ORIGINAL PAPERS

Dent. Med. Probl. 2016, 53, 2, 175–185
DOI: 10.17219/dmp/61634

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ISSN 1644-387X

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Bioelectrical Activity Changes of Selected Muscles of the Face and Neck in Patients with Unilateral Cancer of the Oral Cavity Before and After Surgery

Zmiany aktywności bioelektrycznej wybranych mięśni twarzy i szyi
u pacjentów z jednostronnie umiejscowionym rakiem jamy ustnej
przed zabiegiem chirurgicznym i po nim

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A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
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Abstract

Background. Radical excision of an oral cancer followed by post-surgical radiotherapy is a treatment of choice. Extensive excision of the initial structures in the gastrointestinal tract can impair swallowing and food intake. Early rehabilitation and compensatory mechanisms allow for the efficient return of oral function. It was assumed that this process requires increased activity of the face and neck muscles.

Objectives. Assessment of the electromyographic activity of selected muscles: sternocleidomastoid, masseter, suprahyoid and orbicularis oris (upper, lower part) during swallowing in the patients with oral cancer pre- and post-surgically.

Material and Methods. The study group consisted of 34 patients who were subjected to oral cancer surgery. The patients underwent surface electromyography (sEMG) examination with the use of Zebris EMG 8 bluetooth (Zebris, Isny im Allgäu, Germany) device. The examinations were performed three times: a few days before the surgery (first examination), ca. one month after the surgery (second examination), and approximately three months after the surgery (third examination).

Results. The results show a general median tension increase for the selected muscles at the end of the study. There were no statistically significant differences between the median tensions on the surgical and non-surgical side. The exception was a change in median tensions between the suprahyoid muscles of surgical and non-surgical sides and both parts of orbicularis oris muscle. The highest tension increase was observed within the lower part of orbicularis oris muscle and the suprahyoid muscles on the non-surgical side. The smallest change was observed in masseter of the surgical side – after the increase of median tension in the second study, it returned to the initial value. Patients using compensatory mechanisms showed statistically higher median tensions.

Conclusions. About three months after the surgery, all of the patients presented increased tension in the majority of assessed muscles and accompanying improvements in the efficiency of swallowing (*Dent. Med. Probl.* 2016, 53, 2, 175–185).

Key words: electromyography, oral cancer, masticatory muscles, mouth rehabilitation.

Słowa kluczowe: elektromiografia, rak jamy ustnej, mięśnie żucia, rehabilitacja jamy ustnej.

According to the National Cancer Registry, neoplasms of the head and neck in 2010 represented 3.6% of all cancers in men, and 1.4% of all cancers in women. In Poland, the prevalence of head and neck cancer is 1.4 times (in males) and 1.2 times (in females) higher than the average for the European Union [1]. Five-year age-standardized relative survival was 47% for the larynx cancer, and 28% for the other head and neck cancers in Eastern Europe. In Ireland, the United Kingdom and Northern Europe, the relative survival rate for the larynx cancer and the other head and neck cancers was 62% and 46%, respectively [2]. As a consequence, more people require specialized hospital care and rehabilitation each year [3, 4].

Surgical removal of the tumor in the area of the head and neck causes a disorder of the oral cavity basic functions. Therefore, the purpose of rehabilitation is to restore the ability to swallow food of varied consistency. Each swallowing phase (oral, pharyngeal, esophageal) is associated with an activation of certain anatomical structures. The result is a passage of the bolus to the stomach without aspiration of the food into the airways. Dysphagia may be a consequence of the disturbances at various stages of food ingestion: oral preparatory, oral propulsion, or pharyngeal stages of the swallow [5]. To restore the natural way of eating after extensive resection of the oral cavity cancer and its adjacent tissues, it is important to adapt the patients to swallow in the changed conditions by repeating the exercises. The aim of the exercises is to use the structures left after the oral cancer excision or the adjacent structures that were not damaged during the surgery. Avoiding food aspiration into the airways is especially important. Aspiration of the food into the airways is a consequence of its retention in the pyriform sinuses. It occurs when the hyolaryngeal complex does not raise properly, causing insufficient upper esophageal sphincter opening. Sufficient opening of the upper esophageal sphincter depends on the proper activity of the suprahyoid muscles. The muscles function improvement in the course of the exercises may prolong the time and range of upper esophageal sphincter opening, at the same time decreasing the probability of aspiration [6]. Similarly to that, the head and neck muscles involvement in a proper positioning of the head may help in avoiding the aspiration of the food into the airways. However, it turns out that even the patients who do not adhere to exercise regimes independently develop some compensatory mechanisms to facilitate the oral food intake [7].

Neural networks responsible for the swallowing automatism are related to the central generator in the brainstem. Nucleus of the solitary tract,

nucleus ambiguus, reticular formation are communicated with the motor neurons of the cranial nerves, and they are involved in the process [8]. Automatic part of swallowing allows the peripheral structures to adapt to the structural changes after the surgery. Therefore, the aim of this work was to determine the bioelectrical activity changes in the head and neck muscles involved in the act of swallowing after a unilateral resection of oral cancer.

Material and Methods

The study group consisted of 34 patients (8 females, 26 males) subjected to the oral cancer surgery at Maxillofacial Surgery Department. The criterion for inclusion into the group was the presence of primary oral cancer and its surgical treatment. Exclusion criteria were the presence of recurrence or the second focus of oral cancer. The average patient's age was 60.8 years. The tumor was located on the left side of the oral cavity in 16 of the patients, and on the right side in 18 of them. Each patient underwent pre-surgical histopathological examination which revealed carcinoma planoepitheliale in different clinical stages. Each patient underwent radical tumor resection with various reconstructions (Table 1).

After obtaining individual consent from each of the 34 patients, each patient was subjected to the examination of selected face and neck muscles (bilateral sternocleidomastoid, lower and upper part of the orbicularis oris, masseter, suprahyoid) performed with the use of surface electromyography (sEMG). Zebris EMG 8 bluetooth electromyographic equipment (Zebris, Isny im Allgäu, Germany) and eight double and one single disposable self-adhesive Ag/AgCl snap electrodes (Noraxon, Scottsdale, USA) were used for the examination. Dimensions of the figure 8-shaped adhesive surface of dual Noraxon electrodes is 4 cm x 2.2 cm, the diameter of a single conductive surface is 1 cm and interelectrode distance is 1.75 cm. The diameter of the circular adhesive area of single Noraxon electrode is 3.8 cm. The diameter of the circular conductive area is 1 cm.

During the study, the patients were sitting freely in a comfortable position. The patients' skin was prepared in accordance with the project SENIAM, and electrodes were placed in the same positions in every patient and in each examination [9, 10]. Each patient was examined three times: before the surgery, one month after the surgery, and 3 months after the surgery. The measurements were recorded during swallowing of 3 mL of 0.9% sterile saline.

During the post-surgical period (3–4 days after the surgery), the patients were exercising mus-

Table 1. Basic patient data containing information about the patient, tumor and surgery

On.	Age	Gender	TNM	Location	Therapy
1	55	F	T4aN1M0	gingiva reg 33-38	TR + LMRND + FFF
2	54	M	T3N1M0	gingiva reg 38-36	TR + LSL
3	53	M	T4aN1M0	gingiva reg 33-37	TR + LSL
4	45	M	T4aN1M0	gingiva reg 35-38	TR (hemimandibulectomy) + LSL
5	61	F	T2N0M0	tongue, left side	TR + LSL
6	64	F	T3N1M0	gingiva reg 48-42	TR + RSL
7	58	F	T1N1M0	tongue, left side	TR + LSL
8	53	M	T4aN1M0	tongue, right side	TR+ RSL
9	62	M	T4aN1M0	gingiva reg 43-42	TR + RSL
10	59	M	T3N1M0	gingiva reg 38	TR + LSL
11	37	M	T4aN1M0	gingiva reg 42-35	TR + bilateral SL + RFFF
12	68	M	T2N0M0	tongue, left side	TR + bilateral SL
13	62	M	T2N1M0	gingiva reg 43-48	TR + RSL
14	75	M	T3N1M0	gingiva reg 33-37	TR + LSL
15	72	M	T2N2cM0	floor of the mouth, right side	TR + bilateral SL
16	43	M	T3N2aM0	gingiva reg 46-48, tongue, right side	TR + RSL
17	65	M	T2N1M0	lower lip, right side	TR + RSL + Karapandzic surgery
18	70	F	T4aN1M0	lips angle, right side	TR + RFFF + RSL
19	67	F	T3N2bM0	buccal mucosa, right side	TR + RSL + STSG
20	64	M	T1N0M0	tongue, left side	TR
21	57	F	T3N2bM0	floor of the mouth, right side	TR + bilateral SL
22	48	M	T3N2bM0	tounge, left side	TR + bilateral SL + ALTF
23	47	M	T1N0M0	gingiva reg 46-47	TR
24	63	M	T4aN1M0	gingiva reg 41-46	TR + RSL
25	84	M	T4aN2cM0	gingiva reg 44 – trigonum retromolare	TR + RMRND + LSL
26	62	M	T4aN2aM0	gingiva reg 46 – 34, floor of the mouth, right side	TR + RSL
27	66	M	T2N1M0	tongue, floor of the mouth, right side	TR + RSL + PPMMFF
28	62	M	T4aN2cM0	tongue, floor of the mouth, left side	TR + LSL + RRND + PPMMFF
29	79	M	T2N0M0	lower lip, right side	TR + W-Y plasty
30	48	F	T3N1M0	gingiva reg 27	TR + SL
31	72	M	T4aN1M0	gingiva reg 17-18	TR + SL
32	64	M	T2N2bM0	palatal tonsil, soft palate, left side	TR + LMRND + RFFF
33	68	M	T4aN2aM0	palatal tonsil, soft palate, tuber maxillae, trigonum retromolare, right side	TR + RSL
34	59	M	T2N0M0	palatal tonsil, soft palate, left side	TR

F – female; M – male; Reg – region (numeration in location column is given in FDI teeth notation); TR – tumor resection with a margin of macroscopically unchanged tissues; MRND – modified radical neck dissection; RMRND – right sided modified radical neck dissection; LMRND – left sided modified radical neck dissection; RND – radical neck dissection; RRND – right radical neck dissection; LRND – left radical neck dissection; SL – suprahyoid lymphangiectomy; RSL – right sided suprahyoid lymphangiectomy; LSL – left sided suprahyoid lymphangiectomy; FFF – free fibula flap; RFFF – radial forearm free flap; STSG – split thickness skin graft; ALTF – anterolateral thigh free flap; PPMMF – pedicled pectoralis major myocutaneous flap.

cles of the lips, three times a day for five minutes (trying to whistle, blowing air flow directed to a small piece of paper lying on the table), and swallowing their saliva every full hour. Two weeks af-

ter the surgery, the patients were exercising swallowing of 3 ml of 0.9% sterile saline.

As a control, we used pre-surgical examination results because the bioelectric activity of se-

lected face and neck muscles is individualized for each patient, and may depend on the age and general condition of a patient [11–13].

After each examination, the patients themselves evaluated their functions of the mouth (chewing, swallowing and speech) according to the FIGS [14, 15]. The meaning of chewing, swallowing and speech score in Functional Intra-oral Glasgow Scale is clearly described. If a patient is unable to perform any of the aforementioned functions, the score of choice is 1. If a patient's speech is intelligible only for his/her relatives, the score is 2; if the speech requires multiple repetitions, the score is 3; if the speech requires single repetition, the score is 4; if the speech is fully intelligible, the score is 5. Assessing the swallowing, the patient gives the kind of food he/she is able to swallow, and a degree of difficulty. If a patient swallows liquids only, the score is 2; if a patient swallows semi-solid food only, the score is 3; if a patient swallows solid food with difficulties, the score is 4; in case of swallowing all kinds of food without any difficulties, the score is 5. In case of chewing semisolid food with difficulties, the score is 2; for chewing the semisolid food without difficulties, the score is 3; for chewing solid foods with difficulties, the score is 4; for chewing any food without any difficulties, the score is 5. Compensatory mechanisms after the surgery were also observed and recorded.

All constant variables were checked due to the normality of distributions with Kolmogorov-Smirnov test. These variables are described through the mean, standard deviation, median, quarter, and the minimum and maximum values. Checking the statistical differences between the two groups was performed using Mann-Whitney or *t*-Student test for dependent variables. The level of significance of differences between the two studies were tested in pair-related Wilcoxon test or *t*-Student test for dependent variables. Discontinuous variables were described by the amount and frequency. Pearson's χ^2 test was used to study statistical correlations between the discontinuous variables. Spearman rank correlation was used to study the correlations between ordinal and nominal discontinuous variables (coded variables: 0/1) and continuous variables. The results were described by the correlation coefficient *R* and *p* probability. Statically significant differences were described with the probability of $p < 0.05$. The level of significance $p = 0.051$ – 0.099 was indicated as a borderline statistical significance trend.

Statistical analysis was performed using the statistical program STATA 11 Licence No. 30110532736.

This study was approved by the Bioethical Commission No. KB – 0012/102/12.

Results

During the pre-surgical swallowing, suprahyoid and orbicularis muscles showed similar activity, especially the lower part of the latter one.

The study shows a tension increase in the majority of examined muscles during swallowing 3 mL of saline over the time elapsed since surgery. In the third study, we observed a statistically significant increase in median tension in the suprahyoid muscle on the surgical side, masseter, suprahyoid and sterno-cleido-mastoid of side opposite to the surgery, as well as in the upper and lower parts of the orbicularis oris muscle. There were no statistically significant differences between the medians muscle tensions on surgical or non-surgical side. The exception was the change in median tensions between the suprahyoid muscles on surgical and non-surgical sides, as well as both parts of orbicularis oris muscle. In the case of the suprahyoid muscles on the surgical side, there was a value reduction of the median tension with a slight increase in the third examination. There was a continuous increase in the median tension in suprahyoid muscles on non-surgical side, mostly significant between the first and the second examination. There was also a statistically significant relationship between the upper and lower part of orbicularis oris muscle, which tension was increasing within the time of the examination, and was greater in lower part of orbicularis oris.

The highest tension increase was observed in the third examination in the lower part of orbicularis oris muscle (32.5 μ V) and suprahyoid muscle on the opposite side to the surgery (26.6 μ V). The smallest muscle activity change was observed in the masseter on the surgical side – after the increase of median tension in the second examination, it returned to the initial value (Fig. 1).

Table 2 shows the values that determine muscle tension (minimum, maximum and median) in the subsequent examinations.

We observed statistically significant differences between the self-assessment of oral functions in the subsequent examinations. In the first evaluation after the surgery, the patients evaluated swallowing as the worst performed function on the FIGS. In the second examination after the surgery, the patients also evaluated swallowing function as the worst. Improvement in the functions of swallowing and chewing in the last evaluation in comparison to the examination 1 month after the surgery was placed on a similar level. The smallest changes were statistically related to patients' self-assessment of the speech (Table 3). Between the examinations, there was a change in the percent-

Fig. 1. Median muscle tension in microvolts [µV] during ingestion of 3 ml of 0.9% [µV] physiological saline in patients with uni-lateral oral cancer location

Table 2. Changes in individual muscle tension during subsequent examinations

Muscles	Ex	Ten [µV]			
		N	min.	max.	mediana
UpOrbiOr	1	34	4.6	143.7	18.3
UpOrbiOr	2	34	5.6	297.5	23.9
UpOrbiOr	3	34	11.3	170.4	28.1
LowOrbiOr	1	34	12.1	155.9	33.9
LowOrbiOr	2	34	11.7	229.7	41.2
LowOrbiOr	3	34	9.7	179.0	66.4
O SCM	1	34	2.2	46.7	8.0
O SCM	2	34	2.6	73.7	8.3
O SCM	3	34	2.2	681.5	9.6
O Mass	1	34	2.1	63.0	8.2
O Mass	2	34	2.1	20.8	8.9
O Mass	3	34	4.6	956.7	8.2
O SupHyo	1	34	4.4	108.0	19.1
O SupHyo	2	34	1.9	81.4	14.5
O SupHyo	3	34	4.7	260.6	20.6
N SupHyo	1	34	2.3	133.0	18.8
N SupHyo	2	34	5.1	359.1	37.9
N SupHyo	3	34	5.0	683.2	45.4
N Mass	1	34	1.5	48.1	8.4
N Mass	2	34	3.4	20.0	9.3
N Mass	3	34	0.5	330.7	11.2
N SCM	1	34	1.2	44.7	8.3
N SCM	2	34	2.0	48.7	10.8
N SCM	3	34	1.2	490.1	11.1

O SCM – sternocleidomastoid muscle on surgery side; O Mass – masseter muscle on surgery side; O SupHyo – suprahyoid muscles on surgery side; UpOrbiOr – upper part of orbicularis oris muscle; LowOrbiOr – lower part of orbicularis oris muscle; N SupHyo – suprahyoid muscle on opposite side to surgery; N Mass – masseter muscle on opposite side to surgery; N SCM – sternocleidomastoid muscle on opposite side to surgery; Ten – tension; Ex – examination.

Table 3. Self-assessment of oral function of patients according to the FIGS

Examination	Chewing	Swallowing	Speech	FIGS total
First	4.6	4.6	5	14.3
Second	3.2	2.9	4.1	10.2
Third	3.9	3.7	4.5	12.2
Maximum	5	5	5	15

Fig. 2. Change in the percentage of individual points in the self-assessment of oral function**Table 4.** Collective self-assessment of basic functions of the mouth (speech, chewing, swallowing) in FIGS

Compared examination			Dependent variable	p	N1	N2
Examination	1	2	FIGS total	0.000	34	34
Examination	1	3	FIGS total	0.000	34	34
Examination	2	3	FIGS total	0.000	34	34

age of individual points scored by the patients on the self-assessment of oral function scale (Fig. 2).

There was a statistically significant degradation in general oral functions performance after the surgery, with its significant improvement in the third examination in the self-assessment of oral function in accordance to the FIGS (Table 4). Figure 3 graphically shows changes in total oral function.

Frequently performed compensatory mechanisms in the patients included head tilting to the

side opposite to the surgery, additional swallowing, prolonged breath holding, raising and lowering the head, and the entire body activation. Only one of the patients implemented sucking and oral fissure tightening with tongue during swallowing (Table 5).

Statistically, patients using compensatory mechanisms in relation to the FIGS assessed their oral functions (chewing, swallowing, speech) significantly worse than the patients who did not implement specific method of compensation.

Fig. 3. Changes in self-assessment of the basic functions of the mouth (speech, chewing, swallowing) over time

Table 5. Compensatory mechanisms used by the patients after surgery during swallowing 3 mL of 0.9% physiological saline

Compensation mechanism	Percentage of patients from study group
Head tilt	94.11
Additional swallowing	85.29
Prolonged breath holding	44.12
Head raising	23.53
Head lowering	23.53
Activation of the whole body	23.53
Buccal pressing movements of the cheeks	20.59
Cyclic closure of the jaws	14.71
Sucking	2.94
Oral fissure tightening with tongue	2.94

Negative correlation between medians tension in suprahyoid muscles on non-surgical side and various functions of the mouth was observed. Higher values of median muscular tension were accompanied by lower rating of individual functions on FIGS. Positive correlation between supra-

hyoid muscles medians tension on surgical side and speech was observed. Lower values of median muscular tension were accompanied by lower rating of speech on FIGS.

In the study, we observed a statistically significant increase of median tension of the selected muscles in the patients who have implemented mechanisms to compensate their impaired functions (Table 6). A decrease of median tension was only observed in the second examination. This was observed in median tension of suprahyoid muscle on the surgical side in the patients who implemented chin up compensation and effortful swallowing.

Discussion

Oral cavity cancer is frequently localized in the tongue and floor of the mouth [1]. Location, diagnosis, tumor size, and presence of regional or distant metastases are the basic factors that affect the range of surgery. Impairment of the stomatognathic system after the resection of oral cancer is predictable. However, rehabilitation should be individualized due to different patterns of swallowing that vary in each patient. Fluoroscopic ex-

Table 6. Correlation between the activation of individual muscles and compensatory mechanisms

Compensatory mechanisms	Muscles showing a statistically significant increase or decrease in median values of tension
Prolonged breath holding	O SCM, N SCM
Buccal pressing movements of the cheeks	N SCM
Cyclic closure of the jaws	O Mass, N Mass, N SCM, O SupHyo, N SupHyo
Chin up	O SupHyo
Chin down	O SupHyo, N SCM
Effortful swallowing	O Mass, N Mass, N SCM
Additional swallowing	UpOrbiOr

aminations accurately show the patterns of swallowing. Understanding the individual pattern of swallowing can help in implementing the most effective swallowing rehabilitation, which in different patients may include, *e.g.*, changes in head or body position (postural changes) and swallowing maneuvers. Individually educated patterns will depend on the range of excision. Patients with impaired posterior movements of the tongue will often create a mechanism of „effortful swallowing” with entire body activation. Patients with impaired retraction of the tongue or late pharyngeal phase of swallowing will often create a mechanism for changing the position of the head, *i.e.* chin down. Oral inefficient transport is often associated with the use of the chin up position [16–19].

Life-saving surgery in head and neck cancer patients causes some changes in their quality of life in terms of basic functions such as breathing, chewing, swallowing and speech, as well as in social and professional aspects [20, 21]. All of this in combination with general fatigue, susceptibility to depression, and consequences of radiotherapy in the oral cavity (reduced sensation and mobility of the intraoral structures, pain, dryness and hypersensitivity of the mucous membranes) may effectively impede rehabilitation [22–25]. It should be of great interest for physician teams to select the patients requiring additional methods of nutrition and psychological assistance in order to maintain the quality of the patient’s life at the highest possible level to enable proper rehabilitation [26, 27].

The closure of the mouth is important for the proper process of swallowing. Orbicularis oris muscle closes the anterior oral tract, and thanks to that creates proper pressure in the oral cavity to avoid falling out the bolus from the mouth. Epiglottis, soft palate and vocal folds separate the airway from the gastrointestinal tract. Lack of proper closing of the mouth causes the uncontrolled flow of fluid and impairs swallowing. Loss of necessary intraluminal pressure delays the initiation of the pharyngeal phase of swallowing. Excision of a tumor of the tongue, floor of the mouth, mandible or palate can cause lip dysfunction even if their structure is not damaged [28]. This situation occurs when the tissues surrounding the oral cavity lose bone support and/or innervation. Devine *et al.* observed that cutting the lower lip for tumor exposure does not have to impair lips tightness [29]. In the case of our patients, even when the lips structure was damaged, median bioelectric activity of the lower part of orbicularis oris was noticeably increased. It was even higher than the median tension of upper part of orbicularis oris muscle. This situation was accompanied by better self-assessment of the oral function.

Increased activity of the orbicularis oris muscle, especially its lower part, determined the correct closure of the mouth. In our study, the median tension of this muscle was higher during the second test and reached the highest value in the third examination. The change of tension was accompanied by changes in the self-assessment of oral function by the patients. In the first and third examination, patients evaluated oral swallowing and chewing much better than during the evaluation about one month after the surgery.

Suprahyoid muscles are involved in lifting the larynx during swallowing, thereby creating a respiratory protection from aspiration. Activity patterns of these muscles during swallowing vary and depend, for example, on fluid volumes [30]. The electromyographic examination of the activity of geniohyoid muscles, mylohyoid muscles and the anterior belly of digastric muscle in healthy subjects was performed by Spiro *et al.* [31]. There were differences in the involvement of these muscles in the process of swallowing. The changes were seen both in one subject and also between different patients. The authors suggest that these changes are the result of the adaptive capacity of the patient, not of changes in the process of swallowing [31, 32]. In our group, the mean suprahyoid muscle tension (including anterior bellies of digastric muscles) increased during the post-surgical period. This change was particularly evident in the case of suprahyoid muscles on the side opposite to the surgery. Median suprahyoid muscle tension on the side opposite to the surgery side was 18.8 μ V (first examination), 37.9 μ V (second examination), and 45.4 μ V (third examination). Median suprahyoid muscle tension on the surgery side was 19.1 μ V (first examination), 14.5 μ V (second examination), and 20.6 μ V (third examination). We observed a reduction in median tension of these muscles on the surgery side with a statistically significant increase in the third examination. The median tension reduction in the second examination could be the result of the surgery. Continuously increasing median tension demonstrates an important participation of these muscles in swallowing with a statistically significant improvement of this function on the FIGS in the final examination. Changes in head position, when compensatory mechanisms were implemented, were accompanied by statistically significant increase in activity of sternocleidomastoid muscles on non-surgical side: median tension from 8.3 μ V to 11.1 μ V.

This study shows a relatively large increase in muscle activity bilaterally within suprahyoid muscles, masseter and sterno-cleido-mastoid on non-surgical side and both parts of orbicularis oris

muscle. This situation may be due to some additional steps taken by the patients to implement compensatory mechanisms to facilitate swallowing [33]. Thus, the passage of time results in our patients in increased muscle tension, implementation of compensatory mechanisms, and increase in the effectiveness of oral functions (chewing, speech and swallowing), which were assessed by the patients according to the FIGS. Patients who implemented compensatory mechanisms evaluated functions less than the patients who did not have them implemented. Worse oral functions lead to the beginning compensatory mechanisms implementation by the patients in order to maintain these functions on a functional level. The consequence of the compensatory mechanism implementation was the improvement of the oral function self-assessment.

Maintaining lip tightness is possible when early post-surgical rehabilitation is implemented. Swallowing saliva, as a first step, should start in the second day after the surgery. Muscle exercises improving mobility of the lips are recommended after wounds healing, *e.g.* about two weeks post-surgically.

The surface electromyography method that we used allows for multiple measurements of the selected muscles activity, as well as comparison of the results. It is a non-invasive and objective method. Limitations of this method include being less accurate than tests using intramuscular needle

electrodes, and sensitivity to external factors such as incorrect preparation of skin surface, salivary fistula in the chin area, excessive sweating, non-healing wounds, or uncontrolled saliva dribbling from the mouth. The advantage of surface electromyography is the ability to compare ratings of bio-electrical activity in balance, and during intensive muscle work [34–40].

Increased tension of the selected extraoral muscles indicates the participation of these muscles in creating a new model of swallowing in the patients after resection of a tumor localized unilaterally in the mouth. Increase tension in the selected muscles showed during the examination may suggest the existence of a possible potential in these muscles. This could enable additional exercises implementation, *e.g.* the Shaker exercises, which increase the strength of suprahyoid muscles, and as a consequence elongate the time and range of upper esophageal sphincter opening. Moreover, increased activity of the mylohyoid muscle enables raising the floor of mouth and tongue in order to facilitate the oral food transport. Therefore, thanks to the exercises of the suprahyoid muscles in the course of rehabilitation, it is possible to create a safe and free of aspiration way of swallowing and oral food intake in a patient [6]. This activity also increases with the implementation of various compensation mechanisms by the patients, and ultimately leads to enable the intraoral food intake.

Acknowledgment. I would like to thank prof. Katarzyna Sporniak-Tutak for essential guidance and substantive assistance in preparing the final version of this article, dr Robert Kowalczyk and the whole team at the Maxillofacial Surgery Clinic for their help in performing the examinations.

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Conflict of Interest: None declared

Received: 19.01.2016

Revised: 27.01.2016

Accepted: 31.01.2016