19	98	7	100	12	97	9	97	10	100	11	92	8	108
	II	17	148	9	149	8	135	6	176	11	124	14	138	3	161

area of the anterior part of the alveolar process prior to the extractions was greater or less than the mean for the series (374 mm²). The reductions in area over the 5-year period were, respectively, 132 and 108 mm²; the difference was not significant.

Table XI

Number of adjustments, rebasings and replacements in the follow-up period

		No. of subjects	Adjustments		Rebasings 0—2 y		Replace- ments 0—5 y
			0—2 mo	2 mo—2 y	Indirect	Direct	
Group	E	18	36	33	18	23	8
	A	20	46	20	21	17	8

The corresponding percentage reductions were largely the same, namely 32.7 and 30.8 per cent of the original area.

Clinical observations

No remarkable differences between the treatment groups as regards symptoms after the surgical treatment were reported.

The numbers of adjustments, rebasings and replacements of the dentures are given in table XI. The means for the two groups of treatments did not differ significantly either during the first 2 months or during the other follow-up periods. Between the 2 and 5-year checks, during which time the patients were not summoned for examination, only 6 patients sought treatment; 3 of

these had new dentures made, 2 of them because the old ones had ruptured.

At the final check 10 patients were judged to require new upper dentures, and 7 rebasings and/or correction of occlusion and articulation, owing to aesthetic and/or functional defects.

At the final clinical examination of the denture-bearing mucosa (see *Bergman, Carlsson & Hedegård, 1964*) inflammation was observed in 9 group E and 4 group A patients. The mucosa covering the alveolar process in the anterior segment was judged to be mobile in 9 patients of group E and in 5 of group A. For neither of these comparisons were the differences statistically significant.

At the 5-year follow-up all the patients stated that they were using their upper dentures day and night.

DISCUSSION

In a detailed analysis the largest sources of error in the X-ray cephalometric method were found to be the location of the reference points and the projection; the error in the latter case was incurred chiefly in orienting the patient in the cephalostat. The relatively large focus-film distance used in the present study (300 cm) kept the geometric errors low, and for most of the measurements it would seem that the location of the landmarks was the largest source of error. The application of contrast medium in the midline of the maxilla facilitated the identification of the points on the tops of the alveolar process and ensured a relatively high level of precision in the measurements of the mucosal contour in the hard palate. The change in focus-film distance that had to be made at the 5-year follow-up introduced a further error, despite a compensatory alteration of the object-film distance, but this was small in relation to the total error of the method (*Carlsson, 1967*).

A possibility of evaluating the method error on the basis of the results is provided by a comparison of the variance of the method error with the variance within the material (*Hatton & Granger, 1958*). The variances of the precision (s_e^2) of some of the measurements in the present study, the variances for the whole material at the first examination (s_o^2), and the variances of the changes during the follow-up period (s_d^2) are given in table XII.

The variances of the precision were extremely small in relation to the variance of the individual values for the whole series, and fairly small in relation to the variance of the changes. For both s_0^2 and s_d^2 the biologic variance was thus the chief component and the error variance was of minor importance.

The assignment of the patients to the two treatment groups

Table XII

Variances of the method error (precision of the single measurement, s_e^2), for the individual measurements in the whole series (s_0^2) and the changes during the follow-up period (s_d^2) for certain measurements; millimetres and square millimetres

	s_e^2	s_0^2	s_d^2	Follow-up period (years)
<i>Measurement</i>				
<i>prs(x)</i>	0.27	13.69	1.82	0—5
<i>pr(x)</i>	0.16	14.06	1.56	0—5
<i>as(y)</i>	0.07	28.09	3.03	½—5
<i>ab(y)</i>	0.20	34.81	2.90	½—5
Area	67.24	2872.96	2777.29	0—5

cannot be regarded as random. A comparison between the group means for the X-ray cephalometric measurements at the first examination disclosed no significant differences, however (Table XIII). The sex and age distributions were also quite similar in the two groups (Table I), so that the groups would still seem to be comparable.

Nor can it be ruled out that there was some skewness in the material, for instance owing to the time factor, the long period over which the material was collected and the healing periods during different parts of the year. It would have been better had the patients been assigned at random to the two treatment groups.

There were few losses to follow-up. The X-ray cephalometric registration was complete for all patients at the 2-year check. At the 5-year follow-up 2 persons in group E could not come because they had moved from the district. The losses to the earlier checks were due to temporary absence from the district or illness. The loss was thus unassociated with the factors under study and is unlikely to have affected the results.

The fact that there was no significant difference in the reduction in the antero-inferior parts of the alveolar process during the first 6 months might appear remarkable in view of the difference in the surgical treatment. It is probably due to the fact that the trimming of the labial aspect of the casts performed before the group A dentures were made was intended only to provide room for a thin labial denture flange and therefore comprised on average not more than 1 mm.

Table XIII

Means, \bar{x} , and standard deviations, s , for X-ray cephalometric measurements in the two treatment groups at the initial examination, and values of t for differences between the means of the groups

No. of subjects	$pr(x)$	$pr(x)$	$pu\ 5$	$pu\ 10$	$pu\ 25$	$pu\ 35$	area	$n-st$	$n-sp$	$n-gn$
Group E \bar{x}	8.0	9.4	69.0	59.2	48.8	47.4	365.4	63.7	52.5	120.2
s	3.6	3.7	4.5	5.3	3.5	3.2	45.3	3.7	4.5	5.2
A \bar{x}	8.7	10.2	69.0	58.1	48.0	46.5	381.6	63.7	52.3	121.2
s	4.3	4.0	5.8	4.9	4.1	4.0	72.4	4.0	3.9	10.0
E—A t	0.5	0.6	0.0	—0.7	—0.6	—0.8	—0.8	0.0	—0.2	0.4

After the first 6 months the changes were more extensive in group E than group A. For some comparisons there were, unexpectedly, almost significant differences between the groups. It is difficult to believe that this can be due to the difference in surgical methods especially as the difference appeared to be associated primarily with the changes in the palatal part of the alveolar process.

The two groups might possibly display bias for factors on which the extent of the resorption is dependent. Only a few such factors were examined in this investigation, and then only superficially; it is probable that there was an interaction between various factors, but no analysis of variance was performed, the number of patients being quite small and the groups not strictly randomized.

The state of the health during the follow-up period was noted from the histories. Because of prolonged illness during the previous 3 years 2 patients were recorded as being in poor health at

the final check. For both, the resorption values were considerably above the mean; both belonged to group E.

Sixty-one per cent of group A and 47 per cent of group E had full dentures or their own molars. These displayed less resorption than the patients with anterior teeth present (*cf.* p. 17). The clinical examination of the mucosa of the denture-supporting tissues at the final check disclosed inflammation and mobile mucosa on the top of the alveolar process more commonly in group E than in group A. The number of requisite adjustments between 2 months and 2 years after insertion of the dentures was also greater in group E. Taken together, these results suggest that during the later part of the observation period the group E dentures were more traumatizing than the group A; this is reasonable in view of the greater reduction in the alveolar contour found by X-ray cephalometry in group E. That this might further accelerate the resorption and increase the difference between the groups cannot be excluded.

Taken together, these facts might account for the differences between the treatment groups as regards the extent of the resorption.

The rate of resorption of the alveolar process after the first rapid changes of the early healing period has not been closely examined. *Hedegård* (1962), among others, has found that the resorptive process continues between 18 and 36 months after extraction, and *Wictorin* (1964), who followed 11 patients for 36 months after full extraction, found an extremely slow mean rate of resorption between the 12th and 36th months.

It is obvious that there was a considerable retardation of the alterations after the early months, though the alveolar process continued to diminish throughout the follow-up period. After the first 2 years, however, there was no mean reduction of the alveolar process from the labial aspect, while the height of the process and its palatal part diminished. As a consequence of this the process narrowed from the palatal aspect and there was a reduction in the area of this anterior segment (Tables IV and V). This difference in resorption later in the follow-up period may be due in some measure to the fact that the masticatory pressure is transferred by the denture primarily to the top of the alveolar

process and its palatal part. The analyses of the influence of various factors on the resorption suggest that the loading conditions are of major importance.

Though no significant differences in resorption with respect to the size of the alveolar process and sex were found, the results tend in the same direction as those reported by *Wictorin* (1964).

Nor did age display any close correlation with the bone resorption. Chronologic age can be ascribed significance by virtue of its correlation with biologic factors such as cell activity and tissue reaction.

No study was made of metabolic, hormonal, dietary or other biologic factors; such an analysis is probably most difficult to accomplish.

No changes in the anterior cranial base (*n-st*) and anterior height of the maxilla (*n-sp*) were observed during the 5-year period. Extraction of all the upper teeth therefore probably does not give rise to any appreciable skeletal changes, apart from morphologic changes in the alveolar process.

The reduction in height of the face, both morphologic and postural, during the follow-up period is probably to be ascribed to the prosthetic measures not entirely counteracting the effect of the resorption. The difference between groups E and A as regards the changes in morphologic face height may have been due to the greater vertical dimension probably given the dentures in group E than in group A, as suggested by the difference in postural face heights at the 6-month examination (Fig. 6). And it has been shown that changes in postural face height largely run parallel with changes in morphologic face height in full denture wearers (*Carlsson & Ericson, 1967 a*). The insertion of immediate dentures, too, has been found to result in large changes in the morphologic face height (*Swerdlow, 1964; Carlsson & Ericson, 1967 b*). If such a difference between the groups was unintentionally introduced it would provide a further explanation of the differences in the later resorption, since the patients whose vertical dimension was greatly increased on inserting the new dentures displayed greater bone resorption than those with little or no increase (*Thompson, 1946; Carlsson & Ericson, 1965*).

The mean changes in the position of the upper incisors re-

corded during the follow-up period may be considered to reflect an upward and forward movement of the denture, due to incomplete compensation of the reduction in the anterior segment of the alveolar process by the various prosthetic measures. The X-ray cephalometric technique might be used for further study of this and numerous other problems associated with the provision of immediate dentures and resorption of the edentulous alveolar process.

SUMMARY

With the object of examining the morphologic changes in the facial skeleton, and especially the upper alveolar process, after extraction of all upper teeth and the wearing of an immediate denture, a longitudinal study of 38 patients was carried out in which they were re-examined at a series of 8 follow-ups. At 5 of the examinations (before full extraction and 6 months, 1, 2 and 5 years afterwards) profile radiographs were taken with the head in a cephalostat. At this time contrast medium was applied to the mucosa along the median line of the maxilla, from the soft palate to the vestibulum oris. Thirty-six of the patients were followed throughout the 5-year period. In one group of patients only extractions were performed (group E), and in another group intra-septal alveolotomy was performed after extraction of the upper anteriors (group A).

There were no remarkable differences between the two treatment groups as regards complaints after the surgical treatment. Certain differences in bone resorption during the latter part of the follow-up period might possibly be due to other factors than those associated with the surgical method.

The chief results of the X-ray cephalometric measurements were the following:

(1) The anterior part of the maxillary alveolar process diminished greatly in area during the first 6 months after the extraction of the upper anteriors. Thereafter the reduction continued at a much reduced rate, but was still noticeable at the 5-year follow-up. The area of the anterior part diminished by a mean of 85 mm² during the first 6 months, that is to say, by 23 per

cent of the area before extraction (Fig. 1). Between the 6-month and 5-year checks the area diminished by a mean of 32 mm², or 11 per cent of the area at the former check. After the first 2 years there was no mean reduction of the alveolar process from the labial side, but there was from the palatal side, and also in height. There were large individual variations in the extent of the changes (Fig. 7).

(2) The changes in the anterior part of the alveolar process was found to be correlated to the dentitional status in the lower jaw and hence presumably to the load on the upper denture. The patients with full lower dentures or their own teeth, including the molars, showed a smaller reduction (almost significant) in the anterior part of the alveolar process than the patients with only the lower anteriors present, with or without a denture in the molar segments. There was no significant correlation between the reductions and sex, age or size of alveolar process.

(3) The posterior part of the mucosal contour over the median line of the hard palate changed but little during the follow-up period.

(4) The length of the anterior cranial base (*n-st*) and the anterior height of the maxilla (*n-sp*) remained unaltered during the follow-up period.

(5) The morphologic height of the face diminished by a mean of 2.3 mm during the 5-year follow-up period. The postural height of the face decreased by a mean of 2.0 mm between the 6-month and 5-year checks.

RÉSUMÉ

MODIFICATIONS DES CONTOURS DU PROCÈS ALVÉOLAIRE DU MAXILLAIRE SUPÉRIEUR SOUS LES PROTHÈSES IMMÉDIATES.

ETUDE CÉPHALOMÉTRIQUE LONGITUDINALE SUR CINQ ANS PAR
RADIOGRAPHIES.

Désirant examiner les changements morphologiques se produisant dans le squelette facial, et plus particulièrement dans les procès alvéolaires du maxillaire supérieur, après extraction de toutes les dents du haut et pose de prothèses immédiates, les auteurs ont effectué une étude longitudinale portant sur 38 patients suivis au cours d'une série de 8 examens. Lors de 5 des

examens (avant extraction de toutes les dents et au bout de 6 mois, d'un an, de 2 ans et de 5 ans), des radiographies de profil ont été prises en utilisant un céphalostat. Une substance radio-opaque avait alors été appliquée sur la muqueuse le long de la ligne médiane du maxillaire supérieur, depuis le voile du palais jusqu'au vestibule. Trente-six des patients ont été suivis pendant la période de cinq ans tout entière. Dans un groupe de patients, il n'a été procédé qu'à des extractions (groupe E), dans un autre groupe, l'extraction a été suivie d'alvéolotomie intra-septale (groupe A).

Il n'y a pas eu de différence notable entre les deux groupes de traitement en ce qui concerne les plaintes après traitement chirurgical. Certaines différences concernant la résorption osseuse pendant la dernière partie de la période de contrôle sont peut-être dues à d'autres facteurs que ceux qui sont liés à la méthode chirurgicale.

Les principaux résultats des mesures céphalométriques effectuées par radiographies étaient les suivants.

(1) La partie antérieure du procès alvéolaire du maxillaire supérieur a subi une grande réduction de sa surface au moment des extractions des dents antérieures du haut et pendant les six mois suivants. La réduction s'est ensuite poursuivie à une allure beaucoup plus ralentie, mais était encore décelable au contrôle de la cinquième année. La surface de la partie antérieure diminuait en moyenne de 85 mm² au cours des six premiers mois, soit 23 % de la surface avant extraction (fig. 1). Entre le contrôle du sixième mois et celui de la cinquième année, la surface diminuait en moyenne de 32 mm², soit 11 % de la surface lors du contrôle du sixième mois. Au bout des deux premières années, il ne se produisait en moyenne pas de réduction du procès alvéolaire du côté vestibulaire, mais il se produisait une réduction du côté palatin, et aussi une réduction en hauteur. L'étendue des changements variait beaucoup d'un individu à l'autre (fig. 7).

(2) Les modifications de la partie antérieure du procès alvéolaire se sont révélées être en corrélation avec le type d'éden-tation de la mâchoire inférieure, et par conséquent probablement avec la charge supportée par la prothèse du haut. Les patients ayant une prothèse complète du bas ou ayant leurs pro-

pres dents, y compris les molaires, présentaient une réduction moindre (presque significative) de la partie antérieure du procès alvéolaire que les patients chez qui seules les dents antérieures du bas subsistaient, avec ou sans prothèse au niveau des segments molaires. Il n'existait pas de corrélation significative entre les réductions et le sexe, l'âge ou la taille des procès alvéolaires.

(3) La partie postérieure des contours de la muqueuse couvrant la ligne médiane de la voûte du palais ne présentait que peu de modifications pendant la période de contrôle.

(4) La longueur de la partie antérieure de la base du crâne (*n-st*) et la hauteur de la partie antérieure du maxillaire supérieur (*n-sp*) restaient inchangées pendant la période de contrôle.

(5) La hauteur morphologique de la face diminuait en moyenne de 2,3 mm pendant les 5 ans de la période de contrôle. La hauteur de la face en position de repos diminuait en moyenne de 2,0 mm entre le contrôle du sixième mois et celui de la cinquième année.

ZUSAMMENFASSUNG

FORMVERÄNDERUNGEN DES OBEREN ALVEOLARFORTSATZES NACH EINGLIEDERUNG EINER SOFORTPROTHESE

EINE LONGITUDINALE, KLINISCHE UND RÖNTGENCEPHALOMETRISCHE
UNTERSUCHUNG WÄHREND EINER 5-JÄHRIGEN PERIODE

Um die morphologischen Veränderungen des Gesichtsskelettes und besonders des Alveolarfortsatzes nach Entfernung aller Oberkieferzähne sowie Eingliederung einer Sofortprothese zu eruieren, wurden 38 Patienten zu 9 verschiedenen Kontrollzeitpunkten während einer 5-jährigen Periode untersucht. Bei 5 von diesen Kontrollen (vor, sowie $\frac{1}{2}$, 1, 2 und 5 Jahre nach der Zahnentfernung), wurden Profiliröntgenogramme in einem Cephalostat gemacht. Hierbei wurde in der Mittellinie des Oberkiefers auf die Schleimhaut des Oberkiefers ein Röntgenkontrastmittel aufgetragen. 36 von 38 Patienten standen für die Dauer der Versuche für Untersuchungen zur Verfügung. In einer Patientengruppe wurde als einziger chirurgischer Eingriff die Zahnentfernung vorgenommen (Gruppe E), bei den Übrigen wurde nach der Zahnentfernung eine „intraseptale Alveotomie“ durchgeführt (Gruppe A).

Besondere Unterschiede in der Art der Beschwerden nach der chirurgischen Behandlung konnten zwischen den Behandlungs-

gruppen nicht festgestellt werden. Gewisse Unterschiede des Knochenschwundes während des letzten Abschnittes der Observationszeit könnten teilweise mit anderen Faktoren als durch die Verschiedenartigkeit der chirurgischen Eingriffe erklärt werden.

Die röntgencephalometrischen Analysen ergaben u.a. folgende Resultate:

1) Der anteriore Teil des Oberkieferalveolarfortsatzes nahm während des ersten halben Jahres nach der Zahnentfernung an Umfang kräftig ab. Die Verminderungsgeschwindigkeit wurde danach wesentlich geringer, war aber noch während der ganzen Observationszeit zu bemerken. Im ersten halben Jahr nahm die Fläche mit durchschnittlich 85 mm^2 ab, entsprechend 23 % der Fläche vor der Zahnentfernung. Zwischen den $\frac{1}{2}$ - und 5-Jahreskontrollen nahm die Fläche durchschnittlich 32 mm^2 ab, entsprechend 11 % der Fläche bei der $\frac{1}{2}$ -Jahreskontrolle. Nach den ersten 2 Jahren erfolgte keine Reduktion des Alveolarfortsatzes von der labialen Seite aus, wohl aber von der palatinalen Seite her und in vertikaler Richtung. Im Bezug auf den Umfang der Veränderungen wurden bei dem vorliegenden Patientenmaterial grosse individuelle Variationen festgestellt.

2) Die Veränderungen im anterioren Teil des Oberkieferalveolarfortsatzes standen in Korrelation zu den Gebissverhältnissen im Unterkiefer, und damit wahrscheinlich auch zu der Belastung der Oberkieferprothese. So wiesen Patienten mit Vollprothese oder eigenen Zähnen einschliesslich der Molaren einen geringeren Knochenschwund auf (fast signifikant), als diejenigen, welche nur Frontzähne im Unterkiefer hatten, gleichgültig, ob mit oder ohne Zahnersatz im Seitenzahnbereich. Zwischen den Veränderungen einerseits und Geschlecht oder Alter der Patienten andererseits, konnte kein sicherer Zusammenhang festgestellt werden.

3) Der posteriore Teil der Schleimhautkontur in der Mittellinie des harten Gaumens veränderte sich unter der Observationszeit nur unbedeutend.

4) Veränderungen der vorderen Schädelbasis (*n-st*) und der anterioren Oberkieferhöhe (*n-sp*) wurden nicht beobachtet.

5) Die morphologische Gesichtshöhe (*n-gn*) nahm während der Observationszeit mit durchschnittlich 2,3 mm ab. Die posturale Gesichtshöhe nahm zwischen den $\frac{1}{2}$ - und 5-Jahreskontrollen mit durchschnittlich 2,0 mm ab.

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Addresses:

G. E. Carlsson and B. Bergman,
School of Dentistry,
Umeå 6,
Sweden.

B. Hedegård,
School of Dentistry,
Stockholm 3,
Sweden.