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SONAGRAPHIC AND PALATOGRAPHIC STUDIES OF FULL DENTURE, HALF DENTURE, AND EDENTULOUS CASES

by

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Sound spectrographic (so-called sonagraphic) studies using modern sound analysers are extremely rare in dentistry. *Kaires* (5), however, in 1957 carried out such studies, examining by sound spectrography the palatal pressures of the tongue in phonetics, and the effect on speech of the normal, increased or lowered vertical dimension of dentures and of the edentulous oral cavity. When he made a gross comparison of the relative peaks in the frequency spectra, he noted no differences arising from the different vertical dimensions. The absence of dentures, however, reduced the distribution of relative amplitude, particularly in the higher frequency bands, and the correct vertical dimension resulted in greater intensity in the higher frequency bands. Kaires concluded that "sound spectrographic methods in speech analysis warrant further study".

Palatographic studies had been used earlier in dentistry, (6, 9) *e.g.* by *Reichenbach* (11). The photopalatographic method developed by *Anthony* (1), however, has not yet been applied to many dental studies (4, 22).

The purpose of the present work was to study, by the sonagraphic and photopalatographic methods, the changes in speech caused by full dentures, half dentures and the edentulous oral cavity, and the part they play in speech. The chosen objects of study were the dental sounds *(r, s, t, l, n)* which are important in dentistry because in pronouncing them the tongue touches, differently for each of these different sounds, the palatal surfaces of the teeth and the gingiva at the back of the teeth, and the alveolar process (8, 21). It is unlikely that a similar study has been attempted before.

MATERIAL

The investigation series consisted of 10 patients with full dentures, drawn between 1959 and 1961 from among the full denture patients of the Prosthetic Department of the Institute of Dentistry, University of Helsinki. The construction phases of all the dentures were checked and the dentures finally accepted for use. One of the patients (Case 10) was being privately treated. The denture materials were acrylics; the teeth were porcelain or acrylic.

Table I.
Age of experimental subjects.

Case No.	Male	Case No.	Female
1. R.M.	52 years	6. K.R.	27 years
2. J.E.	54 »	7. A-L.J.	33 »
3. J.V.	58 »	8. A.L.	33 »
4. A.L.	59 »	9. H.A.	63 »
5. J.M.	74 »	10. I.O.	79 »
Mean age	59.4 years	Mean age	47 years
Overall mean 53.2 years			

The mean age of the experimental subjects was 53.2 years. The youngest, 27 years of age, and the oldest, 79 years, were women. The mean age of the women was 47 and that of the men 59.4

years. As a rule, women get dentures earlier than men, and the age distribution of the present subjects does not therefore differ from the normal, although the selection of patients for the present study was made at random, regardless of age.

Table II.
Types and occlusion of dentures.

Dentures			Type of Occlusion
Male			
1.	R.M.	14/14	Ordinary
2.	J.E.	14/14	Edge-to-edge bite of front teeth } Congenital Crossbite of molar teeth } progenia
3.	J.V.	12/12	Ordinary, but crossbite of molar teeth
4.	A.L.	14/14	Ordinary
5.	J.M.	12/12	Ordinary
Female			
6.	K.R.	10/12	Edge-to-edge bite of front teeth } Congenital Crossbite of molar teeth } progenia
7.	A.L.	14/14	Ordinary
8.	A-L.J.	12/12	Ordinary
9.	H.A.	12/12	Edge-to-edge bite of front teeth } Congenital Crossbite of molar teeth } progenia
10.	I.O.	14/14	Ordinary

70 per cent of the prostheses were ordinary full dentures while 30 per cent were full dentures of the incisal edge-to-edge bite and lateral crossbite type. The number of teeth varied, but only half of the dentures had the usual number of teeth, 14/14. In 4 cases the total number of teeth was reduced to 12/12 for prosthetic and anatomical reasons by omitting the second molars. Case 6 (K.R.), with congenital progenia, represents the heavily reduced type 10/12, the second bicuspid also being omitted from the maxillary denture. This case was also anatomically different from the others; the maxillary alveolar processes were very wide, some 13 mm in the canine region and 16—15 mm at the molar teeth, with the result that the palate looked like a high and fairly narrow gully, starting in a steep curve at the canine and the first premolar teeth. This particular denture had very low teeth, though the teeth of many other dentures were also low and rose only 1—2 mm from the base plate, particularly on the palatal side.

Table III.

Wearing of dentures.

Case	Dentures worn previously	Edentulous period prior to new dentures	New dentures worn prior to sound recording
1. R.M.	4 yrs., partial denture	4 months	1 day
2. J.E.	some 12—13 yrs.	—	3 days
3. J.V.	nil	3 months	15 »
4. A.L.	some 5 yrs., partial dentures (12/10)	6 » (without mandibular front teeth)	18 »
5. J.M.	nil	5 months	3 »
6. K.R.	nil	6 »	14 »
7. A-L.J.	nil	over 5 months	(I) 3 days (II) 2 months
8. A.L.	nil (14/14 denture 7 yrs. ago but wore it for 1 month only)	7 years	4 days
9. H.A.	some 10 yrs., partial dentures (14/9)	—	2 years
10. I.O.	some 10 yrs., partial dentures	—	4 »

As is evident from Table III, half of the patients were former denture-wearers while the other half had never worn dentures before. Two (Cases 2 and 10, aged 54 and 79 years), had previously worn full dentures for long periods. Case 10, the private patient, gradually approached full dentures through partial dentures, without edentulous intervals. Half the patients were edentulous for 4—7 months before they received their full dentures. Teeth were usually extracted in one university term and the prosthetic treatment started in the next. Case 8, aged 33, had been edentulous for 7 years, since she had worn the dentures made for her 7 years earlier for one month only. No immediate dentures proper are included in the present series.

Sound recordings with the test dentures took place a few days or weeks after the dentures had been fitted. The period of habituation ranged in 8 cases from 1 to 18 days. A re-recording was made in some cases after 2 months. In two cases recordings were only made after a longer period, 2 and 4 years, during which the dentures had been constantly worn.

COURSE OF INVESTIGATION

I. Length, circumference, width and height measurements were taken of the edentulous jaws and of the full dentures.
II. Using photopalatography, 65 palatograms were made for the six patients. Each patient pronounced, one word at a time, first with and then without dentures, the words of the sentence given below. Contact traces of the painted tongue on the teeth and the palate were then photographed by means of a mirror the width of the palate, inside the mouth. The "paint" employed was a mixture of powdered carbon and cocoa.
III. A magnetophone recording was made of each patient in 4 different phases: 1) edentulous, 2) wearing full dentures, 3) wearing only the maxillary denture, 4) wearing only the mandibular denture. The same test sentence was pronounced by the patient 3 consecutive times in all 4 recordings, viz. "K a a r r a O t t o, a n n a o l l a m a a s s a" (Turn out, Otto, leave it on the ground). To begin with, 80 time-frequency sonagrams were made from the magnetophone recordings at the Institute of Phonetics, University of Helsinki. Subsequently, 200 sections of momentanic frequency spectra were made from these sections, that is to say four sections per phoneme of the person tested. These 4 sections represented the above-mentioned 4 denture-wearing phases.

I. Measurements

The anatomical basis is, apart from other considerations, important for speech (16, 17, 18, 19). Measurements were taken of the edentulous jaws and of the corresponding dentures. Arch lengths and circumferences, widths and heights were measured on plaster casts. The same person took the measurements twice, first with ordinary dividers, then with a slide rule, from which direct readings were obtained. Where differences were noted (maximum discrepancy 1—2.5 mm), the results were checked once more by means of the slide rule. Heights and circumferences were measured by one of the authors aided by a technical assistant. Circumferences were measured with the aid of fairly thick, transparent celluloid tape.

Only the arch width was measured from the edentulous mandibles. No other measurements were taken since the necessary demarcations and landmarks are difficult to determine precisely on plaster casts.

The area of dispersion entered in the tables was obtained by calculating the difference between the highest and the lowest measurement values.

Arch length

Measured

In prosthesis:

The distance between the labial tangent of the medial incisors and a line connecting the distal surfaces of the most posterior teeth of the prosthesis. (Distance to first molars = I MM, to second molars = II MM).

In edentulous maxilla:

The distance between the labial surfaces of the crest (opposite the incisive papilla) and a line connecting the distal surfaces of the maxillary tubers.

Table IV.

Difference in the length between the edentulous maxilla and the maxillary prosthesis (posterior teeth).

Case		Maxillary prosthesis Distance I MM	Maxillary prosthesis Distance II MM	Difference	Edentulous maxilla Distance to line connecting tubers	Mandibular prosthesis Distance I MM	Mandibular prosthesis Distance II MM
R.M.	14/14	33 mm	41.5mm	4 mm	45.5 mm	29mm	39mm
J.E.	14/14	31.5 «	39.5 «	10.5 «	50 «	30 «	40 «
J.V.	12/12	36.5 «	— «	16 «	52.5 «	30 «	— «
A.L.	14/14	30 «	40 «	8 «	48 «	28 «	35 «
J.M.	12/12	33 «	— «	9 «	42 «	31 «	— «
K.R*)	10/12	28 «	— «	20 «	48 «	29 «	— «
A.L.	14/14	30 «	38 «	6 «	44 «	26 «	35 «
A-L.J.	12/12	33.5 «	— «	16.5 «	50 «	26 «	— «
H.A.	12/12	34 «	— «	11 «	45 «	31 «	— «
I.O.	14/14	35 «	42.5 «	4 «	46.5 «	31 «	41 «
Area of dispersion:		8.5 mm	4.5 mm	16 mm	10.5 mm	5 mm	6 mm

*) In this reduced crossbite maxillary full denture (10/12) K.R. has only one bicuspid and one molar on each side.

Circumference

Measured

In prosthesis:

The bucco-labial circumference of the dental arch up to the tangent of the distal surface of the posterior tooth.

In edentulous maxilla:

The bucco-labial circumference of the alveolar process up to the tangent of the tubers.

Table V.

Difference between the circumferences of the edentulous maxilla and the corresponding prosthesis.

Case		Maxillary prosthesis	Difference	Edentulous maxilla	Mandibular prosthesis
R.M.	14/14	110 mm	11 mm	121 mm	102 mm
J.E.	14/14	112 »	12 »	126 »	112 »
J.V.	12/12	100 »	32 »	132 »	89 »
A.L.	14/14	110 »	13 »	123 »	102 »
J.M.	12/12	97 »	21 »	118 »	91 »
K.R.	10/12	82 »	42 »	124 »	83 »
A.L.	14/14	106 »	13 »	119 »	105 »
A-L.J.	12/12	100 »	30 »	130 »	88 »
H.A.	12/12	93 »	28 »	121 »	89 »
I.O.	14/14	118 »	6 »	124 »	112.5 »
Area of dispersion:		36 mm	36 mm	14 mm	29.5 mm

Some dispersion in arch length and circumference is visible, and is attributable, to a minor extent, to the different dimensions of the prosthetic teeth, especially to the variation in the number of teeth. Case 6 (K.R.) is a special case 10/12, with only 10 teeth in the maxillary denture. For this reason the difference between the arch lengths of the edentulous maxilla and the corresponding prosthetic teeth is the greatest, 20 mm, with an empty space left on the denture behind the molar teeth. The smallest difference is 4 mm, and the area of dispersion is thus 16 mm (Table IV). The considerable difference in circumference of the edentulous maxilla (area of dispersion 14 mm) and the maxillary denture (area of dispersion 36 mm; the difference of these dispersion areas is thus 22 mm) is also the result of this factor. In Case 6 the difference is as much as 42 mm (Table V). The dispersion is greatest in the maxillary dentures, while the number of teeth varies from 10 to 14. The area of dispersion of the circumference of the mandibular dentures is slightly smaller (29.5 mm), and the difference is 6.5 mm. There is also less variation in the number of mandibular teeth (12—14).

Arch width

Measured

In prosthesis:

(1) The inter-canine distance (3 to 3) (a) from the tip of the crown to the antimere and (b) from the palatal gingival margin to the antimere,

(2) The inter-molar distance (6 to 6) (a) from the mesio-palatal cusp to the antimere and (b) from the palatal gingival margin to the antimere.

Table VI.

Arch width

Prostheses

Distance between
a) crown tips
b) ging.-pal. (ling.) margin
} of canines, 3—3 — first molars 6—6

Case	Maxillary prosthesis		Mandibular prosthesis	
	3—3	6—6	3—3	6—6
R.M.	a) 33	38.5	a) 23.5	34
	b) 30	34	b) 21.5	31
J.E.	a) 36	43	a) 26	43
	b) 33	40	b) 24	42
J.V.	a) 33	38	a) 28	41
	b) 30	34	b) 24	40.5
A.L.	a) 32	40	a) 25	36
	b) 28	37	b) 20	35
J.M.	a) 34	44	a) 28	40
	b) 32	40	b) 24.5	37.5
K.R.	a) 34	34	a) 25	36
	b) 30	31	b) 22	39
A.L.	a) 32	37	a) 24	33
	b) 30	33	b) 22.5	31
A-L.J.	a) 35	42	a) 24.5	41
	b) 30.5	38	b) 21	38.5
H.A.	a) 34	38.5	a) 26.5	40
	b) 27	38	b) 27	40
I.O.	a) 35	42	a) 29	38
	b) 28	37	b) 25	35.5
Area of dispersion:	a) 4 mm b) 5 mm	a) 10 mm b) 9 mm	a) 5.5 mm b) 5 mm	a) 10 mm b) 11 mm

Table VII.

Arch width

Edentulous jaws.

Case	Edentulous maxilla		Edentulous mandible	
	3–3 (mm)	6–6 (mm)	3–3 (mm)	6–6 (mm)
R.M.	32	44	27	54
J.E.	33	44	31	50
J.V.	34	45	29	52
A.L.	34	45	27	51
J.M.	34	45	34	53
K.R.	32 (8 mm inside)	40 (16 mm inside)	30	47
A.L.	31	42	26	42
A-L.J.	32	47	27	48
H.A.	31	46	32	54
I.O.	34	45	27	47
Area of dispersion:	3 mm	7 mm	8 mm	12 mm

In edentulous jaws:

(1) The inter-canine (3 to 3) and
(2) the inter-molar (6 to 6) distances between the estimated alveoli from the alveolar ridge to the antimere.

The points were determined by bilateral measurement on the dentures, by the dividers, the distance between the central point of the medial incisors and the distal surfaces of the prosthetic teeth in question. The measured distances were transferred onto the ridge of the edentulous plaster cast, using the incisive papilla as the centre.

Canines, second bicuspids and second molars are usually taken as the points for measuring the arch width (7, 10). In the present work, we used canines and first molars, omitting bicuspid measurements since the distance between the first bicuspids approaches the inter-canine distance. The distances between second bicuspids and between first molars, however, did not in the present material differ greatly from each other either. First molars had necessarily to be taken as the points of measurement since in 40 per cent of the dentures the second molar is excluded and the first molar is the last tooth in the denture.

In both dentures, the intercanine widths are roughly equal and the dispersion area is small. For maxillary dentures it is only 4—5 mm and for mandibular dentures 5.5—5 mm (the figure for the edentulous maxilla is 3 mm, and for the edentulous mandible 8 mm). At the molars the dispersion area is already greater: for maxillary dentures 10—9 mm and for mandibular dentures 10—11 mm. The corresponding figures for edentulous jaws are 7 and 12 mm.

When the men and women of the series are compared, it is seen that the maximum and minimum canine widths for women are 1 mm smaller than those for men. *Similarly, the width of the* female prosthetic arch at the molars is 1—3 mm less than that of the male. The arch of the maxillary dentures of women, therefore, is slightly narrower than that of men.

If the arch widths of maxillary and mandibular dentures are compared, it is found that the mandibular dentures of all the patients, male and female, are, on an average, 6 mm narrower at the canines (8 mm in terms of crown tip distance) than the maxillary dentures. At the molars, the ratio is reversed in 4 cases: In the three cases with congenital progenia (Cases 2, 6, 9) both the inter-cusp and the gingival molar widths are found to exceed those of the maxillary dentures (maximum 3 mm and 8 mm, respectively). In Case 3 the molar arch width of the mandibular denture is probably a result of the lingual alveolar resorption, typical of the mandible, which leads to a mandibular arch wider than the maxillary arch, which may in turn be narrowed by the resorption of buccal alveoli. The result is a crossbite of the lateral teeth, as in this case.

Dentures did not differ in width except in molar width, and it seems, therefore, that no great changes occur in the anterior arch or canine areas of the maxillary and mandibular dentures in these cases. Variations in the width of the canine area of the edentulous jaw have been suitably levelled out in the dentures; progenia, for example, has been converted into edge-to-edge bite in the incisor and canine areas. In all cases the arch of the frontal teeth was ordinary (roundish) in shape.

Arch height

Measured

In prosthesis:

At two points:
(1) the distance from the plane connecting the occlusal surfaces of the first molars, at right angles, to the palatal centre (6 to 6), (2) the distance from the line connecting the distal occlusal margin of the canines at right angles to the corresponding centre of the palate (alveolar bend, 3 to 3).

In edentulous jaws:

The relevant points were determined by marking the places of the canines and first molars, measured bilaterally from the prostheses, on the alveolar ridge by means of dividers and with the incisive papilla as the central point.

Table VIII.

Arch height

Difference between the corresponding heights measured on the maxillary prostheses and on the edentulous jaws.

Case		Maxillary prosthesis		Difference		Edentulous maxilla	
		3–3	6–6	3–3	6–6	3–3	6–6
1.	R.M.	10 mm	21 mm	2 mm	11 mm	8 mm	10 mm
2.	J.E.	6 »	17 »	1 »	5 »	7 »	12 »
3.	H.V.	19 »	21 »	7 »	7 »	12 »	14 »
4.	A.L.	10 »	20 »	5 »	6 »	5 »	12 »
5.	J.M.	9 »	21 »	4 »	9 »	5 »	12 »
6.	K.R.	6 »	21 »	3 »	1 »	9 »	20 »
7.	A.L.	8 »	18 »	3 »	6 »	5 »	12 »
8.	A-L.J.	11 »	20 »	4 »	6 »	7 »	14 »
9.	H.A.	10 »	18 »	4 »	6 »	6 »	12 »
10.	I.O.*)	8 »	15 »	3 »	5 »	5 »	10 »
Area of dispersion:		13 mm (19–6)	6 mm (21–15)	6 mm (7–1)	10 mm (11–1)	7 mm (12–5)	10 mm (20–10)

Maximum and minimum measurement values given in brackets

***) Torus platinus.**

It may be seen from Table VIII that the variations in arch height in the canine area are quite considerable. The area of dispersion is 13 mm. In the edentulous maxilla this area of dispersion is only 7 mm.

The mean arch height of the canine area on the prostheses is 9.7 mm and in the edentulous maxilla 6.9 mm.

The mean arch height of the molar area on the prostheses is 19.2 mm, and in the edentulous maxilla 12.8 mm.

Variations in the arch height of the molar area in the prostheses are not great, the area of dispersion being only 6 mm. In the edentulous maxilla the area of dispersion is 10 mm.

The height values of the edentulous maxilla are affected by the individual structural differences between patients, their ages, and the varying degree of resorption of the alveolar processes, which has been levelled out in the dentures. One patient (Case 10) has a fairly wide torus palatinus, and this tends to reduce the height of the palate, especially in the molar region.

II. Results obtained by photopalatography

The photopalatographic apparatus and the mirror of the same width as the palate were fitted in the patient's mouth for photography. The patients' heads were placed in identical positions, as

Fig. 1. Photopalatographic apparatus *in situ*.

Fig. 2. Photopalatographic apparatus *in situ*.

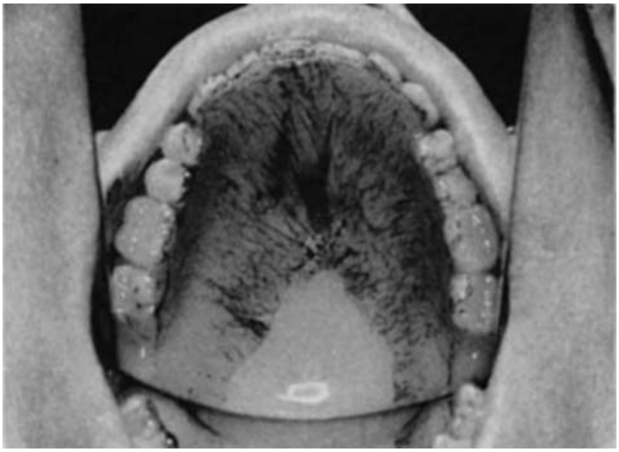

Fig. 3. Palatogram of *t* sound. Wearing full denture. Case A. L.

judged by the naked eye, for each individual photograph, so that the straight part of the hard palate was always horizontal. Accuracy sufficient for the present purpose can be assured even without a firm fixation of the head (Figs. 1—2).

Photopalatograms were taken in this way of 3 male and 3 female subjects (J.V., A.L., R.M., A-L.J., H.A., and K.R.).

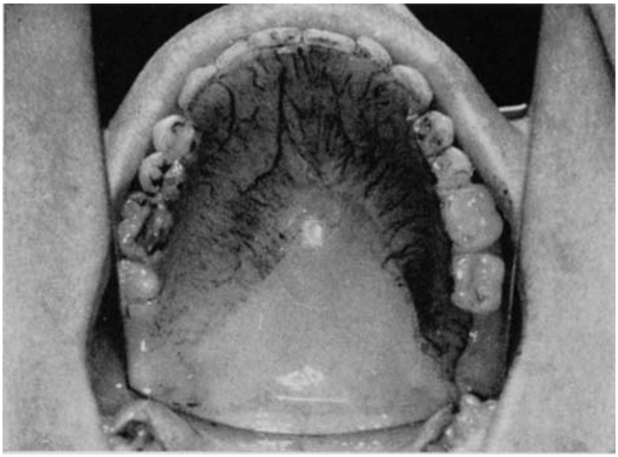

Fig. 4. Palatogram of *t* sound. Wearing only maxillary denture. Case A. L.

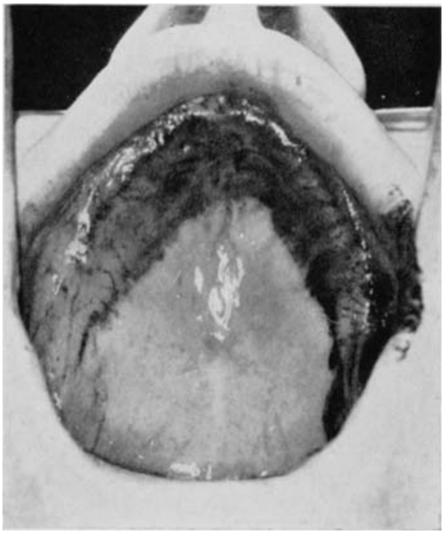

Fig. 5. Palatogram of *t* sound. Edentulous. Case A. L.

Of the men, J.V. had a relatively high, and A.L. and R.M. a medium high, maxillary arch, though the arches were of ordinary width in all. A comparison of palatograms made without the dentures and with the dentures in place showed that the contact sur-

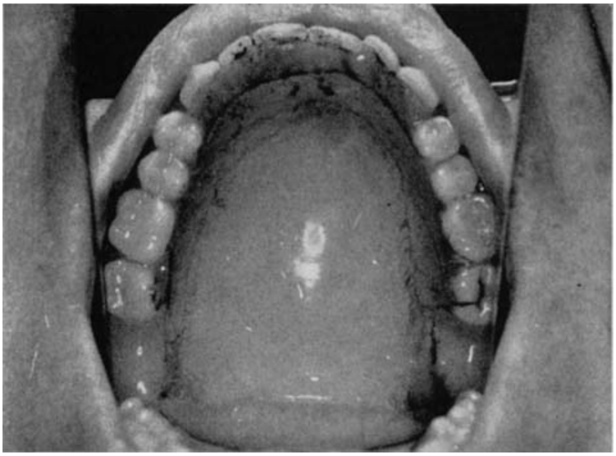

Fig. 6. Palatogram of *n* sound. Wearing full denture. Case A. L.

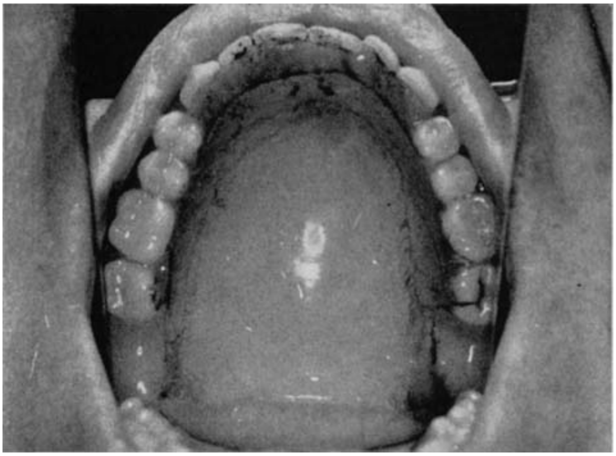

Fig. 7. Palatogram of *n* sound. Wearing only maxillary denture. Case A. L.

face areas only varier in the latter two cases, *i.e.* in those with the medium high maxillary arches. As a rule, the contact areas were smaller when speech was produced without dentures than with them, especially for the sounds *t* and *n*. The reverse may be true with the sound *l*. (See the palatograms for these 3 dental sounds

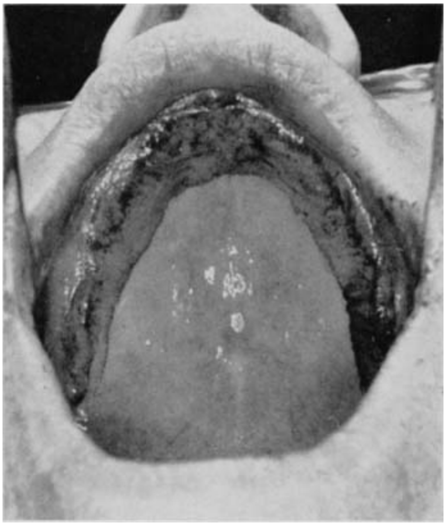

Fig. 8. Palatogram of *n* sound. Edentulous. Case A. L.

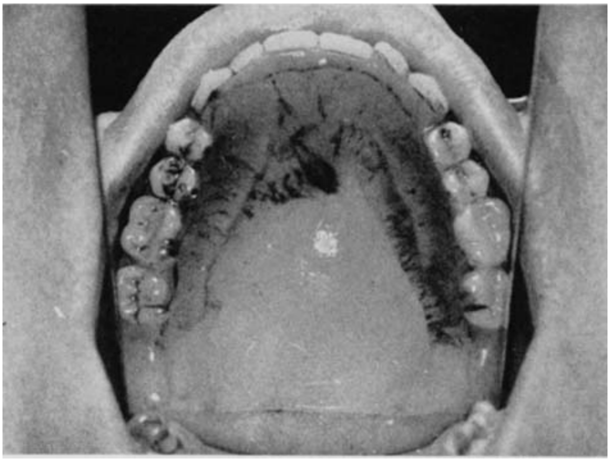

Fig. 9. Palatogram of *l* sound. Wearing only maxillary denture. Case A. L.

for Case A.L., as well as those obtained in this case with only the maxillary denture in place, Figs. 3—5, 6—8, and 9—11). A.L. pronounced his *l* without dentures using an exceptionally large contact surface of the front of the palate, since for him this was

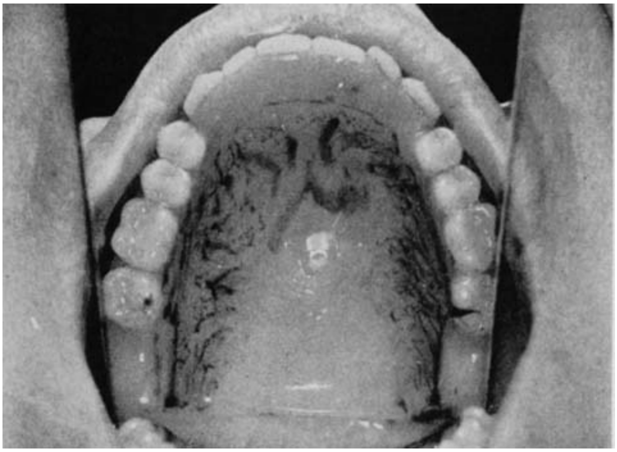

Fig. 10. Palatogram of *l* sound. Wearing full denture. Case A. L.

Fig. 11. Palatogram of *l* sound. Edentulous. Case A. L.

the only possible way of producing sufficiently large lateral channels of the tongue for the semi-dark Finnish *l* sound.

The diminution of contact surfaces usually found when there is a transition from articulation with full dentures to that

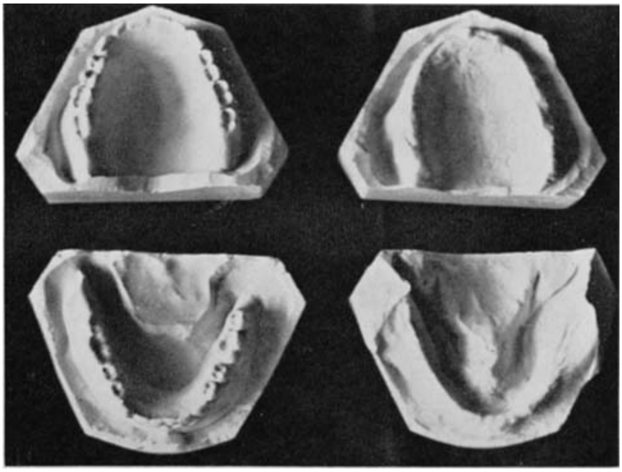

Fig. 12. Plaster casts of prostheses and edentulous jaws. Case A. L.

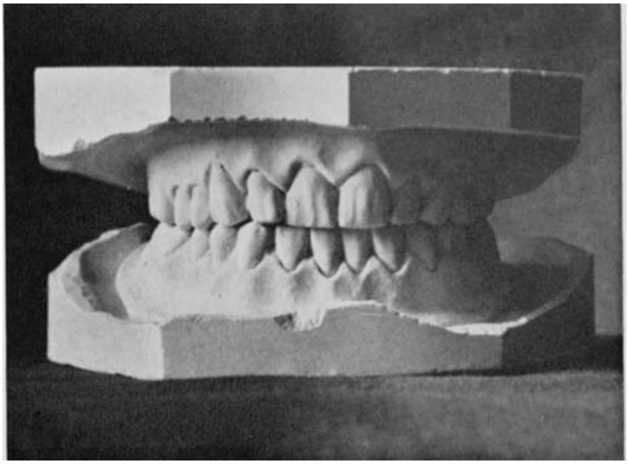

Fig. 13. Prostheses in occlusion. Case A. L.

with only the upper prosthesis and finally no prosthesis, may in our view be attributed to the fact that it is easier (or there is more space) for the front and sides of the tongue to form the semi-circular contact surfaces indispensable for articulation. In these different denture-wearing stages the difference in the sur-

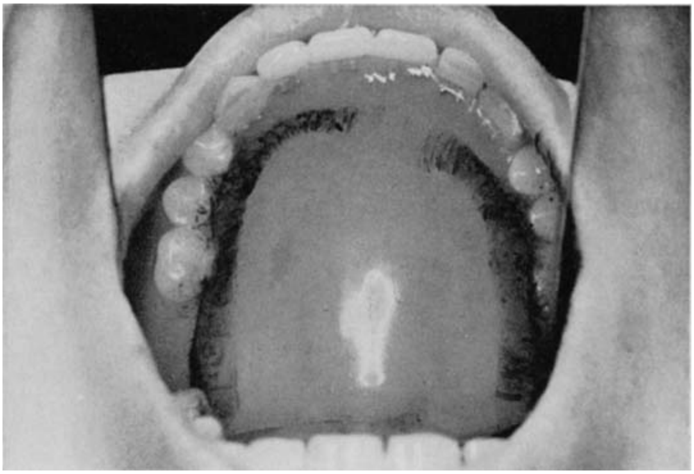

Fig. 14. Palatogram of *r* sound (postalveolar). Wearing full denture. Case A-L. J.

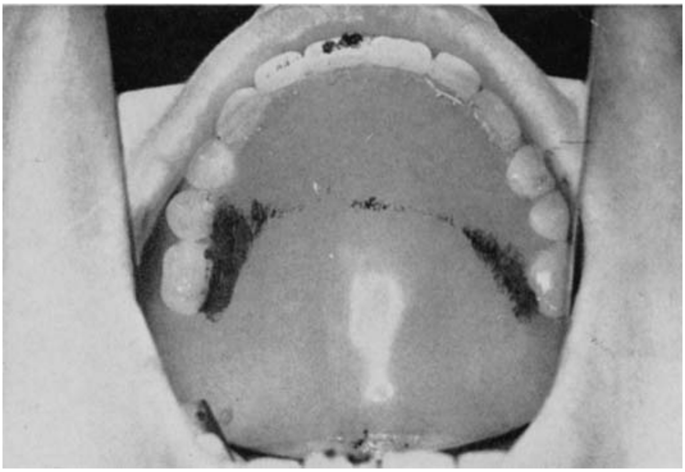

Fig. 15. Palatogram of *l* sound (cacuminal). Wearing full denture. Case A-L. J.

face area of tongue contact traces is even greater with a low than with the ordinary high palate because the mass of the tongue then has less room for dental sound articulation.

The sides of the tongue always tend to push into and fill the

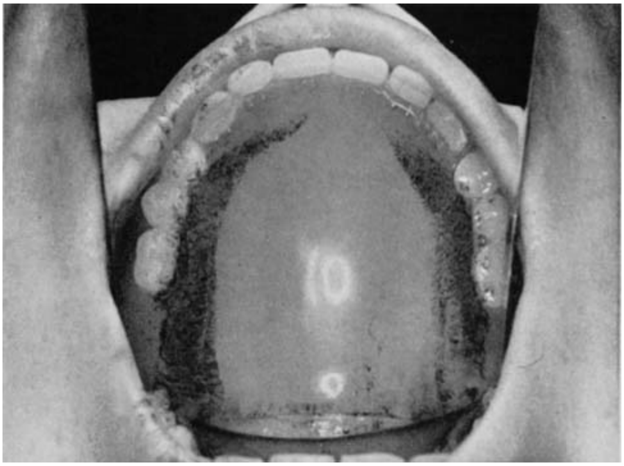

Fig. 16. Palatogram of *s* sound (postalveolar). Wearing full denture. Case A-L. J.

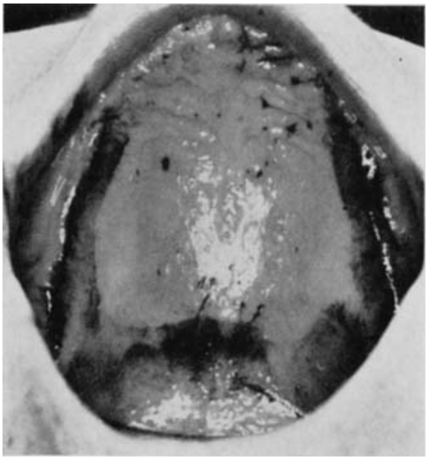

Fig. 17. Palatogram of *r* sound. Edentulous. Case A-L. J.

vacuum which originates between the maxilla and the mandible when the teeth are absent. The result is that the contact trace of the tongue against the palate or the alevolar process diminishes.

Fig. 12 shows the plaster casts of the maxilla and mandible for subject A.L., with and without prostheses. The prostheses in central occlusion are shown in Fig. 13.

Fig. 18. Palatogram of *s* sound. Edentulous. Case A-L. J.

Fig. 19. Palatogram of *l* sound. Edentulous. Case A-L. J.

Of the female test subjects, A-L.J. has a broad and relatively high maxillary arch. With both dentures in place articulation occurs more to the back of the mouth than usual, because of the "push-back" position of the tongue. Her *r* sound was post-alveolar (and not normal medio-alveolar), see Fig. 14. Her *l* sound had an even cacuminal position, see Fig. 15. Like her *r*, her *s* was post-

Fig. 20. Prostheses in *s* phonation. Case A-L. J.

Fig. 21. Prostheses in central occlusion. Case A-L. J.

alveolar and not normal medio-alveolar (Fig. 16). In this case the arch of the front teeth on the denture has obviously been placed so much more palatally than the original arch that the artificial teeth reduce and limit the movements of the tongue.

The same subject's palatograms for dentureless speech show

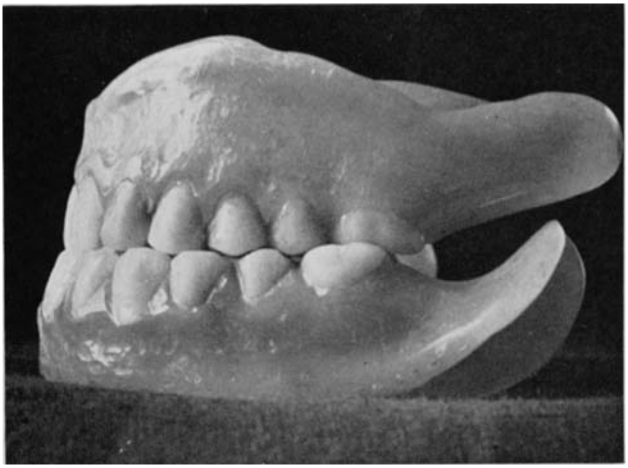

Fig. 22. Incisal edgebite and lateral crossbite. Plaster casts of case H. A.

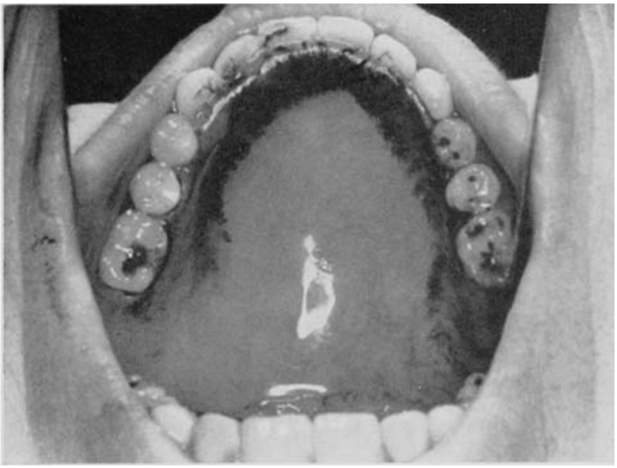

Fig. 23. Palatogram of *l* sound. Wearing full denture. Case H. A.

that the tongue tip strictures present in the sounds *r* and *s* are twice as wide as during speech with dentures. They are at the same time larger than normal. The *l* sound, in dentureless speech, was normal (medio-alveolar), Figs. 17—19. The position of this subject's front teeth when saying *s* and in central occlusion is

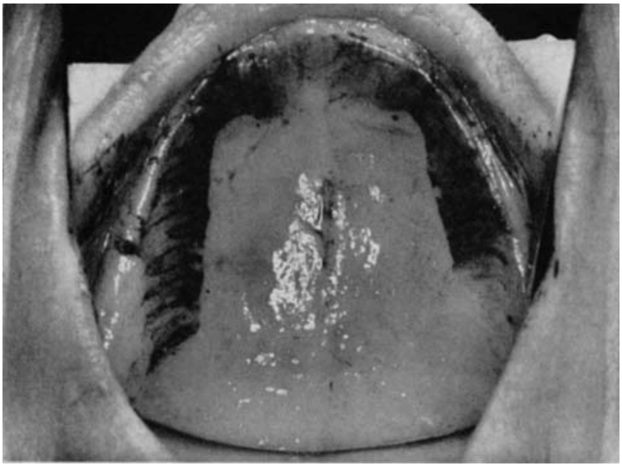

Fig. 24. Palatogram of *t* sound. Edentulous. Case H. A.

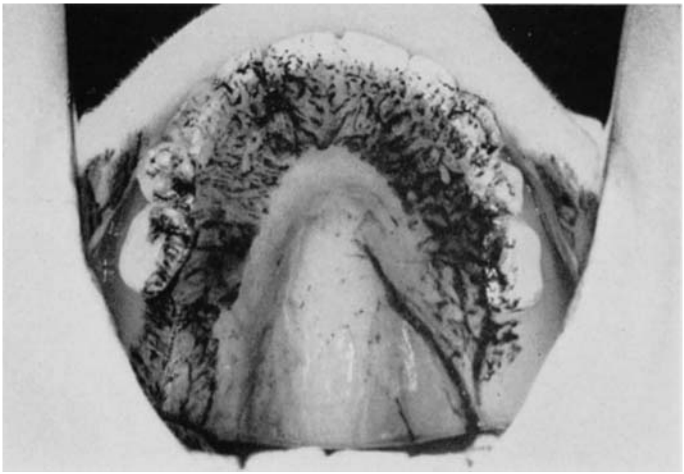

Fig. 25. Palatogram of *n* sound. Wearing full denture. Case K. R.

shown in Figs. 20 and 21. The distance between the incisors and the premolars during *s* is normal, at approximately 1 mm (Fig. 20).

Subject H.A. represents the type with incisal edge-to-edge bite and lateral crossbite (Fig. 22). Since her maxillary arch is fairly

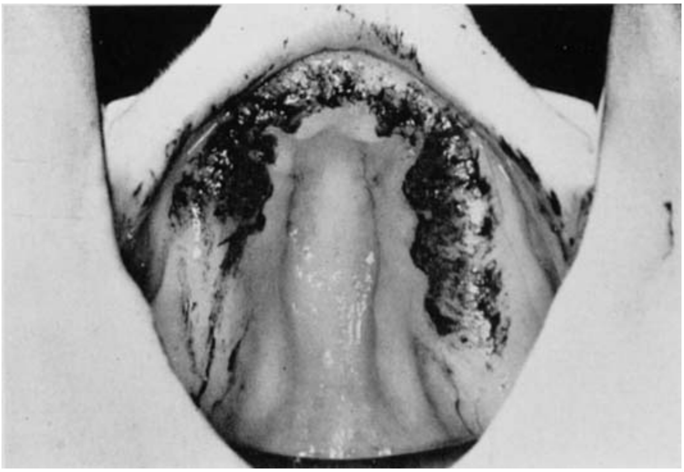

Fig. 26. Palatogram of *n* sound. Edentulous. Case K. R.

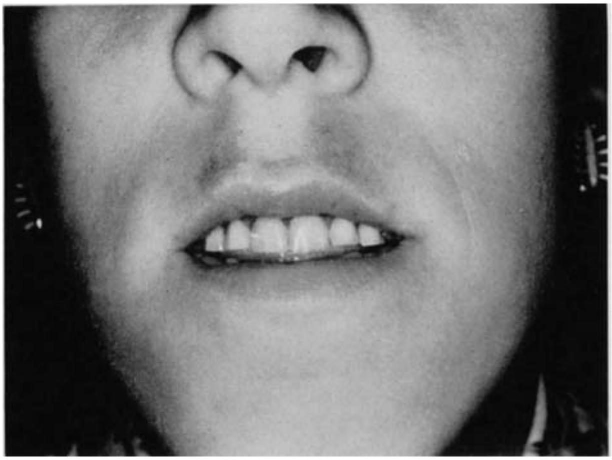

Fig. 27. Frostheses in *s* phonation. Space between incisor edges somewhat wider than normal. Case K. R.

wide and high, she encounters no physiological difficulties in the formation of dental sounds either with or without dentures (see *e.g.* the corresponding palatograms of *t* sound, Figs. 23 and 24). The congenital progenia of this patient was in fact replaced by edge-to-edge bite of the upper front teeth, which does not reduce tongue space; on the contrary, it provides the tongue with better and less limited space of movement than the progenic arrangement of front teeth would have done.

The third female subject, K.R., of whom photopalatograms were taken, represents incisal edge-to-edge bite and crossbite and, for her palatal shape, quite a narrow and fairly high maxillary arch. More than any other factor the height and the gully-like shape of the palate prevent the spread of the traces for dental sounds much beyond the normal width, although on the other hand the front and middle parts of the tongue do not easily find space inside the exceptionally narrow, gully-like maxillary arch. Palatograms typical of her are those taken for the *n* sound (Figs. 25 and 26), which show that the contact surfaces are on the alveolar ridges and do not appreciably widen towards the centre of the palate. Incisal edgebite produces a distinct separation of the front teeth in the *s* sound. In Fig. 27 the space between the edges of the front teeth is approximately 1 1/2—2 mm, *i.e.* somewhat wider than normal.

III. Sonagraphic measurements

The American sound-recording spectrograph, called "sonagraph" by its producers Kay Electric Co. (Pine Brook, N.J.), was invented during the Second World War and introduced in the U.S.A. in 1947 (3), since which time it has gained rapid acceptance in many parts of the world. It has now spread to very many phonetic and medical research institutes. The apparatus was donated to the Institute of Phonetics of the University of Helsinki in 1955 (13). The duration, tone colour, pitch and intensity of sounds can all be analysed by this equipment, whereas several different devices were previously required (12), and even then the results could not be considered nearly as accurate as those that can now be obtained by the sonagraph.

The most important parts of this apparatus are: (1) a recording cylinder, covered by special paper sensitive to electricity, (2) an amplifier and the accompanying loudspeaker, (3) an amplitude display unit used to register intensity curves, (4) a pitch display unit for intonation curves, and (5) a sectioner by which instantaneous sound spectra or sections (intensity-frequency spectra) are produced (Fig. 28).

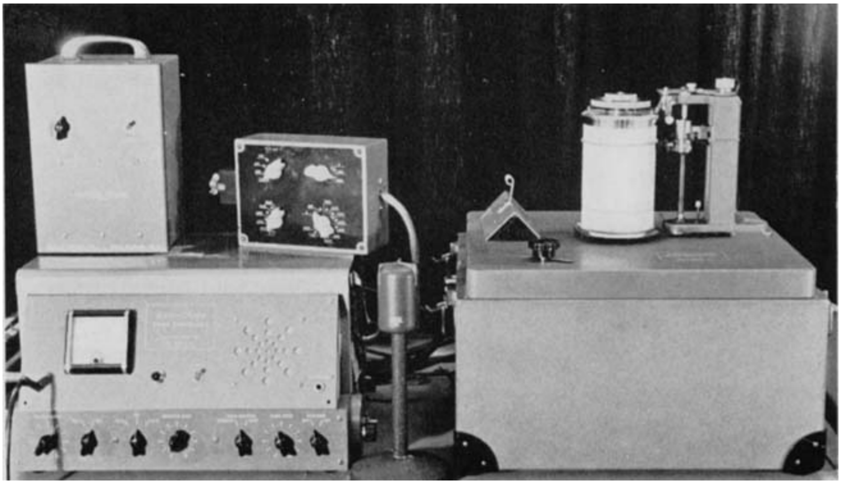

Fig. 28. The sonagraphic apparatus.

For the purpose of the present study, basic sonagrams were first made of each sentence or part of a sentence (3). A maximum passage of 2.4 seconds can be recorded in one basic sonagram. Fig. 29 shows the variant of the test sentence *(Kaarra, Otto, anna olla maassa)* as spoken by the male patient A.L., with full dentures in place. The lower part of the sonagram, with a dense pattern of parallel, roughly horizontal lines (partial tone lines), shows the time-frequency spectrum of the spoken sentence. The upper part consists of an intensity curve which can keep to determine the limits of the sounds (13, 14).

The equipment proved particularly useful in the present study, especially in the determination of the point of release of the explosive sounds. The vertical lines of the sonagram in the picture show which moments of the test sentence for the sections have been chosen, using the sectioner lever, on the sonagram paper.

Fig. 30 shows the sections taken from the dental sounds *r, t, n, l, s* in the test sentence, as spoken by the female subject K.R. with full dentures in place.

From the sections, and using the combined decibel and frequency grading, the formant and component values in the tables (A—D) characterizing each sound variant were measured. The intensity dispersion areas, shown in decibels in Tables A—D, may

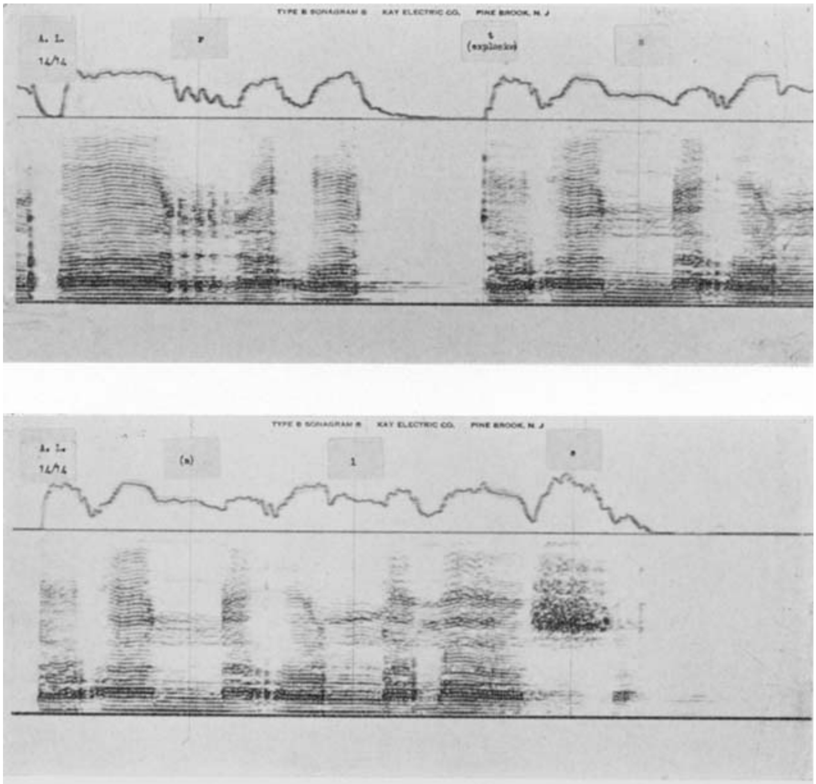

Fig. 29. Basic sonagram of test sentence "Kaarra, Otto, anna olla maassa" (Spoken with full denture in place. Case A. L.)

sometimes be too narrow as the intensity recording range in the sonagraph is fairly narrow (45 db). The optimal recording range for normal hearing would be circa 20 decibels larger (65 db) (2). There is a potential error especially when measurement of some F or C values for the test sentences was impossible.

The attached Tables A, B, C, and D have been compiled from the original working tables of each test patient by combining into dispersion areas the lowest and highest hz-values for the formants and components of the prosthetic variant (full dentures, maxillary denture, mandibular denture, edentulous jaws) of each sound. If some acoustic structural part (F or C) did not occur regularly in the measured sound sections of the five male and

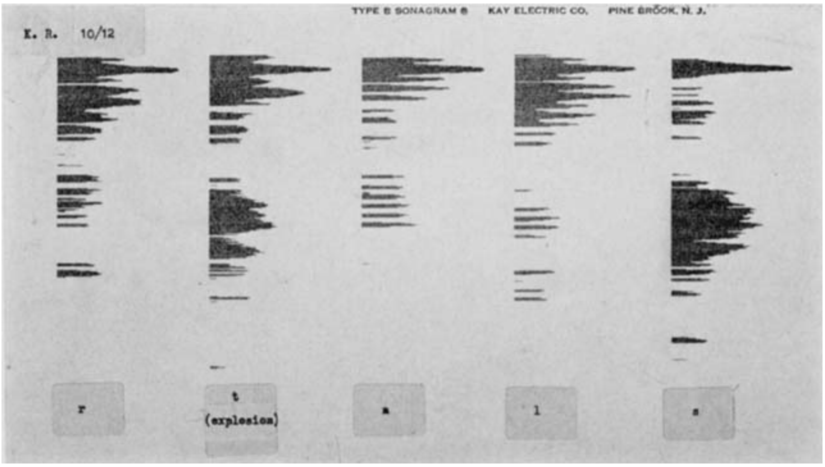

Fig. 30. Sections of the dental sounds in the test sentence (Spoken with full denture in place. Case K. R.)

five female subjects, the number of the measurement values recorded (4—1) was entered in brackets after the dispersion area values.

The following list shows the F and C values that, where required, have been taken into account in measurements, and the acoustico-physiological explanation that has been given to them in the present study.

List of abbreviations

The most important of the a b b r e v i a t i o n s (14) used in this study of various formants and other phonetic concepts are:

F1 = pharyngeal formant, depending mostly on the pharyngeal cavity (situated behind the tongue channel).

FV = formant depending mostly on the velar cavity. (The velar cavity is situated, in certain sounds and sound phases, between the tongue channel and the pharyngeal arch channel).

F2 = oral formant, depending mostly on the oral cavity (situated in the front of the tongue channel).

FS = subdorsal or preoral formant. (The channel between the incisors forms the front aperture of the subdorsal cavity, the back aperture being formed by the channel below the alveolar arch which, however, is either completely or nearly closed in dental consonants).

FN1 = formant of the epi-hypopharyngeal cavity. (The epi-hypopharyngeal cavity, which is formed by the velic passage opening considerably, consists of the hypopharynx, the meso-pharynx and the epipharynx) (15).

FN2 = formant of the epiphrayngeal cavity.

FN3 inf., FN3 med. and FN3 sup. = formants of the lower (inferior), middle (medius) and upper (superior) nasal passage, respectively.

FB = formant of the buccal cavity, *i.e.* of the lateral passages of *l*-sounds.

F4 = formant of the vestibule of the larynx.

CA = the noise component of the alveolar groove.

CI (CI 1, CI 2, CI 3, CI 4 etc. in the order of frequency range) = the noise components of the incisors.

N.B. F3 is only present in vowels, where it is interpreted as the multiple resonance of F1 and/or F2 (2).

The normal frequences of the formants and components in the analyzed consonants r, s, t, l and n according to the new sonagraphic measurements by Sovijärvi.

The following formant table gives the results of analysis regarding five dental consonants (in connection with the wovel *a)* of general Finnish spoken by two (2) men.

formants or components	*r*	*s*	*t*	*l*	*n*
FN1	—	—	—	—	200—250
F1	250—500	250—550	250—500	400—500	300—450
FV	600—750	650—900	700—850	650—900	600—750
F2	900—1300	900—1300	1050—1200	1000—1200	1250
FN2	—	—	—	—	1300—1600
FS	1400—1800	1400—2100	1750—2000	1700—1800	1600
FB	—	—	—	2000—3200	—
FN3 inf.	—	—	—	—	1950—2300
FN3 med.	—	—	—	—	2300—2700
FN3 sup.	—	—	—	—	2700—3300
F4	—	—	—	3000—3200	3300—3450
CA	2050—2450	2500—3000	2200—2800	—	—
CI	2550—4850	3100—8000	3100—9000	—	—

Table A. *Men. The tabulated analyses of the test subjects' sound sections.*

The direction of the arrows indicates the rise (pointing right) or fall (pointing left) of the formant area, as compared with full dentures.

		Full dentures 14/14		Upper denture 14/—		Lower denture —/14		Edentulous Without dentures	
		hz	db	hz	db	hz	db	hz	db
r	F1	250—500	22—33	250—550	17—37	200—450	17—32	200—600→	20—32
	F2	950—1150	19—38	1000—1350→	11—33	1050→—1400→	11—31	1000—1450→	17—28
	FV	500—750	29—39	600→—850→	26—35	550—750	23—36	650→—850→	22—38
	FS	1300—2200	6—31	1450→—2050←	13—22	1450→—1850←	6—30	1400→—1600←	7—28
	CA	2250—2900	12—27	2150←—2750←	17—24	2000←—2550←	11—23	1900←—2850	12—30
	CI1	2600—4100	10—31	2650—4200→	13—17	2800→—3900←	6—22	2600—3150←	7—18
	CI2	3350—4500	(4) 11—26	3700→—4950→	(4) 3—18	3300—3900←	(4) 6—15	3000←—3650←	(3) 12—21
	CI3	3950—4950	(3) 4—17	4450→—5700→	(3) 3—11	3750←—4400←	(3) 7—18	5100→	(1) 6
	CI4	4450—6650	(3) 5—8	—	—	—	—	—	—
s	F1	250—550	(4) 17—23	250—550	(4) 14—23	300—500	3—19	250—300←	(4) 13—22
	F2	950—1200	4—18	1000—1200	(4) 9—27	850←—1500→	4—19	1000—1450→	(4) 7—29
	FS	1600—2300	(3) 7—17	1100←—1900←	(3) 3—10	1400←—1850←	(4) 7—19	1300←—2150←	8—17
	FV	500—800	15—24	650→—850	15—27	650→—750	11—27	600→—800	15—28
	CA	2800—3300	15—40	2700←—3150←	11—38	2100←—2900←	7—38	2200←—3250	10—36
	CI1	3750—4100	15—41	3200←—4000←	13—22	2650←—4000←	15—37	2750←—3900←	11—35
	CI2	4450—5450	12—29	4000←—5500	16—21	3650←—5250←	3—22	3100←—5600→	7—37
	CI3	5200—5900	9—23	4900←—5350←	(4) 12—17	4500←—5700←	(4) 3—16	4850←—5400←	6—22
	CI4	5850—6900	(4) 5—16	5800—6350←	(4) 6—11	5650←—6450←	(2) 8—15	5800—6400←	(2) 7—15
	CI5	6700—7600	(4) 6—15	7000→—7500←	(2) 10—10	7000	(1) 11	7000	(1) 11
	CI6	7950	(1) 4	—	—	—	—	—	—

Table B. *Men. The tabulated analyses of the test subjects' sound sections.*
The direction of the arrows indicates the rise (pointing right) or fall (pointing left) of the formant area, as compared with full dentures.

		Full dentures 14/14		Upper denture 14/—		Lower denture —/14		Edentulous Without dentures	
		hz	db	hz	db	hz	db	hz	db
t	F1	300—500	11—38	250—350 ←	11—24	300—500	11—22	250—600 →	8—34
	F2	1000—1250	(4) 3—19	950—1150 ←	(4) 15—18	900 ←—1450 →	7—16	950—1450 →	11—22
	FS	1650—2200	(4) 5—11	1500 ←—1850 ←	(3) 6—18	1550 ←—1850 ←	(3) 12—22	1350 ←—1850 ←	12—16
	CA	2400—3150	12—30	2200 ←—2950 ←	(4) 8—15	2450—3050 ←	6—18	2000 ←—3100	7—22
	CI1	3150—4200	17—23	2900 ←—3950 ←	(4) 10—23	3050 ←—3950 ←	11—28	2700 ←—3850 ←	3—21
	CI2	3850—4950	(3) 10—23	3700 ←—4500 ←	(3) 10—21	3500 ←—4700 ←	9—23	3950 →—4250 ←	(4) 9—23
	CI3	4500—6100	(3) 6—21	4450—5500 ←	(3) 7—13	4600 →—5400 ←	(3) 7—14	4700 →—4850 ←	(3) 7—8
	CI4	6500—7500	(2) 14—15	—	—	7050 →—7450	(2) 3—8	5100 ←—7100 ←	(2) 8—9
	FV	600—900	12—23	500 ←—700 ←	9—32	500 ←—800 ←	17—35	550—800 ←	18—37

Table B. Men (continued)

		Full dentures 14/14		Upper denture 14/—		Lower denture —/14		Edentulous Without dentures	
		hz	db	hz	db	hz	db	hz	db
l	F1	450— 550	31—40	450— 650→	29—40	250←— 700→	20—40	250←— 500	17—38
	F2	950—1250	26—33	950—1150←	15—33	1000—1450→	11—31	800←—1450→	12—38
	FV	650— 850	19—38	700— 950→	(4) 18—36	550←—1050→	18—39	550←— 850	23—38
	FS	1200—1650	(4) 11—21	1400→—1600	7—23	1400→—1700	7—22	1150—1850→	4—13
	FB	2200—3300	5—32	2350→—3550→	13—33	2250—2950←	11—27	2100←—2950←	7—18
	F4	3000—3450	6—19	2950—3050←	(3) 5—22	2800←—3350←	(3) 9— 9	2850←—3200←	(3) 12—22
n	FN1	150— 300	22—36	250→— 300	27—36	250→— 300	27—38	250→— 300	20—38
	F1 F2	450— 550 1000—1250	24—30 6—24	450— 550 950—1350→	23—28 5—26	500— 550 950—1300	22—35 9—25	400— 600 850←—1300	20—29 9—30
	FN2	1250—1550	9—18	1200—1550	(4) 4—18	1200—1700→	11—23	1350→—1500	3—25
	FS	1600—2100	(4) 7—14	1450←—1550←	(2) 9—15	1650—2000←	(3) 7—12	1700→—1950←	(4) 5—15
	FN3 inf.	2100—2250	(4) 8—17	2050—2200	(4) 7—15	2100—2250	5—16	2000←—2300	5—14
	FN3 med.	2400—2450	(4) 12—16	2400—2650→	(4) 10—17	2350—2700→	7—26	2300←—2600→	5—21
	FN3 sup.	2650—2850	11—21	2700—3050→	(4) 5—20	2550←—3000→	9—33	2600—2950→	(4) 7—30
	FV	700— 850	20—33	700— 850	16—32	700— 750←	24—36	650— 900	18—35
	F4	2900—3100	4—21	2900—3100	(2) 9—27	2900—3350→	(4) 12—17	2950—3400→	(3) 12—25

Review of sonagraphic analysis results

A general review of the results shows that the acoustic structure of sounds was impaired in edentulous cases. In particular, the high acoustic components (CA and CI) had weakened, affecting the clarity and precision of *s* and *t* sounds. For patients who had not had a long edentulous period, the formation of all dental sounds, for formants and components, was more defective than for those who had had to live through a prolonged edentulous period. The longer the edentulous period the better they were able to form the sounds of the test sentence without prostheses.

The formant areas, which were reduced when pronounced by edentulous patients without prostheses, rose to normal pitch when pronounced with full dentures.

Detailed review of the acoustic structure of dental sounds pronounced without dentures, with half dentures, and with full dentures.

1. Men

Sound r. The oral formant F 2 usually tends to rise slightly higher than the full-denture variant, when half-dentures or no dentures are worn (the upper limit of the area of dispersion rises from 1150 hz to 1350 or 1450 hz). The explanation is that the posterior aperture of the oral cavity is usually enlarged to equal the smaller contact surface of the tongue in the palate, as seen in the palatogram taken from the half-denture and edentulous variant. For the same reason, the formant of the velar cavity (FV) also tends to rise in these three variants, hereafter referred to as *defective*. The CI group always shows the loss of the fourth component (CI 4) in the defective variants, indicating that the partial or complete absence of the incisors reduces and weakens the noise component of the incisors (CI).

Sound s. The most important difference between the half-denture variants is that the alveolar noise (CA) is lower when the patient wears only the mandibular denture and has no upper teeth. Similarly, the average level of the peaks of incisor noise, the CI component, is lower with mandibular dentures than with

Table D. *Women. The tabulated analyses of the test subjects' sound sections.*
The direction of the arrows indicates the rise (pointing right) or fall (pointing left) of the formant area, as compared with full dentures.

		Full dentures 14/14		Upper denture 14/—		Lower denture —/14		Edentulous Without dentures	
		hz	db	hz	db	hz	db	hz	db
t	F1	250—550	(4) 18—26	250—500	8—32	250—500	18—33	250—550	9—33
	F2	1000—1550	10—25	1000—1600	3—28	1000—1250 — ←	10—25	1000—1400 — ←	9—20
	FS	1400—2150	10—17	1400—1900 — ←	8—19	1300—2400 ← →	16—25	1450—2100	(4) 14—23
	CA	2800—3700	· 13—32	2000—3700 ← —	10—23	1850—3100 ← ←	10—37	2500—4300 ← →	13—30
	CI1	4100—4750	(4) 12—23	2550—4750 ← —	3—19	3100—4800 ← —	12—18	3250—5350 ← →	(3) 12—25
	CI2	4800—5350	(4) 9—17	2800—5300 ← —	9—17	3700—4750 ← ←	(3) 10—23	3850—4600 ← ←	(2) 16—23
	CI3	5450—6150	(4) 8—19	3400—6150 ← —	3—14	4250—5900 ← ←	(3) 12—14	5300—5500 ← ←	(2) 21—23
	CI4	6500—7250	(4) 5—13	6200—6900 ← ←	(2) 8—15	6900	(1) 6	5900—6350 ← ←	(2) 10—16
	CI5	7350—7450	(2) 3—13	6700 ←	(1) 14	—	—	—	—
	FV	550—1000	15—32	600—850 — ←	(4) 19—30	650—850 → ←	14—37	550—850 — ←	9—25

Table C. *Women. The tabulated analyses of the test subjects' sound sections.*

The direction of the arrows indicates the rise (pointing right) or fall (pointing left) of the formant area, as compared with full dentures.

		Full dentures 14/14		Upper denture 14/—		Lower denture —/14		Edentulous Without dentures	
		hz	db	hz	db	hz	db	hz	db
r	F1	200— 500	25—33	200—500	17—34	200— 400←	20—36	200— 500	27—33
	F2	1000—1450	12—23	1050—1450	13—25	850←—1450	10—21	850←—1300←	11—18
	FV	600— 750	25—31	450←—800	17—33	550— 850→	17—32	650— 750	15—32
	FS	1400—1750	13—18	1350—1850→	3—26	1550→—2000→	10—21	1450—1900→	12—25
	CA	2250—3100	15—26	2850→—3250→	20—33	2300—3000←	17—28	1650←—3150	15—25
	CI1	3150—3850	(3) 11—18	3450→—4350→	(4) 12—18	2800←—3600←	(4) 12—18	2200←—3500←	(2) 9— 9
	CI2	3700—4150	(2) 10—12	3450←—4300→	(3) 10—16	3200←	(1) 12	2800←	(1) 16
	CI3	4900	(1) 15	—	—	—	—	3150←	(1) 13
s	F1	500	(2) 10—16	200←— 300←	(3) 12—18	250←— 400←	(3) 9—11	200←— 450←	(3) 8—15
	F2	1050—1650	(3) 7—15	1000—1350←	(2) 8—11	1000—1550←	(3) 9—20	1000—1250←	(2) 7—20
	FS	1550—2200	(4) 3—13	1650	(1) 16	1450←—2050←	(2) 17—17	1700→—1900←	(2) 12—13
	FV	850— 900	(2) 12—13	700←— 800←	(3) 9—19	450←— 750←	(3) 11—12	700←— 850	(3) 12—17
	CA	3250—3700	16—32	3050←—3300←	15—38	2800←—3600←	17—31	2950←—3150←	11—22
	CI1	3700—4700	26—33	3500←—5500→	19—27	3800→—4700	9—25	3550←—4600←	22—31
	CI2	4700—6400	15—22	3950←—6150←	11—27	4150←—5700←	(4) 11—16	4500←—5600←	(4) 15—25
	CI3	5250—7100	10—20	4300←—6700←	(4) 10—25	4950←—6250←	(2) 13—17	5200—6650←	(4) 8—26
	CI4	6050—7800	11—23	4950←—7650←	(3) 10—23	5450←—7050←	(2) 13—16	6450→—7400←	(3) 9—12
	CI5	7850	(1) 16	6200←—7550←	(2) 10—13	6050←—7800←	(2) 10—11	—	—
	CI6	—	—	7500	(1) 9	6850	(1) 10	—	—

Table D. Women (continued)

		Full dentures 14/14		Upper denture 14/—		Lower denture —/14		Edentulous Without dentures	
		hz	db	hz	db	hz	db	hz	db
l	F1	200— 650	32—39	200— 650	29—38	200— 650	32—39	200— 650	31—38
	F2	1000—1150	20—32	← 900—1350 →	14—30	1000—1300 →	19—37	950—1200	21—26
	FV	550— 900	25—39	500— 900	28—38	600— 850	31—40	550— 900	30—38
	FS	1500—1650	7—19	← 1250—1550 ←	17—24	← 1350—1950 →	14—30	← 1350—1600	9—16
	FB	2450—2850	6—33	2500—2950 →	12—20	→ 2600—3050 →	13—31	2400—3000 →	11—25
	F4	3000—3300	12—32	← 2900—3300	(4) 14—18	→ 3150—3500 →	11—15	→ 3150—3500 →	11—21
n	FN1	200— 250	28—38	200— 250	14—40	200— 250	31—40	200— 250	31—38
	F1	400— 500	23—35	400— 450	12—40	400— 500	23—40	400— 500	27—39
	F2	1000—1450	11—23	← 900—1150 ←	(4) 9—22	← 900—1200 ←	11—25	← 850—1150 ←	8—20
	FN2	1250—1550	12—24	→ 1450—1600	10—29	→ 1350—1550	14—24	1300—1600	(4) 12—28
	FS	1600—2150	12—17	→ 1700—1900 ←	(3) 10—25	1550—1800 ←	8—19	1600—1950 ←	(4) 12—18
	FN3 inf.	2000—2400	3—21	→ 2100—2150 ←	(3) 3—25	→ 2200—2200 ←	(4) 3—18	2050—2200 ←	(4) 9—16
	FN3 med.	2450—2600	9—21	2400—2750 →	(4) 3—27	2450—2700 →	(4) 12—17	2450—2700 →	(4) 14—20
	FN3 sup.	2700—3100	14—20	→ 2800—3150	(4) 10—24	2650—2900 ←	9—23	2700—3050	10—17
	FV	650— 750	20—27	650— 700	11—32	650— 800	23—36	600— 750	18—26
	F4	3150—3500	9—25	3150—3500	3—26	← 3050—3650 →	6—15	3100—3500	12—18

maxillary dentures. Furthermore, the upper limit of the CI group is usually lower when maxillary teeth are missing.

In both half-denture variants, however, the CA and CI groups are lower than in the full-denture variant. This suggests that the high noise area typical of *s*, which in Finnish ranges from 2,800 hz to 6,000—7,000 hz, depends on the incisors of both jaws but more so on the maxillary than on the mandibular teeth. Surprisingly, the edentulous *s* variant is for men somewhat better for both noise components than that pronounced with the mandibular denture, but poorer than that pronounced with the maxillary denture. The proficiency of the edentulous variant therefore lies somewhere between the two half-dentures.

Sound t. The absence of lower incisors has a more detrimental effect than that of upper incisors, for the alveolar noise (CA) is lower with maxillary prosthesis alone. The same is true of the incisor noise, for with maxillary dentures its area extends to a maximum of 5,500 hz while with mandibular dentures it may rise considerably higher (7,050—7,450 hz). The individual CI peaks are also generally lower with maxillary dentures alone. The edentulous variant of *t* again falls between the two half-denture cases. The edges of the lower incisors thus seem to play an important part in shaping the explosive noise for the pronunciation of *t*.

Sound l. Only the oral cavity formant F2 shows a symptomatic rise with mandibular half-dentures and in edentulous cases (1,250—1,450 hz). This is probably a result of the greater aperture of the buccal channel and the lateral tongue channels when the molars of the upper jaw or both jaws are missing.

Sound n. In the absence of mandibular dentures, the subdorsal formant FS shows a decrease. This is evidently the result of the increased volume of the subdorsal cavity of the tongue, while the oral aperture remains the same size as in the pronunciation of the full-denture variant.

2. Women

Sound r. The variants without maxillary dentures and without any dentures differ to approximately the same degree from the full-denture variant: F2 is lowered, FS rises, and the peaks of the

CI noise components are lowered and reduced. Hence for these *r* variants the part played by maxillary teeth is more important than that played by mandibular incisors.

Sound s. The essential components CA and CI are approximately equal in the half-denture variants for women and take a lower average level than in the full-denture variant. The *s* variant, however, with mandibular dentures is slightly poorer than with maxillary dentures. The edentulous variant is this time slightly better than either half-denture variant, which shows that skilful articulation of *s* is possible with the gingivae alone.

Sound t. For the frequencies of the CA and CI noises, the defective variants are lower, or darker, in components than the full-denture variant. As for the half-denture variants of men it is found that the mandibular prosthesis gives a better *t* sound. The edentulous variant is on an average slightly better than either of the half-denture variants. This is directly connected with the fact that the female subjects of the experiments had a longer average edentulous period than had the male patients.

Sound l. The half-denture variants show a slight rise in F2 as compared with the full-denture variant. The increased size of lateral apertures causes the rise of the buccal cavity formant FB in the defective variants. The rise is greatest with the mandibular denture in place.

Sound n. For FS, the upper limit of the area of dispersion is lowered in all defective variants, which again results from the increased size of the corresponding cavity volume.

SUMMARY AND CONCLUSIONS

The investigation covered 10 full-denture patients, with four denture-wearing variants: (1) full dentures in place, (2) only maxillary denture in place, (3) only mandibular denture in place, and (4) edentulous, with no dentures. Measurements of arch height, width, length and circumference were taken on edentulous jaws and prostheses. These measurements were discussed.

The photopalatographic and sonagraphic methods were used to study the dental sounds with the above denture-wearing variants. The subjects were made to pronounce the sentence: K a a r r a, O t t o, a n n a o l l a m a a s s a, (Turn out, Otto, leave it on the ground). The analyses of the sound sections of the experimental subjects were tabulated.

The study leads to the following conclusions:

The formant or component areas, which are lowered when pronunciation takes place without dentures and with completely edentulous jaws, rise to the normal level when full dentures are worn.

The maxillary dentures are more important than the mandibular prostheses for the pronunciation of *s* and *r* sounds in the creation of the correct alveolar and incisor edge noises.

The mandibular dentures are more important for *t* sounds: the edges of the mandibular incisors seem to play the greatest part in forming the incisor explosive noise.

On comparison of the *l* and *n* sounds produced with the different denture-wearing phases, no essential differences were found (15, 21).

RÉSUMÉ ET CONCLUSIONS

ÉTUDES SONAGRAPHIQUES ET PALATOGRAPHIQUES DE PLUSIEURS CAS DE PROTHÈSE COMPLÈTE, DE PROTHÈSE SEMI-COMPLÈTE ET D'ÉDENTATION.

Cette étude concerne 10 patients édentés, avec quatre variantes en ce qui concerne le port des prothèses: (1) prothèses complètes en place, (2) prothèses du haut seulement en place, (3) prothèses du bas seulement en place, et (4) édentés, sans prothèses. On a mesuré la hauteur de la voûte, sa largeur, sa longueur et sa circonférence sur les mâchoires édentées et sur les prothèses. Ces mesures on fait l'objet d'une discussion.

La méthode photopalatographique et la méthode sonagraphique ont été employées pour étudier les sons dentaux dans les différents cas indiqués ci-dessus. Les sujets ont prononcé la phrase: "Kaarra, Otto, anna olla maassa". (Sors, Otto, laisse le par terre). Les analyses des sections phonétiques des sujets de l'expérience on été représentées par des tableaux.

Cette étude conduit aux conclusions suivantes:

Les zones de formants et d'éléments qui se trouvent abaissées quand la phonation se fait sans prothèses et avec des mâchoires totalement édentées, montent au niveau normal lorsque des prothèses complètes sont portées.

Les prothèses supérieures ont plus d'importance que les prothèses inférieures pour la prononciation des sons *s* et *r* en créant correctement les bruits alvéolaires et les bruits du bord incisif.

Les prothèses inférieures ont plus d'importance pour le sont *t*: les bords des incisives inférieures semblent jouer un rôle primordial pour la formation des bruits explosif incisifs.

Aucune différence essentielle ne peut être discernée en ce qui concerne les sons *l* et *n* prononcés par les différents types de porteurs de prothèses.

ZUSAMMENFASSUNG UND SCHLUSSFOLGERUNGEN

SONAGRAPHISCHE UND PALATOGRAPHISCHE UNTERSUCHUNG ÜBER DEN EINFLUSS DER PROTHESEN AUF DIE ARTIKULATION DER ZAHNLAUTE

Zehn Vollprothesenträger wurden unter vier verschiedenen Bedingungen untersucht: 1) mit beiden Prothesenteilen im Mund, 2) nur mit Oberkieferprothese, 3) nur mit Unterkieferprothese, 4) ohne Zähne, d.h. ohne Prothesen. An den Prothesen und den zahnlosen Kiefern wurden Messungen über Wölbungshöhe, Breite, Länge und Umfang vorgenommen und überprüft.

Die photopalatographische und die sonagraphische Methode wurde zur Untersuchung der unter den obengenannten Bedingungen artikulierten Zahnlaute angewandt. Der Versuchssatz lautete: *Kaarra, Otto, anna olla maassa.* (Mach einen Bogen darum, Otto, lass es auf der Erde liegen.) Die bei der Analyse der Intensitäts-Frequenz-Spektren (Sektionen) festgestellten Ergebnisse wurden in Gesamttabellen zusammengefasst.

Die Untersuchung legt folgende Schlussfolgerungen nahe:

Die Bereiche der Formanten oder Geräuschkomponenten, die beim zahnlosen Artikulieren ohne Prothese abgesunken waren, kehren beim Tragen der Vollprothese auf die normale Höhe zurück.

Bei der Aussprache der *s*- und *r*-Laute sind zur Erzielung des richtigen Geräusches an Zahnwall und Frontzahnschneiden die Prothesen des Oberkiefers wichtiger als die des Unterkiefers.

Die Unterkieferprothesen sind wiederum wichtiger bei den *t*-Lauten: die Schneiden der unteren Frontzähne scheinen hauptsächlich für die Bildung des Inzisivengeräusches bei der Verschlusssprengung verantwortlich zu sein.

Ein Vergleich der unter den vier verschiedenen Bedingungen artikulierten Varianten der *l*- und *n*-Laute fördert keine wesentlichen Unterschiede zutage.

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