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Erstveröffentlichung in / First published in:

Onkologie. 2013, 36(10), S. 547 - 552 [Zugriff am: 29.04.2020]. Karger. ISSN 1423-0240.

DOI: <https://doi.org/10.1159/000355154>

Diese Version ist verfügbar / This version is available on:

<https://nbn-resolving.org/urn:nbn:de:bsz:14-qucosa2-716351>

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Evaluation of Selected Speech Parameters after Prosthesis Supply in Patients with Maxillary or Mandibular Defects

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Keywords

Ablative tumor surgery-related defects ·
Oral and maxillary areas · Prosthesis supply ·
Speech performance · Speech intelligibility

Summary

Background: Ablative surgery of oropharyngeal tumors frequently leads to defects in the speech organs, resulting in impairment of speech up to the point of unintelligibility. The aim of the present study was the assessment of selected parameters of speech with and without resection prostheses. **Patients and Methods:** The speech sounds of 22 patients suffering from maxillary and mandibular defects were recorded using a digital audio tape (DAT) recorder with and without resection prostheses. Evaluation of the resonance and the production of the sounds /s/, /sch/, and /ch/ was performed by 2 experienced speech therapists. Additionally, the patients completed a non-standardized questionnaire containing a linguistic self-assessment. **Results:** After prosthesis supply, the number of patients with rhinophonia aperta decreased from 7 to 2 while the number of patients with intelligible speech increased from 2 to 20. Correct production of the sounds /s/, /sch/, and /ch/ increased from 2 to 13 patients. A significant improvement of the evaluated parameters could be observed only in patients with maxillary defects. The linguistic self-assessment showed a higher satisfaction in patients with maxillary defects. **Conclusion:** In patients with maxillary defects due to ablative tumor surgery, an increase in speech performance and intelligibility is possible by supplying resection prostheses.

Schlüsselwörter

Tumorbedingte Defekte · Mund- und Kieferbereich ·
Defektversorgung · Sprechleistung ·
Sprachverständlichkeit

Zusammenfassung

Hintergrund: Durch Tumoroperationen im Mund-, Kiefer- und Gesichtsbereich entstehen oftmals Defekte an den «Sprechorganen» und damit eine Beeinträchtigung der Sprache bis zur Unverständlichkeit. Ziel der vorliegenden Untersuchung war die Beurteilung ausgewählter Sprachparameter mit und ohne Defektversorgung mittels Resektionsprothesen. **Patienten und Methoden:** Der Sprachklang von 22 Patienten wurde mit und ohne defektprothetische Versorgung aufgezeichnet. Dies erfolgte mit einem digitalen Audiotonband (DAT)-Recorder. Der nasale Sprachklang und die Bildung der Laute /s/, /sch/ und /ch/ wurden von 2 erfahrenen Logopädinnen eingeschätzt. Zusätzlich füllten die Patienten einen nichtstandardisierten Fragebogen zur sprachlichen Selbsteinschätzung aus. **Ergebnisse:** Die Anzahl der Patienten mit einer Rhinophonia aperta verminderte sich nach der Defektversorgung von 7 auf 2. Dabei erhöhte sich die Anzahl der Patienten mit einer verständlichen Umgangssprache von 7 auf 20. Die korrekte Lautbildung von /s/, /sch/ und /ch/ erhöhte sich von 2 auf 13 Patienten. Die untersuchten Parameter verbesserten sich signifikant nur bei der Patientengruppe mit Oberkieferdefekten nach prothetischer Versorgung. Die sprachliche Selbsteinschätzung zeigte eine höhere Zufriedenheit der Patienten nach defektprothetischer Versorgung bei der Gruppe mit Oberkieferdefekten. **Schlussfolgerung:** Mittels einer defektprothetischen Versorgung kann nach Tumoroperationen eine deutliche Verbesserung der Sprechleistung und der Sprachverständlichkeit bei Oberkieferdefekten erzielt werden.

Introduction

In human interaction, speech is an essential way of communication [1, 2]. A pronounced disturbance of speech significantly decreases the quality of life [3, 4]. Furthermore, limitations in social and professional life are unavoidable [4–8]. Ablative tumor surgery in the oral and maxillofacial region is frequently necessary to preserve a patient's life. These surgical interventions lead to extensive defects of the speech organs, e.g., palate, maxilla, mandible, teeth, cheeks, and lips, which

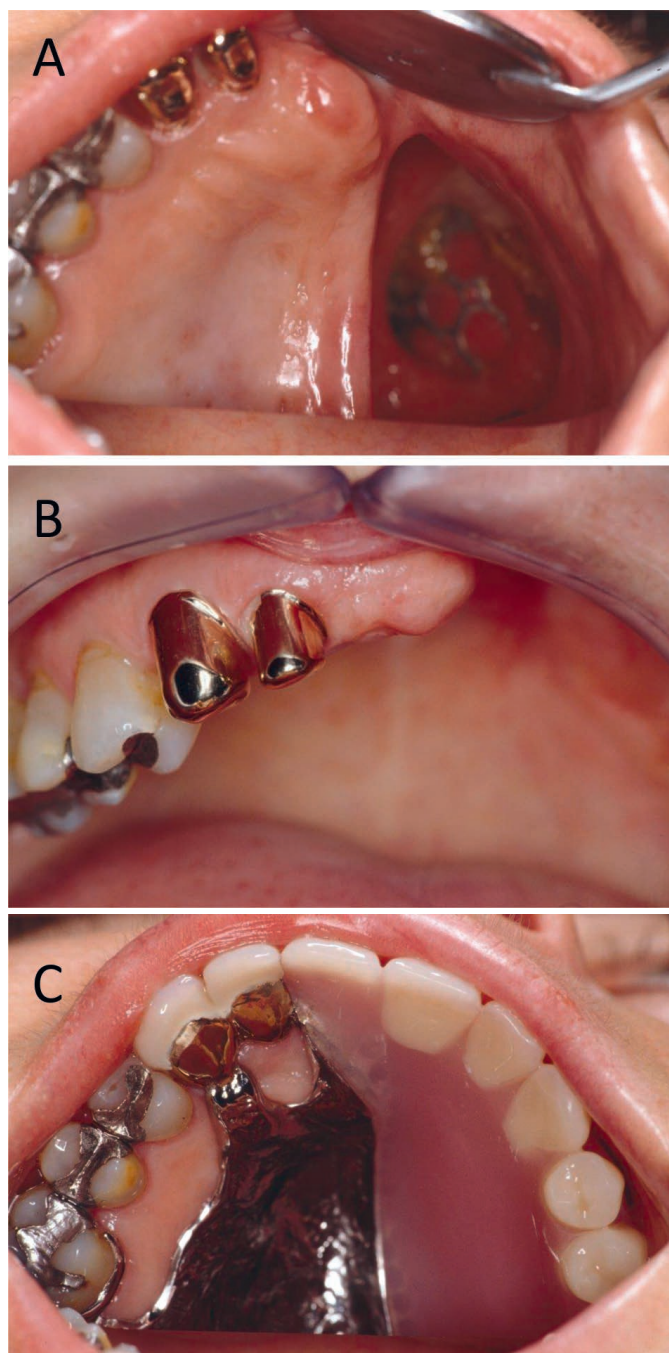


Fig. 1. (A) Situation after maxillary resection; (B) preparation of the teeth for anchoring the resection prosthesis; (C) patient with resection prosthesis in situ.

may result in a disturbance of speech, including speech unintelligibility [9, 10]. Furthermore, the areas of initiation, i.e. the air-containing cavities located above the glottis, are altered. As these cavities are involved in sound production, the phonation may be influenced: Vowels with a laryngeal sound are altered in their structure leading to a resonatory transformation, and a correct production of certain consonants may become impossible.

In addition, ablative tumor surgery causes masticatory, deglutitional, degustational, and salivational dysfunctions [11, 12]. Furthermore, the patients suffer from an esthetic impairment that cannot be easily covered. These patients are exposed to severe psychological stress [7, 13]. Limitations in the activities of daily life and in the social environment may be the result. The pronounced esthetic alterations and functional disorders of the oral facial system may cause social exclusion, social isolation, and emotional lability [6]. The affected patients feel socially unacceptable.

The reconstruction of defects is possible by reconstructive surgery [8, 14, 15]. In patients suffering from a reduced general condition, e.g. aged patients, the means of reconstructive surgery are limited. In these patients, the supply of an epithesis is an alternative option of treatment. A considerable need was observed for this group of patients [13]. Nowadays, the focus of resection prosthesis (maxillary/mandibular defects) and epithesis (facial defects) is on esthetics, mastication, and deglutition as well as on wearability and comfort [12, 16]. Not enough attention is paid to speech-related functions and sound production [17].

The aim of the present study was the assessment of rhinophonia and the production of /s/, /sch/, and /ch/ sounds. Therefore, patients with and without defect reconstruction by resection prosthesis were evaluated.

Patients and Methods

The protocol of the study was approved by the ethical review committee of the Medical Faculty 'Carl Gustav Carus', Dresden, Germany (EK 940998). 64 patients who underwent an ablative tumor surgery and consecutive supply with a prosthesis were randomly selected for this retrospective study. The defects were located in the maxilla or mandible and facial area (orbit, ear, nose, cheek), respectively. Patients with facial defects were excluded from the study due to different locations and dimensions of the defects. Otherwise, comparable patient groups would not have been possible. Before the beginning of the study, all patients underwent an evaluation by an otorhinolaryngologist to identify alterations of the organs of speech not caused by ablative surgery and auditory defects. The following patients were not included in the study due to several reasons:

- 19 patients had a facial defect
- 7 patients denied the voice recording without their prosthesis
- 7 patients had an auditory defect
- 5 patients refused to continue the study
- 4 patients died

Thus, 22 patients were evaluated in the present study. Table 1 shows an overview regarding gender and defect localization. The patients were 28–81 years old, with a mean age of 55 ± 14 years. The prosthesis supply

Table 1. Gender and type of defects of the patients included in the study

Defect	Men	Women	Defect areas
Maxillary defects	5	7	12: 4 hemilateral defects; 8 extensive partial defects (not exceeding the midline)
Mandibular defects	7	3	10: 1 hemilateral defect; 9 partial defects, 4 of these with continuity resection and 5 with partial glossectomy
Total	12	10	22

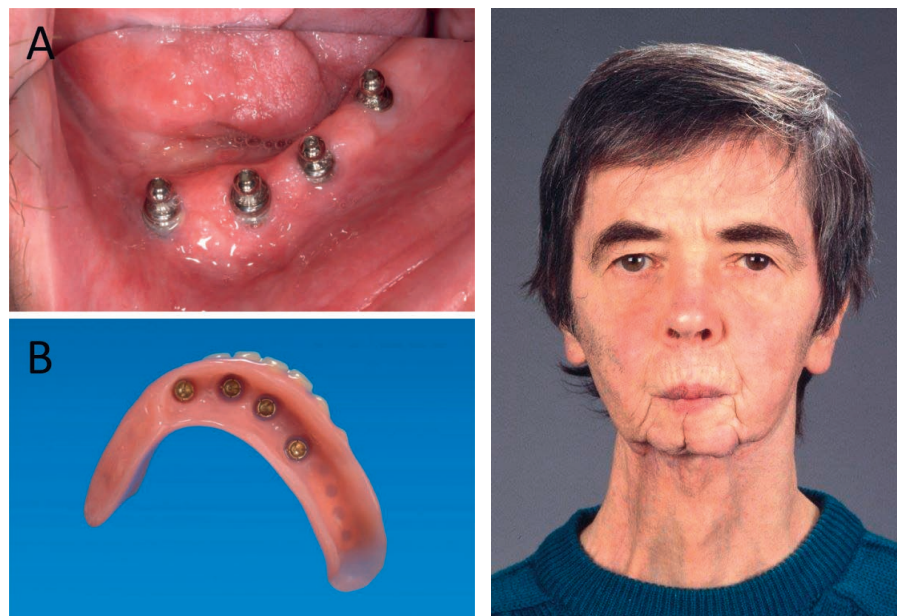


Fig. 2. Situation after partial mandibular and glossectomy. (A) Dental implants are inserted into the remaining part of the mandible; (B) resection prosthesis, view from the caudal side, (C) patient with resection prosthesis in situ.

and the follow-up care were performed in the Department of Oral and Maxillofacial Surgery and the Department of Prosthetic Dentistry of the University Hospital Dresden. All prostheses were functionally evaluated considering the adjacent soft tissue, marginal adhesion and retention. At the time of examination, the prostheses were in situ free of complaints for 12 months. Characteristic defects are shown in figures 1 and 2.

The evaluation was performed by 2 experienced speech therapists. In order to achieve reproducible results, standardized acoustical conditions (secondary soundproofing) and a standardized sequence of evaluation were set up. Additionally, the inter-rater agreement was examined. Every patient underwent speech recording with and without prosthesis. The speech recording was performed using a digital audio tape (DAT) recorder (DA-P1; TEAC Corporation, Tokyo, Japan) and audiocassettes (DENON R 120 DT; Nippon Columbia, Tokyo, Japan). The microphone (Sennheiser ME 66; Sennheiser electronic, Wedemark, Germany) was set up at a sampling frequency of 48 kHz. The distance between the patient's mouth and the microphone was 30 cm. The speech recording included a list of 54 meaningful words and meaningless combinations of sounds according to defined phonetic criteria. Furthermore, the German text of the fable 'The Ant and the Grain of Wheat' and a casual conversation were part of the evaluation.

The auditory assessment of the nasal sounds was performed using von Mühler's classification system [18]. The production of the sounds /s/, /sch/, and /ch/ was evaluated by playback of the DAT recordings under identical playback conditions. The parameters were assessed separately in series. In detail, the following parameters were included:

- rhinophonia
 - colloquial speech
 - resonance/alteration of sounds
 - nasal emission
 - shift in articulation
- production of the sounds /s/, /sch/, and /ch/

The groups of defects mentioned in table 1 with and without prosthetic supply served as stratification variable. Furthermore, each patient completed a non-standardized questionnaire containing a linguistic self-assessment. The patients were asked to judge their speech effort, their satisfaction with the speech performance, and for an evaluation of a potential speech therapy, on a 7-point numeric scale (0 – not at all/none/very little to 6 – highly/definitely/completely).

The statistical tests for the comparison with or without defect formation in the defect groups were performed by contingency tables with Fisher's exact test. To evaluate the inter-rater agreement of the speech therapist, Cohen's kappa was used. The level of statistical significance was set at $\alpha = 0.05$.

Results

The evaluation of the inter-rater agreement showed the following results. To this purpose, 264 ratings were examined:

- 242 identical ratings
- 20 ratings differing in 1 classification grade
- 2 ratings differing in 2 classification grades

Thus, 91% of the evaluations of the speech therapists were identical. The values for Cohen's kappa were calculated between 0.688 and 1.000. According to the corresponding categorization, these values can be considered as 'good' and 'very good'.

The results of the patient examination are depicted in table 2. The evaluation of the patients showed a correct rhinophonia in 15 patients with supply of prostheses compared to

Table 2. Summary of the auditory results

Parameter	Without resection prostheses					With resection prostheses in situ				
	R. aperta	R. clausa	R. mixta	Normal R.	n	R. aperta	R. clausa	R. mixta	Normal R.	n
Rhinophonia ^a										
Maxillary defects	6	4	1	1	12	1	4	1	6	12
Mandibular defects	1	0	0	9	10	1	0	0	9	10
Total	7	4	1	10	22	2	4	1	15	22
Colloquial speech ^b	C0	C1	C2	C3	n	C0	C1	C2	C3	n
Maxillary defects	0	1	6	5	12	6	5	1	0	12
Mandibular defects	0	6	2	2	10	3	6	1	0	10
Total	0	7	8	7	22	9	11	2	0	22
Resonance ^c	R0	R1	R2	R3	n	R0	R1	R2	R3	n
Maxillary defects	1	3	7	1	12	7	4	1	0	12
Mandibular defects	10	0	0	0	10	10	0	0	0	10
Total	11	3	7	1	22	17	4	1	0	22
Nasal emission ^d	NE0	NE1	NE2	NE3	n	NE0	NE1	NE2	NE3	n
Maxillary defects	5	1	6	0	12	9	3	0	0	12
Mandibular defects	10	0	0	0	10	10	0	0	0	10
Total	15	1	6	0	22	19	3	0	0	22
Shift of articulation ^e	S0	S1	S2	S3	n	S0	S1	S2	S3	n
Maxillary defects	1	0	3	8	12	10	1	0	1	12
Mandibular defects	7	1	2	0	10	7	1	1	1	10
Total	8	1	5	8	22	17	2	1	2	22
Production of sounds ^f	incorr. phon.	corr. phon.			n	incorr. phon.	corr. phon.			n
Maxillary defects	11	1			12	1	11			12
Mandibular defects	9	1			10	8	2			10
Total	20	2			22	9	13			22

^aR = Rhinophonia.

^bC0 = Normal speech, C1 = intelligible speech, C2 = intelligible speech with sound distortions, C3 = unintelligible speech.

^cR0 = Without alterations, R1 = slight alterations, R2 = noticeable alterations, R3 = highly noticeable alterations.

^dNE0 = No nasal emission, NE1 = minor nasal emission, NE2 = considerable nasal emission, NE3 = major nasal emission.

^eS0 = No shift, S1 = one sound shifted, S2 = two sounds shifted, S3 = more than two sounds shifted.

^fProduction of sounds /s/, /sch/, and /ch/: incorrect phonation; correct phonation.

Table 3. The p values for the differences between maxillary and mandibular defects for each parameter

Parameter	Maxillary defects	Mandibular defects
Rhinophonia	0.055	1.000
Colloquial speech	< 0.001	0.206
Resonance	0.010	– ^a
Nasal emission	0.015	– ^a
Shift of articulation	< 0.001	1.000
Production of sounds	< 0.001	0.500

^aNo statistical test possible.

10 patients without prostheses. The number of patients suffering from a rhinophonia aperta decreased from 7 (without prosthesis) to 2 (with prosthesis). The number of patients with an intelligible colloquial speech (grade 0 – correct colloquial speech and grade 1 – minor limited colloquial speech) increased from 7 to 20 after prosthesis supply. The highest increase (from 1 to 11 patients) was observed for patients suffering from maxillary defects. For these patients, an improvement of resonance could be detected after prosthesis supply. The nasal emission was improved in 7 patients (D1: 1 patient; D2: 6 patients) when wearing their prostheses. After prosthesis supply, only 3 patients (D1: 3 patients) with nasal emissions were detected. Only patients suffering from maxillary defects were affected. The shift of articulation could be decreased by the supply of a prosthesis in patients with maxillary defects. Without prosthesis, 1 patient was judged to have

Table 4. The p values for the differences between the results with and without prosthesis supply of maxillary defects for each parameter

Parameter	Without prosthesis	With prosthesis
Rhinophonia	0.001	0.085*
Colloquial speech	0.043	0.691*
Resonance	< 0.001	0.059*
Nasal emission	0.007	0.221*
Shift of articulation	0.001	0.850*
Production of sounds	1.000	0.002

*Indicating statistically significant differences.

a regular finding; with prosthesis, this number increased to 10 patients with regular findings. Considering the correct production of the sounds /s/, /sch/, and /ch/, an increase was obvious when patients were supplied with prostheses. Without prosthesis, 20 patients could not correctly produce these sounds, whereas with prosthesis supply 13 patients were able to produce them properly. Again, the highest increase was observed in the group with maxillary defects (11 out of 12 patients). In patients with mandibular defects, an improvement could only be shown in single cases.

Regarding the results of colloquial speech, resonance, nasal emission, and shift of articulation, patients suffering from a maxillary defect showed statistically significantly different values compared to the group with mandibular defects (table 3). The speech of patients with maxillary defects improved considerably when prostheses were supplied. The results of the

statistical test are shown in table 4. The differences in all parameters, except for rhinophonia, were statistically significant. In patients with mandibular defects, no statistically significant differences could be observed.

The self-assessment of the patients showed a higher satisfaction when maxillary defects were supplied with resection prostheses (3.90 ± 1.50). Patients suffering from mandibular defects declared a lower satisfaction with their speech performance (2.80 ± 1.75). Only 6 patients were supported by speech therapy.

Discussion

Speech and speech performance are crucial means in order to make a diagnostic and post-therapeutic evaluation of patients with alterations in the oral and maxillofacial area [19]. The method is applied in patients with congenital malformations, e.g. cleft palate [20]. Furthermore, it is used in situations after surgical interventions with or without ensuing defects, e.g. orthognatic surgery and the application of soft palate obturators [21, 22].

In different studies, phonetic tests were applied to evaluate modifications of removable prostheses [16, 23–28]. In the present study, the highest increase considering certain phonetic parameters was found in patients with maxillary defects. The parameters were selected considering rhinophonia and the production of the sounds /s/, /sch/, and /ch/. Rieger et al. [29] have described similar results. They observed, in 9 patients with maxillary defects, that rehabilitation of the speech performance is possible. The pre-operative level of speech performance could be achieved by supplying resection prostheses. When the defects extended to the soft palate, these positive results could not be reached.

In the present study, 10 patients suffering from mandibular defects, including 5 patients with partial glossectomy and 4 patients with continuity resection, were evaluated. Both kinds of defects present a challenge for reconstructive surgery or reconstruction using resection prostheses [30–33]. The reconstruction of mandibular defects by free tissue transfer or microvascular reconstruction, e.g. iliac crest or fibular flaps, is desirable [34]. In cases where a reconstruction with autologous tissue is not possible due to the general condition, resection prostheses are an alternative for rehabilitation. One of the limits of the study is that there is no comparison between patients having received a surgical reconstruction and patients with resection prostheses. However, this topic has to be elucidated in further studies. The results of Gebelein [17] suggested that patients suffering from a tumor of the floor of the mouth had the lowest speech performance compared to other tumors in the oropharyngeal area. These findings are supported by results of the present study. No significant increase regarding

speech performance could be observed in patients with mandibular defects. According to the literature, it seems to be recommendable to support patients after ablative tumor surgery in the oropharyngeal area with speech therapy [35–38]. The results in the present study demonstrate that a minority of patients is supported by speech therapy. Only 6 (1 with maxillary defect, 5 with mandibular defects) out of 22 patients received this therapy. In these cases, the referral was prescribed by the attending physician. Additionally, the motivation was enhanced by the relatives. The patients' expectations regarding speech therapy are very high. For the patients evaluated in the present study, speech therapy is a necessity. For patients suffering from maxillary defects, the therapy effort would have to be higher compared to patients with mandibular defects [4, 8, 17, 36–38].

Speech therapy should be part of the interdisciplinary follow-up care of patients suffering from defects after ablative tumor surgery. The prescription of speech therapy by a physician is legally recommended [39]. Patients suffering from extended maxillary or mandibular defects may develop some possibilities of compensation. However, in the experience of the authors, these mechanisms of compensation were not sufficient considering phonetic parameters and speech performance. To the best of our knowledge, there is no up-to-date literature evaluating this topic. Further studies are necessary to elucidate the possibilities of compensation.

Conclusions

A statistically significant improvement of speech performance and speech intelligibility can be achieved by the supply of a resection prosthesis after ablative tumor surgery in the maxilla. Only minimal enhancement of the evaluated phonetic functions could be observed in patients who had received resection prostheses to repair mandibular defects. Speech therapy should be part of the comprehensive interdisciplinary care after the supply of resection prostheses.

Acknowledgements

The current study is part of the B1 subproject (Director: Prof. Reiber) and was granted by the Reha-Forschungsverbund BBS (Rehabilitation Research Network Berlin-Brandenburg-Sachsen). The authors are grateful to Dr. S. Thiel, Mrs. L. Hellwig, and Mrs. E. Schreiber for their support in this study.

Disclosure Statement

The authors declare that there is no conflict of interest.

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