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ORIGINAL ARTICLE

# Impairments in Food Oral Processing in Patients Treated for Tongue Cancer

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## Abstract

Patients surgically treated for oral cancer are affected by several underestimated deglutition disorders risk factors. This study aims to characterize the level of these food oral processing (FOP) impairments in a group of patients treated by surgery for tongue cancer. Twenty-seven consecutive patients surgically treated for tongue cancer were evaluated concerning their chewing capacity (Mastication-test), and responded to questions concerning their capacity to bite, chew and manipulate food with their tongue, and their quality of life. According to the Mastication-test, 16 patients suffered total FOP incapacities (TI group), characterized by high tumor stage, invasive carcinological surgery and necessity of reconstructive surgery; 12 patients were partially or not impaired (PI/NI-group). Tongue movement score and number of dental units were lower in the TI group than in the PI/NI-group. Subjective FOP criteria were clearly impaired in the TI group and correlated with a poor oral health-related quality of life. One year after surgery, there is a decrease in BMI for TI group patients while the PI group patients had a significant increase in BMI. All patients surgically treated for oral cancer suffered FOP impairments, but not with the same severity. Totally impaired subjects are at higher risk from long-term malnutrition. Functional evaluation of FOP should form part of the post-operative follow-up for all patients suffering from tongue cancer, using a quick combined evaluation of chewing efficiency, oral health quality of life and nutritional status.


**Keywords** Tongue cancer · Food oral processing · Mastication · Deglutition · Deglutition disorders · Oral health-related quality of life

## Introduction

Tongue cancers are the most common cancers of the oral cavity, and constitute about 20% of all cancers of the upper aero-digestive tract [1, 2]. These cancers can originate from the tongue itself and/or from adjacent oral structures, in particular the buccal floor of the mouth and the tonsil pillars. Surgical excision is the first curative option for tongue cancers. Excision extent, associated with mutilations of the neighboring organs, determine the patient's functional, and sometimes vital prognosis. Radiotherapy and/or chemoradiotherapy are indicated in association with surgery if there are unfavorable anatomopathological results. The tongue is a complex organ organized in an intrinsic and extrinsic musculature. It is closely associated with its neighboring structures (soft palate, internal face of the cheeks and larynx) involved in the oral functions: speech, taste, chewing and swallowing. Major deficiencies are still observed, despite progress made in head and neck reconstructive surgery using vascularized free flaps, or in prosthetic rehabilitation, which is always difficult in this context [3–9]. Moreover, radiotherapy and chemotherapy exacerbate the negative effects of surgery on ingestive functions, for example dryness of the mouth or swallowing incapacities [10–13]. After treatment, patients are affected by several chewing risk factors that may impair

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their nutritional status and quality of life [14–16], and they have to cope with the negative impacts of the disease and its treatments.

The source of malnutrition in surgically treated patients is multifactorial, involving functional, psychological and metabolic considerations [14, 16, 17]. The metabolic considerations are related to catabolism/anabolism imbalance. Tumor proliferations raise catabolism, while anabolism is reduced by pain due to surgery and neurophysiological factors such as anxiety, stress and depression. The extent of surgical bone resection, mandibular continuity, number of dental functional units and tongue mobility seem to be risk factors for masticatory impairment expressed by multiple food restrictions [16, 18–21]. However, masticatory impairments and disabilities are seldom objectively investigated, and there has been little study on the consequences of treatments on nutritional changes. A short PubMed search with the keywords “tongue cancer”, “mastication” and “nutrition” brought up just one review and one cohort study [14, 16]. Data on food restriction in persons surgically treated for tongue cancer are reported, and there are no specific studies assessing chewing deficiencies in these patients and their impact on nutritional status and quality of life. In particular, it is not known whether surgical patients can compensate for their disabilities by adopting unilateral chewing, and to what extent these adaptive processes depend on the oral condition and/or the extent of tongue surgery. Remedial nutritional measures regarding chewing and/or swallowing deficiencies require interdisciplinary cooperation and must be implemented in patients’ management.

Food oral processing (FOP) is the first step in the eating process [22]. It includes all oral functions and actions during which food is broken down structurally for the purpose of both safely swallowing it and transporting it to the stomach for further digestion. Diagnosis of impairments in FOP is important as it can identify those patients at risk from deglutition disorders and malnutrition. This study aimed to characterize the level of impairments in FOP in a group of patients treated surgically for tongue cancer.

## Patients and Methods

### Study Design

This observational study was conducted in the University Hospital of Clermont-Ferrand. Data were collected from a group of consecutive patients being surgically treated for tongue cancer and examined during the systematic post-surgery follow-up period between January 1st, 2014 and April 30th, 2015. The mean time after surgery was $3.96 \pm 2.67$ years. Subjects treated only by exclusive radiotherapy or concomitant chemoradiotherapy were not included in the study. Subjects for whom tumor progression or new cancer location was diagnosed during the study period were not included. Finally, because of known major deficiencies [19, 20], subjects with a mandibular continuity interruption that could not be reconstructed were also excluded. Persons with neuromotor or mental disabilities and persons who did not speak French were also excluded. During the appointment, after clinical and radiographic examination, patients were asked to complete a validated questionnaire on oral health-related quality of life [23] and to answer an original questionnaire on their capacity to bite, chew and manipulate food with their tongue. Chewing evaluation was measured during a special appointment.

### Study Criteria

#### Oral Health Criteria

**Size and Localization of Tumor** Tumor volume was determined using the seventh edition of the international TNM Classification of Malignant Tumors, which defines four tumor stages: T1, T2, T3 and T4, depending on the size of the lesion. Three tumor localizations were discerned: (i) mobile tongue, (ii) mobile tongue with floor of mouth extension, (iii) mobile tongue with floor of mouth extension and other (i.e. extension to adjacent structures including the mandibular bone).

**Treatments** The anatomical extent of the surgical resection was ranked in three categories: partial glossectomy (less than one-third of the mobile tongue), subtotal glossectomy (resection of more than one-third but less than two-thirds of the mobile tongue), and glossectomy (resection of more than two-thirds of the mobile tongue, with or without non-transfixant mandibular localized resection). Occurrences of reconstructive surgery (free flap/myocutaneous flap/a local flap) and/or postoperative radiotherapy (extent of the irradiated territory and total irradiation dose) were examined.

**Tongue Mobility** Tongue mobility was evaluated by a tongue movement test developed for patients with mandibulectomy and/or glossectomy [19] and scored from 0 (lowest) to 8 (highest).

**Dental Functional Units** A posterior functional dental unit (PFU) is defined as a pair of posterior antagonist natural teeth with at least one contact area during chewing. To record the number of PFUs, participants were asked to chew 2–3 cycles on a 200-µm articulating paper. The number of molars and premolars on the lower arch that made at least one-colored mark gave the number of posterior functional units [24]. The maximum number of PFUs that can be recorded in fully dentate caries-free adults without periodontal disease or orofacial dysmorphology is 10.

### Food Oral-Processing Criteria

Impairments in FOP and deglutition disorders were evaluated by objective and subjective measurements.

#### Objective Evaluation of FOP Impairments

**Mastication Test** It has been widely demonstrated that analyzing the distribution of food particles in a chewed bolus helps characterize the result of mastication [25]. When subjects are asked to chew food and spit out the bolus when they are ready to swallow it, the composition of the bolus reflects the results of the spontaneous physiological process of mastication. This includes the individual strategies and neurophysiological processes necessary to adapt mastication so as to transform the food into a swallowable bolus. Carrot was used as test food to define the range of variations of bolus granulometry mean values (D50) for normal mastication. The upper limit of normal median particle size for young subjects with good oral health is estimated at 4 mm [26]. The mastication test (M-test) also helped us study food refusals, which could be related to deglutition disorders and to some changes in food choices, and to consumption behaviors. Patients whose D50 mean value for carrots were under 4 mm were deemed to have normal mastication (NI), those with D50 mean value above 4 mm were deemed partially impaired (PI).

**Food Refusals** Food refusals were examined each time the subjects refused to swallow the first and second carrot sample, and each time the subjects expectorated the sample before the end of the first chewing cycle. Patients who were unable to chew carrot samples were deemed totally impaired (TI).

**Kinematic Parameters of Mastication** Video recording was used to evaluate kinematic parameters as previously described [27, 28]. The variables recorded were chewing time (CT: time in seconds between the moment when the carrot piece was placed in the mouth and swallowing, identified by immediate swallow after the end of rhythmic rotary movements), and number of chewing cycles (CC: number of chewing actions during the CT period; this included all the rotary patterns, with and without lip closure). Chewing frequency (CF) was calculated as the ratio CC/CT.

**Subjective Evaluation of FOP Impairments** FOP impairments were evaluated subjectively with an original questionnaire developed to assess the level of difficulties for three functions related to FOP: biting the food, manipulating the food with the tongue, the jaw and the lips, and chewing and swallowing. Five questions rated difficulty biting five foods (apple, cooked egg, bread (French baguette), banana and cheese), nine rated difficulty manipulating nine foods in the mouth (shredded raw carrot, minced meat, mashed potatoes, cooked white rice, french fries, cheese, banana, apple puree with chunks, apple puree without chunks), and ten rated difficulty chewing and swallowing ten foods (dry sausage, french fries, pieces of meat, minced meat, raw apple pieces, raw carrot pieces, shredded raw carrot, peanuts, cheese and banana).

Each difficulty was scored on a 10-mm visual analog scale from 0 (no problem at all), to 10 (maximum difficulty). After summing, biting difficulty was scored from 0 to 50, difficulty in food manipulation from 0 and 90 and chewing and swallowing difficulty from 0 to 100. For each function, the presence of difficulty was examined for scores over 25 for biting, over 45 for food manipulation and over 50 for chewing and swallowing.

The texture of the meals taken during the last 2 weeks (breakfast, lunch and dinner) was collected and categorized as follows: soft/ground diet texture or normal diet texture. Modification of diet texture was considered when at least one occurrence of soft/mixed diet meal texture was declared.

#### Oral Health-Related Quality of Life

The GOHAI (Global Oral Health Assessment Index) questionnaire focuses on oral health quality of life (QoL) [29]. An approved French version was used [23]. The questionnaire comprises 12 items grouped into three fields: (i) functional (eating, speaking, swallowing), (ii) psychosocial (concerns, relational discomfort, appearance), and (iii) pain or discomfort (drugs, gingival sensitivity, discomfort when chewing certain foods). A score of 51–56 is regarded as average and a score of 50 or less is regarded as low, reflecting a poor oral health quality of life.

### Statistical Analysis

Statistical analysis was performed using Stata software (StataCorp, College Station, US). All tests were two-sided, with type I error at 0.05. Continuous data were expressed as mean ± standard deviation or as median [interquartile range], according to statistical distribution (assumption of normality assessed with the Shapiro–Wilk test). Continuous parameters were compared between independent groups using a Student *t* test or Mann–Whitney test if the *t* test assumptions were not met. For categorical parameters, comparisons were performed using the $\chi^2$ test or when appropriate the Fisher exact test. Owing to sample size, non-parametric tests were often preferred.

These analyses were completed by factorial mixed data analysis (FMDA) to uncover the underlying relationships and categorize subjects into two groups for impairments in FOP: the group of patients without or with partial oral impairments (PI/NI group: patients agreeing to chew carrot samples), and the group with total oral impairments (TI group: patients who failed the M-test). The parameters selected to be included in the FMDA were determined according to univariate results and clinical relevance.

## Results

During the study period, 27 consecutive patients satisfied the clinical criteria for inclusion and agreed to participate in the study. The M-test showed that 16 patients had total FOP incapacities, 11 patients were partially impaired, and one was not impaired. Demographic and oral health criteria are reported in Table 1.

Based on the variables included in FMDA, the factors related to poor quality of life and to difficult FOP are of opposite sign to the increase in BMI after surgery (Fig. 1). Patients without or with partial oral impairments and patients with total oral impairments could be distinguished according to their failure in the M-test (Fig. 2). Mean values and patients' distribution for subjective and objective evaluation of FOP are given in Table 2.

## Discussion

This is the first study describing oral deficiencies and impairments in patients surgically treated for tongue cancer. It confirms data from a previous cohort study that recorded subjective evaluation after telephone interview [16] and demonstrated that all patients suffered from FOP impairments, but not at the same level. This study showed that depending on ability to chew a piece of raw carrot, only one subject had no chewing deficiencies, being able

**Table 1** Demographic and oral health data of study group, and comparisons between groups with or without total impairment of food oral processing [*$\chi^2$ or Fisher's exact test; §Student or Mann–Whitney test]

| | PI group ($n=11$) | TI group ($n=16$) | Total ($n=27$) | $p$ value |
|---|---|---|---|---|
| *Demographic data* | | | | |
| Gender ratio (women/men) | 4/7 | 5/11 | 9/18 | |
| Age (years) | 58.4 | 65.6 | 62.7 | |
| *Oral health criteria* | | | | |
| Tumor localization | | | | 0.670* |
| Mobile tongue | 7 | 5 | 12 | |
| Mobile tongue + floor of mouth | 4 | 6 | 10 | |
| Other (including bone involvement) | 0 | 5 | 5 | |
| Tumor stage (TNM) | | | | 0.012* |
| T1 | 7 | 2 | 9 | |
| T2 | 4 | 6 | 10 | |
| T3 | 0 | 3 | 3 | |
| T4 | 0 | 5 | 5 | |
| Surgery | | | | 0.074* |
| Partial glossectomy | 7 | 6 | 13 | |
| Subtotal glossectomy | 3 | 2 | 5 | |
| Glossectomy + partial mandibulectomy | 1 | 8 | 9 | |
| Reconstruction surgery | | | | 0.042* |
| Yes | 1 | 8 | 9 | |
| No | 10 | 8 | 18 | |
| Postoperative irradiation | | | | 0.001* |
| Yes | 2 | 14 | 16 | |
| No | 9 | 2 | 11 | |
| Average dose (Gray) | 60 | 60.5 | 60.5 | |
| Perceived dry mouth | | | | 0.130* |
| Yes | 4 | 11 | 15 | |
| No | 7 | 5 | 12 | |
| Tongue mouvement score | 6.3 | 3.8 | 4,8 | 0.007§ |
| Dental functional units | 5.1 ± 2.3 | 0.9 ± 2.2 | 2,6 | < 0.001§ |

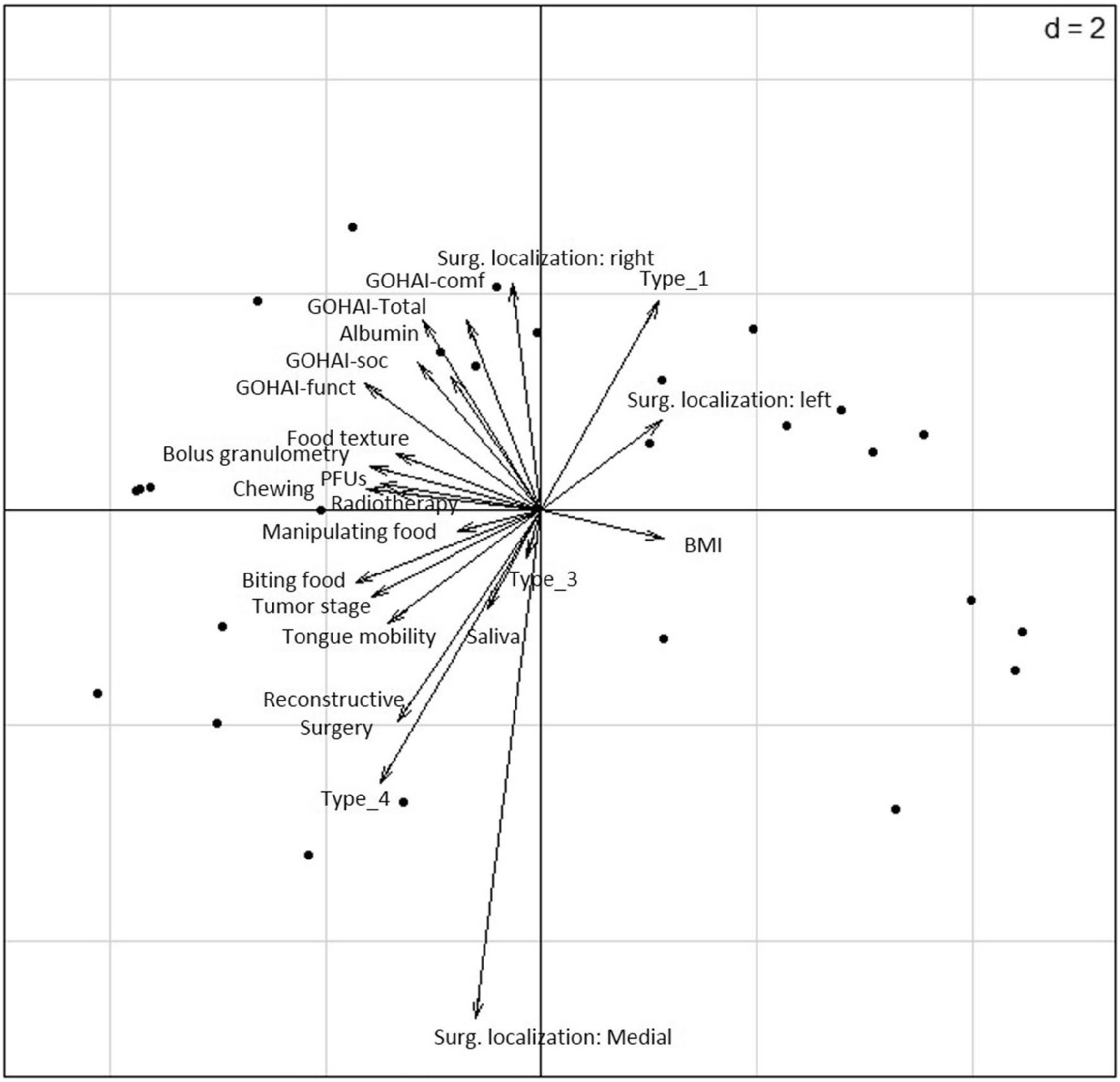


**Fig. 1** Factorial mixed data analysis (FMDA) representing all relationships between variables (black points: patients)

to produce a carrot bolus with a mean granulometry value below 4 mm. The others could all be categorized as either partially impaired, for those producing a carrot bolus with a mean granulometry over 4 mm, or totally impaired for those unable to chew the carrot samples. This test could differentiate totally impaired patients presenting a more severe tumor T stage, more extensive surgery, and post-surgical radiotherapy. These TI patients also presented more severe postoperative complications. Chewing with back teeth, biting and manipulating food in the mouth are more strongly impacted in totally impaired patients than in their partially impaired counterparts. Moreover, totally impaired patients were also at higher risk of malnutrition 1 year after surgery, while BMI increased slightly in partially impaired patients. All patients described a poor oral health-related quality of life, but the totally impaired patients were more affected that the partially impaired ones. This study suggests that the carrot M-test could be used in routine daily care to identify, at low cost, patients treated for tongue cancer who should be referred for post-operative nutritional follow-up.

This study suggests that the severity of FOP impairments could be related to postoperative loss of weight in patients treated with tongue cancer. However, the TI group had fewer teeth on the arches than the PI group, and this study did not account for whether FOP impairments were due to the tongue deficiencies or rather to the lack of teeth. Interactions between tongue, teeth and nature of food have a dominant role as an entraining stimulus for metabolic rhythms, the timing of daily food intake and the fidelity of food entrainment mechanisms. During FOP, the teeth are not simple tools that mechanically reduce the food to particles and mix

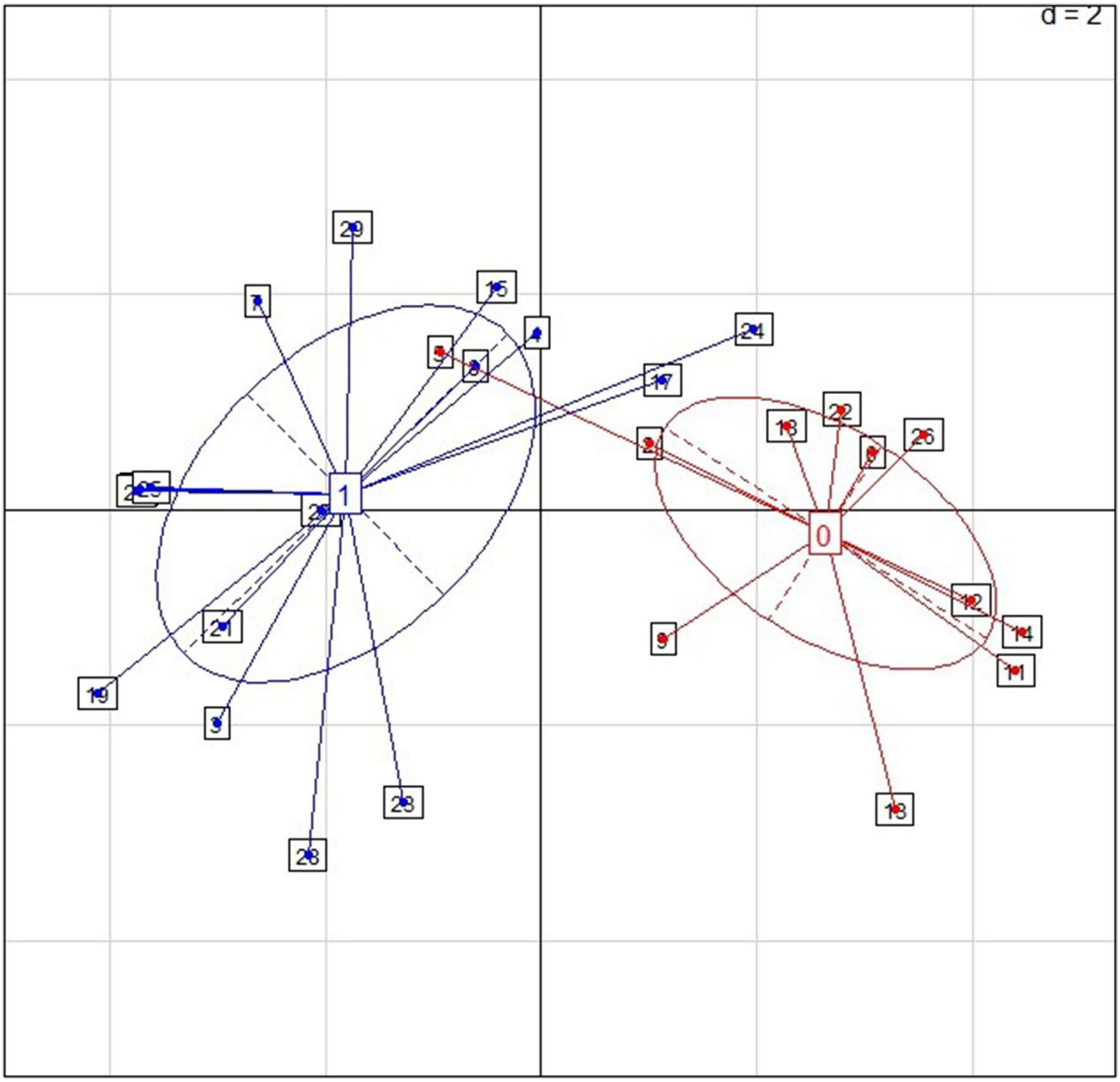


**Fig. 2** FMDA shown the distribution of individual profiles according to the profiles of discriminating variables represented in Fig. 1. Assignment of the main criterion "Acceptance of mastication test of carrot" (blue colour: PI/NI-group) and "Refusal" (red colour :TI group)

saliva and food to produce an easy-to-swallow bolus. They are also essential to the neuromotor control of chewing and swallowing, through the tongue receptors and the periodontal and pulpal sensory receptors that are triggered during interarch contacts [30]. Periodontal mechano-reception provides feedback on the magnitude, direction and rate of occlusal load application for sensory perception and motor function [31]. Thus any dental disease that affects the numbers, structure or position of the teeth is assumed to have an impact on chewing and swallowing. Given the dominant role of food as an entraining stimulus for metabolic rhythms, the timing of daily food intake and the fidelity of food entrainment mechanisms are likely to have clinical relevance [32]. The relationships between FOP and digestion have previously been investigated in different ways. Increasing FOP shortens the time needed by the stomach to comminute food particles to a diameter small enough to pass through the pylorus [33]. FOP is also involved in maintaining good motility in the digestive tract by enhancing physiological gastric motion through the activation of parasympathetic nervous activity [34–39]. Moreover, adequate mastication facilitates the initial steps of digestion by stimulating saliva production and activating the cephalic controls that initiate the assimilation of foods [40, 41].

Poor nutritional status also has many consequences for the postoperative period and follow-up. In particular, poor wound healing and wound site infections are increased in patients with malnutrition [42–44]. Further controlled studies should be designed to demonstrate the existence of causal relationships between FOP impairments, oral status

**Table 2** Comparisons of mean values of data for food oral processing and quality of life related to oral health between patients with total impairments in food oral processing and patients with none or partial impairments in food oral processing (student or Mann–Whitney test)

| | PI group ($n = 11$) | TI group ($n = 16$) | $p$ value |
|---|---|---|---|
| *Food oral processing* | | | |
| Objective FOP impairments criteria. M-test | | | |
| Duration (s) | 30.6 | NA | |
| Number of cycles | 48.6 | NA | |
| Frequency (cycle/s) | 1.6 | NA | |
| Carrot bolus granulometry (D50) (mm) | 5.8 | NA | |
| Subjective FOP impairments criteria | | | |
| To bite | 8.6 | 34.7 | 0.0001 |
| To manipulate | 12.9 | 28.4 | 0.042 |
| To chew and swallow | 17.9 | 67.2 | 0.001 |
| Texture of meals per subjects | | | |
| Normal | 7 | 1 | 0.002 |
| Soft/grinded | 4 | 15 | |
| Nutritional status | | | |
| Preoperative BMI (kg/m$^2$) | 25.9 | 24.3 | |
| Follow-up BMI | 27.3 | 22.8 | |
| Delta BMI | + 6% | 5% | 0.016 |
| Oral health-related quality of life | | | |
| Functional field | 16 | 10 | 0.018 |
| Psychosocial field | 21.6 | 16.4 | 0.005 |
| Pain or discomfort field | 12.3 | 10.9 | 0.160 |
| Total | 49.9 | 37.3 | 0.001 |

and nutritional status in patients treated for oral and/or tongue cancer. Clinical issues for such research should be examined. Two options are in balance to maintain FOP and BMI for patients treated for tongue cancer: changing food or improving oral health. Changing food could be suggested for patients who fail the M-test despite good oral health or dental rehabilitation. In further studies, a validated scale for functional oral intake, such as FOIS [45, 46], could be considered to categorize patients in order to search for correlations between the results of the mastication tests and the severity of dysphagia.

Currently, there are no guidelines on oral rehabilitation after tongue cancer treatment. Oral rehabilitation is mostly considered between 6 months and 1 year after the end of all treatments. This is particularly valid when implants for prosthodontic rehabilitation are planned, even more so on head and neck area radiation, despite successful results with single-use implants during ablative surgery [4, 47]. Oral rehabilitation is now usually covered by social security insurance and appears essential for potentiating efforts made for tongue reconstruction and rehabilitation [48]. Tongue and dental condition rehabilitation must be performed as soon as possible in each situation that we face, with the aim of restoring all oral functions as best we can. When carcinological challenge allows it, the principle of tongue preservation should be applied [49], but when extensive tongue resection is indicated, the reconstruction using free flaps must be enhanced as far as possible to restore volume and functional aspects [50–53].

## Conclusion

This study suggests that functional evaluation of FOP should be considered for patients treated for tongue cancer. Quick combined evaluation of chewing efficiency using the mastication test, oral health quality of life using the GOHAI test and nutritional status should be part of the follow-up of all patients operated on for tongue cancer. This study also provides criteria for further controlled studies designed to demonstrate the existence of a causal relationship between FOP impairments, and oral and nutritional status in patients treated for oral and/or tongue cancer.

## Compliance with Ethical Standards

**Conflicts of interest** The authors declare they have no conflicts of interest.

**Ethical Approval** This study was approved by the local ethics committee (CECIC: 2010/06; IRB No: 5044).

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